UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Occurrence Summary and Use Support Document for the Six-Year Review of National Primary Drinking Water Regulations

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1.1 Purpose and Scope

This document summarizes contaminant occurrence findings for 30 regulated contaminants in support of the Environmental Protection Agency’s (EPA’s) Six-Year Review of National Primary Drinking Water Regulations (“Six-Year Review”). Included is detailed information regarding each contaminant’s occurrence in drinking water and related information relevant to initial exposure assessments. Brief reviews regarding each contaminant’s production, uses and occurrence in ambient water are also included. To provide some regulatory context, the Six-Year Review process is briefly described.

This document is divided into four sections. This section (Section 1) contains general information – applicable to all contaminants– which includes a description of all data sources used for this analysis and the statistical methodology used to estimate national occurrence from the data that are national in scope. The following three sections are organized by contaminant group. Section 2 provides information for all inorganic contaminants (IOCs), Section 3 provides information for all synthetic organic contaminants (SOCs), and Section 4 provides information for all volatile organic contaminants (VOCs). (See Page ii for a list of the contaminants included in each section.) Within each contaminant group section there is a detailed Table of Contents specific to each contaminant. For a general overview or summary of a particular contaminant’s occurrence findings, please refer to the conclusion section for that specific contaminant.

1.2 Review Process

The Environmental Protection Agency’s Office of Ground Water and Drinking Water (OGWDW) is responsible for implementing the provisions of the Safe Drinking Water Act (SDWA). The 1996 SDWA amendments require the U.S. EPA to review existing National Primary Drinking Water Regulations (NPDWRs) no less often than every six years and, if appropriate, revise them. As long as an NPDWR revision maintains or provides for greater protection of public health, the SDWA 1996 amendments give the Administrator discretion to determine if revision is appropriate. EPA believes the revision must continue to meet the basic statutory requirements of the SDWA (e.g., generally setting the maximum contaminant level as close to the maximum contaminant level goal as is feasible), to determine if a revision is appropriate. EPA also believes the revision must present significant opportunities to improve the level of public health protection and/or to achieve cost savings while maintaining, or improving, the level of public health protection. The Six-Year Review workgroup is reviewing the factors relevant to this formal re-assessment of each national primary drinking water regulation.

EPA developed a protocol document — *EPA Protocol for the Review of Existing National Primary Drinking Water Regulations* (USEPA, 2001) — to describe the process and strategy for Review that EPA will use to meet its statutory requirement. To most efficiently utilize limited resources, EPA plans to perform a series of analyses at the beginning of each Review cycle, intended to target those NPDWRs that are the most appropriate candidates for revision. The Agency plans to use available, scientifically-sound data to make decisions regarding whether or not to revise a regulation. EPA will review the following key information to make decisions regarding regulatory changes: current health risk assessments, technology assessments (including reviews of laboratory analytical methods and treatment techniques), and occurrence and exposure assessments. This current document presents information specific to occurrence and exposure in support of the Six-Year Review.

EPA will consider regulatory revisions based on the various components of each primary drinking water regulation, including possible changes to Maximum Contaminant Levels (MCLs), Maximum Contaminant Level Goals (MCLGs), treatment techniques, analytical method capabilities, and treatment capabilities. In some cases, EPA may also consider revisions to monitoring or system reporting requirements as part of the Six-Year Review; however, in most cases, these types of revisions will be considered through other vehicles. In rare instances, EPA may consider dropping a contaminant from regulation. For any NPDWR that is a potential candidate for revision based on its review, EPA will also take economic considerations into account before making its “revise/not revise” decision. Moreover, EPA will apply basic risk management principles to determine whether these candidate regulations warrant regulatory revision to ensure that any revision will present a significant opportunity to improve the level of public health protection and/or present a significant opportunity for cost savings while maintaining, or improving, the level of public health protection.

1.3 Data Sources

Numerous data sources were used in this report to provide information on contaminant use, production, occurrence, and potential exposure. The primary data sources used for background use, production, and release reviews include the Agency for Toxic Substances and Disease Registry (ATSDR) and Toxics Release Inventory (TRI). Information on contaminant occurrence in ambient water primarily derives from the National Water Quality Assessment Program (NAWQA). Drinking water contaminant occurrence analyses are generated from State drinking water compliance monitoring data from a national cross-section comprised of occurrence data from 16 States. This 16-State national cross-section is the largest compliance monitoring data set compiled to date by EPA. These primary data sources are described in detail in the subsequent sections of this Introduction. In addition to the primary data sources, supplemental contaminant occurrence information for drinking water and ambient water is also reviewed whenever available. These supplemental data sources and findings are included in the contaminant specific sections of this report.

1.3.1 Agency for Toxic Substances and Disease Registry

In 1980, Congress created the Agency for Toxic Substances and Disease Registry (ATSDR) to implement the health-related sections of laws that protect the public from hazardous wastes and environmental spills of hazardous substances (ATSDR, 2001). The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), commonly known as the “Superfund” Act, provided the Congressional mandate to remove or clean up abandoned and inactive hazardous waste sites and to provide federal assistance in toxic emergencies. As the lead Agency within the Public Health Service for implementing the health-related provisions of CERCLA, ATSDR is charged under the Superfund Act to assess the presence and nature of health hazards at specific Superfund sites, to help prevent or reduce further exposure and the illnesses that result from such exposures, and to expand the knowledge base about health effects from exposure to hazardous substances (ATSDR, 2001).

In the 1984 amendments to the Resource Conservation and Recovery Act of 1976 (RCRA), which provides for the management of legitimate hazardous waste storage or destruction facilities, ATSDR was authorized to conduct public health assessments at these sites, when requested by EPA, States, or individuals. ATSDR was also authorized to assist EPA in determining which substances should be regulated and the levels at which substances may pose a threat to human health (ATSDR, 2001).

With the passage of the Superfund Amendments and Reauthorization Act of 1986 (SARA), ATSDR received additional responsibilities in environmental public health. This act broadened ATSDR's responsibilities in the areas of public health assessments, establishment and maintenance of toxicologic databases, information dissemination, and medical education (ATSDR, 2001).

ATSDR issues Toxicological Profiles for over 250 substances, including 23 of the 30 contaminants discussed in this report. These profiles contain exhaustive reports on the substances’ health effects, chemical and physical properties, use and production, potential for human exposure, and analytical methods. Whenever available, ATSDR was used as a primary source in this report for contaminant use and production information.

1.3.2 Toxic Release Inventory

The Toxics Release Inventory (TRI) is a publicly available EPA database that contains information on specific toxic chemical releases and other waste management activities reported annually by certain covered industry groups as well as federal facilities. Facilities are required to use their best readily available data to calculate their releases and waste management estimates. If facilities do not have actual monitoring data, submitted values are derived from various estimation techniques. Reporting Year (RY) 1999 is the most recent TRI data available.

In 1986, the Emergency Planning and Community Right-to-Know Act (EPCRA) established the TRI of hazardous chemicals. Through EPCRA, Congress mandated that larger facilities publicly report when TRI chemicals are released into the environment. TRI provides citizens with accurate information about potentially hazardous chemicals and their use so that communities have more power to hold companies accountable and make informed decisions about how toxic chemicals are to be managed. This public reporting is required for facilities with more than 10 full-time employees that annually manufacture or produce more than 25,000 pounds, or use more than 10,000 pounds, of TRI chemical (USEPA, 1996; USEPA, 2000c). Under these conditions, facilities are required to report the pounds per year of the contaminant released into the environment both on- and off-site. The on-site quantity is subdivided into air emissions, surface water discharges, underground injections, and releases to land.

Although the TRI data can be useful in giving a general idea of release trends, it is far from exhaustive and has significant limitations. For example, only industries which meet TRI criteria (at least 10 full-time employees and manufacture and processing of quantities exceeding 25,000 lbs/yr, or use of more than 10,000 lbs/yr) are required to report releases. These reporting criteria, therefore, do not account for releases from smaller industries. Threshold manufacture and processing quantities also changed from 1988 to 1990 (dropping from 75,000 lbs/yr in 1988 to 50,000 lbs/yr in 1989 to its current 25,000 lbs/yr in 1990) creating possibly misleading data trends. Also, reported releases are annual estimates. The amounts reported could have been released evenly over the course of the year or, possibly, in a single large burst. Finally, the TRI data is meant to reflect releases and should not be used to estimate general exposure to a chemical (USEPA, 2000a; USEPA, 2000b).

Twenty-six of the 30 contaminants discussed in this report are listed as Toxic Release Inventory (TRI) chemicals. Whenever available, TRI data were used to describe environmental releases of each contaminant; the distribution of these releases (with respect to the method of release and overall geographic distribution); and the geographic distribution of the releases relative to the 16 cross-section States.

1.3.3 National Water Quality Assessment

Although the Six-Year Review assesses contaminant occurrence in finished drinking water (assessing occurrence in water sampled from within public water systems), an evaluation of contaminant occurrence in ambient (raw, unfinished) water provides background information regarding the presence of a contaminant in the environment. In a drinking water context, ambient water is source water existing in surface waters and aquifers before treatment. The most comprehensive and nationally consistent data describing ambient water quality in the United States are being collected and managed through the efforts of the United States Geological Survey's (USGS) and its National Water Quality Assessment (NAWQA) program. (NAWQA, however, is a relatively young program and complete national data are not yet available from their entire array of sites across the nation. Also, data is not yet available on all the contaminants in this report. As the NAWQA program continues, important addition spatial and temporal coverage of this ambient occurrence data will become available for occurrence analyzes.)

The USGS instituted the NAWQA program in 1991 to examine water quality status and trends in the United States. NAWQA is designed and implemented in such a manner to allow consistency and comparison between representative study basins located around the country, facilitating interpretation of natural and anthropogenic factors affecting water quality (Leahy and Thompson, 1994).

The NAWQA program consists of 59 significant watersheds and aquifers referred to as "study units." The study units represent approximately two thirds of the overall water usage in the United States and a similar proportion of the population served by public water systems. Approximately one half of the nation's land area is represented (Leahy and Thompson, 1994).

To facilitate management and make the program cost-effective, approximately one third of the study units at a time engage in intensive assessment for a period of 3 to 5 years. This is followed by a period of less intensive research and monitoring that lasts between 5 and 7 years. This way all 59 study units rotate through intensive assessment over a ten-year period (Leahy and Thompson, 1994). The first round of intensive monitoring (1991-96) targeted 20 watersheds and the second round monitored 16 basins beginning in 1994.

Whenever available, ambient data for the inorganic contaminants were downloaded directly from the USGS website. These data follow the parameters and guidelines discussed above. No particular limitations apply specifically to the downloaded IOC data.

For pesticides (classified as SOCs), NAWQA includes analyses of 76 pesticides and 7 selected pesticide degradation products in about 8,200 samples of ground water and surface water in 20 of the nation’s major hydrologic basins (USGS, 1998). The 76 herbicides, insecticides, and fungicides targeted in the study account for approximately 75 percent of the total amount (by weight) of pesticides used for agriculture in the U.S., and also a substantial portion of urban and suburban use. The minimum reporting limit (MRL) for the SOCs varied by contaminant.

For this Six-Year Review report, data for pesticide occurrence in ambient water was used from *Pesticides in Surface and Ground Water of the United States: Summary of Results of the National Water Quality Assessment Program* (USGS,1998). This published report includes the USGS analyzed NAWQA sample data from 1992 to 1996. (More recent NAWQA sampling round results have recently become available and include sample results data from 1996 to 1998. However, the data so far published are not as comprehensive as the 1992-1996 data, and the more comprehensive data, while available on the USGS website, has not been completely quality reviewed or analyzed by USGS. Therefore, this current Six-Year Review occurrence assessment uses the data from the published 1998 report. In the subsequent draft of this Six-Year Review report, the 1996 to 1998 NAWQA data will be reviewed and potentially incorporated.)

For volatile organic chemicals (VOCs), the national synthesis will compile data from the first and second rounds of intensive assessments. Study units assessed in the second round represent conditions in more urbanized basins, but initial results are not yet available. However, VOCs were analyzed in the first round of intensive monitoring and data are available for these study units (Squillace et al., 1999). The minimum reporting limit (MRL) for all VOCs listed in this report was 0.2 µg/L (Squillace et al., 1999). Additional information on analytical methods used in the NAWQA study units, including method detection limits, are described by Gilliom and others (1998).

Furthermore, the NAWQA program has compiled, by study unit, data collected from local, State, and other Federal agencies to augment its own data. The data set provides an assessment of VOCs in untreated ambient ground water of the conterminous United States for the period 1985-1995 (Squillace et al., 1999). Data were included in the compilation if they met certain criteria for collection, analysis, well network design, and well construction (Lapham et al., 1997). They represent both rural and urban areas, but should be viewed as a progress report as NAWQA data continue to be collected that may influence conclusions regarding occurrence and distribution of VOCs (Squillace et al., 1999).

In addition to the NAWQA studies/data described above, information is also presented regarding pesticide concentrations in reservoirs and finished drinking water (Blomquist, et al., 2001) . In 1999, a pilot monitoring program was initiated by USGS and EPA to provide information on pesticide concentrations in drinking water. Prior to implementation of this pilot program, there were few available datasets that contained information on pesticide concentrations in finished drinking water on a national scale, as most available data sets generally cover only selected compounds or local areas. This pilot program was implemented to begin to fill this important data gap, and to provide more information about appropriate methods for a national monitoring of pesticides in drinking water. The NAWQA data sets provide the only nationally consistent pesticide concentration data for a large suite of compounds. OPP currently uses the NAWQA data in their drinking-water and aquatic-exposure assessments; however, these data are not collected from public water supplies and, therefore, may not directly reflect human exposure to pesticides via drinking water.

Drinking water utilities that withdrew from reservoirs were sampled because reservoirs are vulnerable to pesticide contamination, integrate pesticide loading from their watersheds, and show smaller temporal variations than streams. Sampling frequencies were designed to measure long-term mean and short-term peak concentrations of pesticides in drinking water. Samples were collected quarterly throughout the year and at weekly or bi-weekly intervals following the primary pesticide application periods. Water samples were collected from the raw-water intake and from the finished drinking-water tap prior to entering the distribution system. At some sites, samples were also collected at the reservoir outflow. Three different laboratory methods were selected for use during the pilot monitoring program— a USGS approved method and two developmental methods. Only results from the USGS approved method (known as "method 2001" or "schedule 2001") are presented in this report.

Twelve water-supply reservoirs were sampled. The sites were in California, Indiana, Ohio, Oklahoma, Louisiana, Missouri, South Carolina, South Dakota, New York, North Carolina, Pennsylvania, and Texas. In 1999, drought conditions affected parts of the Eastern United States and California; therefore sampling was extended through 2000 at nine sites. This report presents results for alachlor, carbofuran, and simazine in both raw and finished water.

1.3.4 The National Highway Runoff Data and Methodology Synthesis

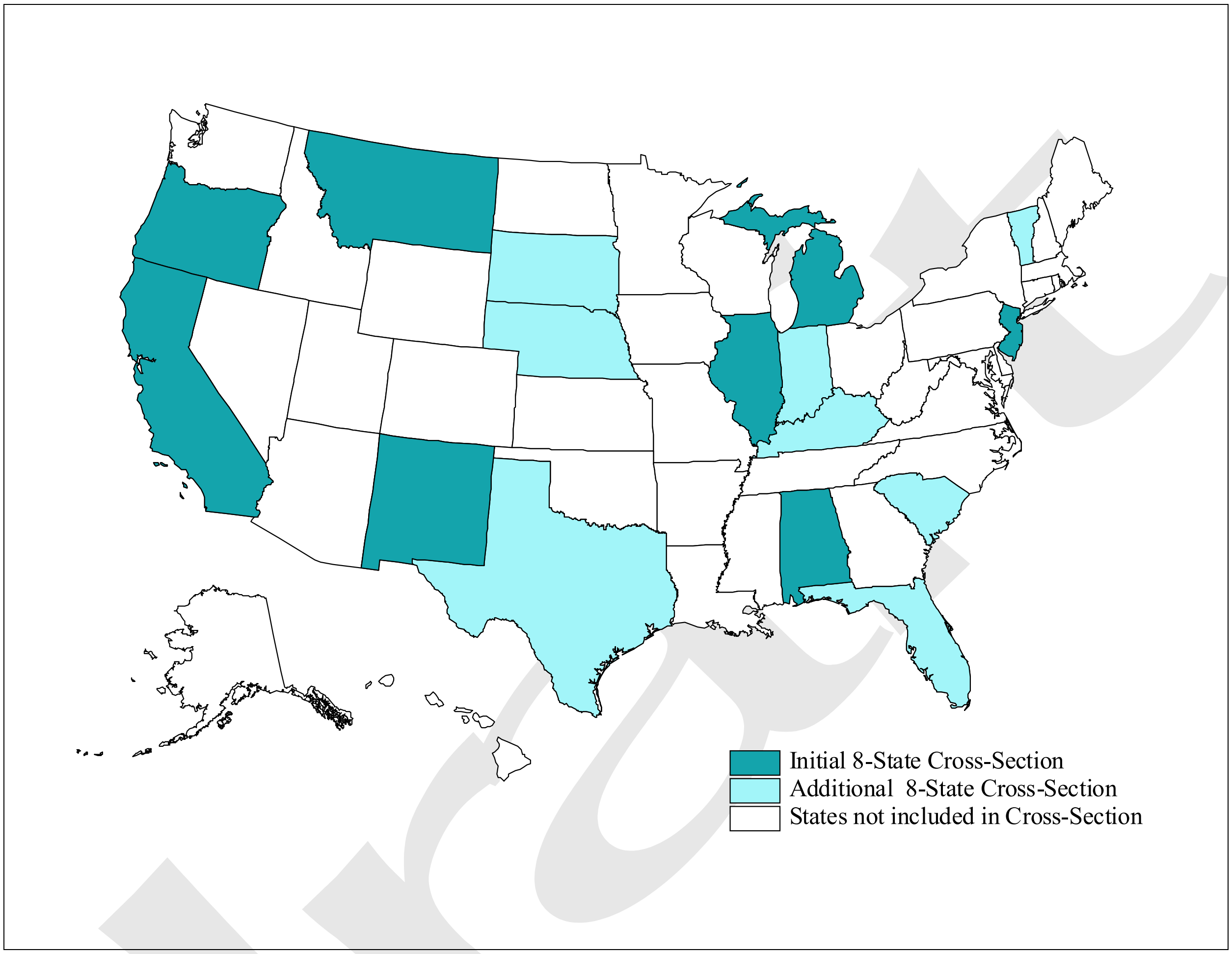
The National Highway Runoff Data and Methodology Synthesis has reviewed 44 highway and urban runoff studies implemented since 1970 (Lopes and Dionne, 1998). Two national studies were included in this review: the National Urban Runoff Program (NURP) and studies associated with the USEPA National Pollution Discharge Elimination System (NPDES) municipal stormwater permits. NURP, conducted in the 1970s and early 1980s, had the most extensive geographic distribution. The NPDES studies took place in the early to mid- 1990s (Lopes and Dionne, 1998).

1.3.5 16-State Cross-Section Data

The State public water system (PWS) compliance monitoring occurrence data used in this analysis were submitted by States for EPA review and study of the occurrence of regulated contaminants in PWSs (see USEPA, 1999). In the USEPA (1999) review, all 50 States were evaluated through a methodology that included ranking of States' pollution potential, dividing States into quartiles based on these rankings, and then selecting States that equally represent the four pollution potential quartiles. Another factor considered (when selecting states equally across the four pollution potential quartiles) was selection of states distributed geographically to include a broad representation of climatic and hydrologic variability across the United States. In this way, a subset, or cross-section, of States could be selected to reflect a national representation of pollution potentials and climatic/hydrologic difference.

An initial national cross-section of 8 States was selected because it provided a balanced national cross-section of State occurrence data, was based only on high quality and adequately complete State occurrence data sets, and that, in aggregate, is indicative of national contaminant occurrence. This national cross-section development and use methodology was the subject of critical internal review and external peer review in the USEPA (1999) study. An additional group of 8 States were added to build upon and expand the coverage of the 8-State cross-section of occurrence data (USEPA, 2002). The additional 8 States were selected using the same criteria for selection of the initial 8 cross-section States, and therefore were added in a manner that maintained the pollution potential and geographic national balance of the cross-section. The analyses presented in this report are based on data from the final group of 16 States, including Alabama, California, Florida, Illinois, Indiana, Kentucky, Michigan, Montana, Nebraska, New Jersey, New Mexico, Oregon, South Carolina, South Dakota, Texas, and Vermont (see Figure 1.3-1).

Figure 1.3-1. Map of the 16 Cross-Section States



The 8 initial plus 8 additional States that are shaded in the figure comprise the 16-State cross-section used for analysis.

1.3.5.1 Data Management

A brief discussion of data management is included below; for further detailed discussion of the extensive data management of the State data sets used in the analyses included in this report, see USEPA (1999), Cadmus (2000), Cadmus (2001), and USEPA (2002). The data used in the cross-section analyses were limited to only those data with confirmed drinking water source and population served information. Only standard SDWA compliance samples were used; samples identified as “special,” “duplicate,” or “investigation,” or samples of unknown type were not used in the analyses. (For example, investigation samples can signify an investigation of identified contamination at a particular PWS. Inclusion of the investigation sample results would bias the calculation of mean concentration for the system, and therefore the investigation samples are excluded.)

Raw data from the States were received in a very wide variety of formats, structures, and content. Each data set was reviewed to ensure it contained the basic data elements (data fields) necessary to conduct a consistent analysis for this study. These elements were reviewed with State data management staff both before and after data were received and reviewed to ensure consistent and appropriate data set interpretations. Every State data set reviewed for this study contained unique data elements or unique treatment of common elements. Even after initial screening and conversion to roughly similar formats and data set structure, unique factors were always uncovered during data analysis. Many of the confounding factors were resolved only through direct consultation with the States. As a general rule, when errors or ambiguities in various data elements could not be resolved, those particular data elements were not included in the analyses to avoid problematic results or results based on data of questionable quality. This data quality measure eliminated relatively very few observations (compared to the thousands of analytical results included in the data sets).

Decisions also had to be made on how to quantitatively include "less-than" or "non-detection" data. Some states record the minimum reporting level (or limit) (MRL) in the analytical result column and also include a "<" in a corresponding column to identify an analytical result record for which no contaminant was detected. (Such samples are often referred to as "no-detects" or "non-detections." More precisely, these samples can be referred to as "censored data," meaning that there apparently is no quantitative information for those records below the MRL, or censoring, concentration.) Other states simply include a zero in the analytical result column to signify a non-detection. Although non-detection data do not play a role in the Stage 1 analysis, the non-detection data did pose a problem within Stage 2 analysis (described below in Section 1.4).

Summary record counts were generated to determine what (and how many) MRLs were present in the data for each contaminant. (There are sometimes multiple approved laboratory analytical methods that can be used to analyze drinking water samples, and different analytical methods can have different minimum reporting levels.) For the parametric statistical analysis conducted for the Six-Year Review, each record must have a quantitative, non-zero value. Therefore, all non-detection data (often reported as "zero" or simply "<") were set equal to the non-zero modal MRL for the particular state reporting the record in question. For the states that set all non-detections equal to zero, the non-detections were set equal to the overall non-zero modal MRL for the entire 16 state cross-section. Table 1.3-1 describes the number and type of public water systems, the population served by those systems, and the overall non-zero modal detection limit for each contaminant from the 16-State cross-section data set used for Stage 2 analysis.

Table 1.3-1. Contaminant Occurrence Data From the 16-State Cross-Section

Contaminant	Total Number of Systems	Number of Ground Water Systems	Number of Surface Water Systems	Total Population Served by Systems	Non-Zero Modal MRL (mg/L)
IOCs					
Beryllium	18,933	17,509	1,424	104,573,700	0.001
Chromium	19,695	18,169	1,526	105,380,000	0.01
Fluoride	20,803	19,210	1,593	107,075,700	0.1
Mercury	18,995	17,445	1,550	105,096,700	0.001
Thallium	17,972	16,504	1,468	104,291,600	0.001
SOCs					
Alachlor	14,330	12,917	1,413	95,678,600	0.0002
Bis(2-ethylhexyl)phthalate	9,418	8,591	827	78,293,000	0.0006
Carbofuran	13,925	12,531	1,394	94,338,000	0.0009

Contaminant	Total Number of Systems	Number of Ground Water Systems	Number of Surface Water Systems	Total Population Served by Systems	Non-Zero Modal MRL (mg/L)
Chlordane	13,184	11,854	1,330	97,459,900	0.0002
1,2-Dibromo-3-chloropropane	14,042	13,008	1,034	87,727,200	0.00002
Diquat	9,159	8,337	822	73,602,900	0.0004
Glyphosate	7,862	7,069	793	70,081,900	0.006
Heptachlor	14,245	12,835	1,410	96,563,400	0.00004
Heptachlor Epoxide	14,133	12,729	1,404	96,222,900	0.00002
Hexachlorobenzene	14,011	12,625	1,386	94,035,300	0.0001
Hexachlorocyclopentadiene	13,922	12,536	1,386	93,429,200	0.005
Oxamyl	13,157	11,798	1,359	92,345,800	0.002
Picloram	12,907	11,555	1,352	93,235,500	0.0001
Simazine	14,533	13,136	1,397	98,178,100	0.001
Toxaphene	13,805	12,408	1,397	95,108,100	0.001
VOC.					
Benzene	23,266	21,670	1,596	110,866,600	0.0005
Carbon Tetrachloride	23,028	21,454	1,574	110,605,500	0.0005
1,4-Dichlorobenzene	18,961	17,615	1,346	72,994,500	0.0005
1,2-Dichloroethane	23,038	21,463	1,575	110,794,100	0.0005
1,1-Dichloroethylene	19,101	17,576	1,525	106,607,600	0.0005
Dichloromethane	21,530	20,019	1,511	110,146,100	0.0005
1,2-Dichloropropane	21,988	20,410	1,578	110,450,100	0.0005
Tetrachloroethylene	22,362	20,795	1,567	110,557,800	0.0005
1,1,2-Trichloroethane	22,284	20,758	1,526	110,366,500	0.0005
Trichloroethylene	23,035	21,461	1,574	110,612,900	0.0005

The reduced number of systems sampling for SOC data, as compared to IOC and VOC, may relate to state waivers for pesticides and herbicides. For example, New Jersey has an extensive SOC waiver protocol.

Note: All population values are rounded to the nearest hundred.

1.3.6 Additional Data

In addition to the primary data sources described above, previously compiled contaminant occurrence information is also presented whenever available. This information generally includes reviews of previous occurrence surveys and studies of contaminant occurrence in both ground water and surface water drinking and non-drinking water sources. Furthermore, some of the information is national and some regional in nature, providing additional, and sometimes historical, contaminant information that supplements the other contaminant occurrence, use, and production information presented in this report. However, the detailed national estimates of contaminant occurrence, described in the following Section 1.4, were conducted only using the 16-state national cross-section data.

1.4 Occurrence Analysis

A two stage occurrence estimation approach has been developed to assess the 16-State cross-section data of regulated contaminant occurrence. The initial stage, "Stage 1 Analysis," provides a straight-forward, clear, and conservative assessment of occurrence. Using the occurrence data aggregated from the 16-State cross-section, calculations were made of the percent of PWSs with *at least one analytical result* that exceeds a specified health threshold. These initial occurrence measures were developed for each contaminant according to water system source water type (ground water, surface water) for the aggregated 16-State cross-section data set. These "Stage 1 Analyses" are descriptive, non-parametric statistics that provide a general characterization of contaminant occurrence.

Similar estimates based on the population served by water system provide a "Stage 1" preliminary characteristic of exposure potential. Stage 1 results are most closely representative of short term exposure since the Stage 1 analyses are based on the single maximum analytical value recorded at each water system. Assessed relative to MCLs (which reflect public health considerations for long-term exposure to contaminants in drinking water), these Stage 1 analyses are conservative (cautious regarding public health concerns) in the sense that they are descriptive statistics based on peak, rather than long-term mean, concentrations. For a complete description of the Stage 1 methodology and a comprehensive presentation of the detailed Stage 1 findings, please refer to *First Stage Occurrence and Exposure Report for Six-Year Review* (Cadmus, 2000).

The second "Stage 2 analysis," a rigorous parametric statistical modeling approach, was developed to enable more specific and detailed occurrence estimations. While Stage 1 analysis estimates, for example, the percent of PWSs with *at least one analytical result* exceeding a specified health threshold, Stage 2 analysis estimates the percent of PWSs with an estimated *system mean concentration* exceeding a specified health threshold. The Stage 2 analytical results are stratified by source water type and system size. (For example, estimates can be made for the number of systems, with a mean concentration of a contaminant greater than some specified concentration, that use ground water and serve fewer than 500 people, that use surface water and serve fewer than 500 people, that use ground water and serve 501 to 3300 people, etc.). These estimates are expressed as the probability of threshold exceedance. These Stage 2 occurrence estimates also include quantified estimation errors for the values estimated. (These quantified estimation errors are important because they provide a measure of the level of confidence in an statistical estimation.)

Since the Stage 2 occurrence estimations represent mean concentration values, they are more representative of long-term exposure to contaminants in drinking water. These Stage 2 estimates contribute to the initial assessments of health risks from exposure to contaminants through consumption of drinking water. The Stage 2 estimates also can be used in assessments of the costs and benefits associated with the establishment of a revised regulatory limit for any particular drinking water contaminant. A general description of the Stage 2 analysis is presented below. For a complete description of the Stage 2 methodology and a comprehensive presentation of the stratified Stage 2 findings, please refer to *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations* (USEPA, 2002). The entire two stage occurrence estimation approach (including the development of the national cross-section of state data, as well as the Stage 1 and Stage 2 analyses) was peer-reviewed and received generally favorable support.

The statistical model developed for the Stage 2 analyses for the Six-Year Review is a Bayesian-based hierarchical model. One advantage of this modeling approach is that it is able to fully use the occurrence information contained in sample "non-detections" (all the analytical results with values less than the MRL) in estimating system mean concentration. (This is important because the sample non-detections typically comprise the majority of occurrence data for most drinking water contaminants.) The Bayesian-based model first estimates mean concentration values for each PWS in the 16-State cross-section. In the process of generating the system means, a standard deviation associated with the mean is also generated. (The standard deviation defines, in a general sense, the variability of the estimated system mean concentrations.) Importantly, the Bayesian-based modeling approach also generates estimations of error which enable a quantiative assessment of the uncertainty associated with all model estimates.

The estimated system means and standard deviations are then used as input to a Markov chain Monte Carlo method. The Monte Carlo method is, in general terms, any technique using a large number of randomly selected values to determine a single estimated total. This method works well for estimating the total number of public water systems with an (estimated) mean concentration greater than some specified threshold concentration, because the underlying probability distributions –defined by the individual estimated system means and standard deviations– are known, but the final results (the actual total number of systems with actual contaminant means greater than some specified threshold) is more difficult to determine. Approximately 500 Monte Carlo simulations (using the stratum-level mean and standard deviation as model input) are used to estimate the number of systems for each source water type and system-size category that are expected to exceed each specified concentration threshold. The estimated number of systems that exceed each threshold for a given stratum is then divided by the total number of systems in that stratum, resulting in the percent of systems estimated to exceed a specified threshold for a specific stratum (the estimated mean "probability of threshold exceedance").

Once the probability of threshold exceedance has been estimated through the Stage 2 analysis, the number of systems (and population served by systems) with potential threshold exceedances can be estimated. The total number of systems in the 16-State cross-section with mean contaminant concentrations that are expected to exceed specified threshold concentrations is calculated by multiplying the percentage of systems with an estimated mean concentration threshold exceedance (estimated by the statistical model) by the total number of systems in the 16-State cross-section with data for that particular contaminant. The total population served by systems in the 16-State cross-section potentially exposed to contaminant concentrations greater than the health threshold is estimated by multiplying the population served by systems in the 16-State cross-section with data for that particular contaminant by the model-generated percentage of population served by systems with estimated mean concentration threshold exceedance. (See Table 1.3-1 for the total number of systems and population served by systems in the 16-State cross-section for each of the 30 contaminants.)

Because the 16-State cross-section data set was developed to contain data on contaminant occurrence that is indicative of national occurrence, national contaminant occurrence can be also estimated. The total national number of systems (or population served by systems) estimated to exceed a specified threshold is extrapolated by multiplying the representative cross-section probability of exceedance by the national numbers for systems (and population served by systems) documented in the *Water Industry Baseline Handbook, Second Edition* (USEPA, 2000d). The total number of ground and surface water community water systems (CWSs) plus non-transient, non-community water systems (NTNCWSs) in the Baseline Handbook is 65,030, and the total population served by ground and surface water CWSs plus NTNCWSs is 213,008,182 persons. (The handbook presents the system and population served numbers stratified by source water type and population served size categories as well.)

To derive the national occurrence estimate for a specific threshold/source water type/population served size category, the national number of PWSs (or population served by PWSs) from the handbook is simply multiplied by the probability of exceedance (a percentage) estimated by the statistical model. In the tables presented in this report, only the total number of systems (and population served by systems) estimated to exceed each threshold are presented. For stratified contaminant occurrence findings, please refer to *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations* (USEPA, 2002).

Contaminant occurrence findings based on the Stage 1 and Stage 2 analyses (using the 16-State cross-section data) are summarized in tables presented in the specific contaminant chapters that follow this introductory chapter. All Stage 1 and Stage 2 occurrence findings (presented as percentages) are displayed to 3 significant figures and all population values are rounded to the nearest hundred. Importantly, note that the Stage 2 findings are based on model estimations conducted separately for ground water systems, surface water systems, and combined ground and surface water systems. Since these groups of systems were modeled separately, the sum of occurrence estimates for ground water systems and surface water systems will not equal the total occurrence estimate for combined ground and surface water systems. For more information of the details of the Stage 2 Bayesian-based modeling, please refer to USEPA (2002).

1.5 References

Agency for Toxic Substances and Disease Registry (ATSDR). 2001. *About the Agency for Toxic Substances and Disease Registry*. Available on the Internet at: http://www.atsdr.cdc.gov/about.html (Last updated June 28, 2001).

Blomquist, J.D., J.M. Denis, J.L. Cowles, J.A. Hetrick, R.D. Jones, and N.B. Birchfield. 2001. *Pesticides in Selected Water-Supply Reservoirs and Finished Drinking Water, 1999-2000: Summary of Results from a Pilot Monitoring Survey*. U.S. Geological Survey Open-File Report 01-456. 65 pp.

Cadmus. 2000. *First Stage Occurrence and Exposure Report for Six-Year Review.* Draft report submitted to EPA for review May 12, 2000.

Cadmus. 2001. *Data Quality Overview of Contaminant Occurrence Data - DRAFT.* Draft report submitted to EPA for review January 31, 2001.

Gilliom, R.J., D.K. Mueller, and L.H. Nowell. 1998. *Methods for comparing water-quality conditions among National Water-Quality Assessment Study Units, 1992-95*. U.S. Geological Survey Open-File Report 97-589. Available on the Internet at: http://ca.water.usgs.gov/pnsp/rep/ofr97589 (Last updated October 09, 1998).

Lapham, W.W., K.M. Neitzert, M.J. Moran, and J.S. Zogorski. 1997. USGS compiles data set for national assessment of VOCs in ground water. *G. Water Mon. Rem*. 17(4):147-157.

Leahy, P.P., and T.H. Thompson. 1994. *The National Water-Quality Assessment Program*. U.S. Geological Survey Open-File Report 94-70. 4 pp. Available on the Internet at: http://water.usgs.gov/nawqa/NAWQA.OFR94-70.html (Last updated May 29, 2001).

Lopes, T.J. and S.G. Dionne. 1998. *A Review of Semivolatile and Volatile Organic Compounds in Highway Runoff and Urban Stormwater*. U.S. Geological Survey Open-File Report 98-409. 67 pp.

Squillace, P.J., M.J. Moran, W.W. Lapham, C.V. Price, R.M. Clawges, and J.S. Zogorski. 1999. Volatile organic compounds in untreated ambient groundwater of the United States, 1985-1995. *Env. Sci. and Tech.*. 33(23):4176-4187.

USEPA. 1999. *A Review of Contaminant Occurrence in Public Water Systems*. EPA Report/816-R-99/006, Office of Water, 78 pp.

USEPA. 2000a. *TRI Explorer: Are Year-to-Year Changes Comparable?* Available on the Internet at: www.epa.gov/triexplorer/yearsum.htm (Last modified May 5, 2000).

USEPA. 2000b. *The Toxic Release Inventory (TRI) and Factors to Consider when Using TRI Data*. Available on the Internet at: http://www.epa.gov/tri/tri98/98over.pdf (Last modified August 11, 2000).

USEPA. 2000c. What is the Toxic Release Inventory. Available on the Internet at: http://www.epa.gov/tri/general.htm (Last modified February 28, 2000).

USEPA. 2000d. *Water Industry Baseline Handbook*, *Second Edition (Draft)*. March 17.

USEPA. 2001. *EPA Protocol for the Review of Existing National Primary Drinking Water Regulations - DRAFT*. U.S. Environmental Protection Agency, Office of Drinking Water. May 2001.

USEPA. 2002. *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT*. EPA Report/815-D-02-005, Office of Water, 55 pp.

USGS. 1998. *Pesticides in Surface and Ground Water of the United States: Summary of Results of the National Water Quality Assessment Program (NAWQA). PROVISIONAL DATA -- SUBJECT TO REVISION*. Available on the Internet at: http://water.wr.usgs.gov/pnsp/allsum/, last updated October 9, 1998.

2.0 INORGANIC CONTAMINANTS

2.1 Beryllium

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Tables and Figures

2.1.1 Introduction, Use and Production

Beryllium (Be) is the lightest structural metal known. Pure beryllium is hard and grayish. Beryllium is never found free in the environment but can be found in compounds in mineral rocks, coal, soil, and volcanic dust (ATSDR, 1993). Beryllium compounds have no particular smell. Beryllium exists in the environment in approximately 40 mineralized forms. The most common forms for beryllium are beryl, a beryllium aluminum silicate ($3BeO.Al_2O_3.6SiO_2$) and bertrandite, a hydrated disilicate ($4BeO.2SiO_2.H_2O$). The most important commercial forms of beryllium are the metal itself, beryllium-copper alloys, and beryllium oxide (Ciccone & Associates, 1984).

Most beryllium ore that is mined is converted into alloys. Most of these alloys are used in making electrical and electronic parts or as construction materials for machinery and molds for plastics. Pure beryllium metal is used in nuclear weapons and reactors, aircraft and space vehicle structures, instruments, x-ray machines, and mirrors. Beryllium oxide is also made from beryllium ores and is used to make specialty ceramics for electrical and high-technology applications (ATSDR, 2000).

Beryllium metal is used in aircraft disc brakes, x-ray transmission windows, space vehicle optics and instruments, aircraft/satellite structures, missile guidance systems, nuclear reactor neutron reflectors, nuclear warhead triggering devices, fuel containers, precision instruments, rocket propellants, navigational systems, heat shields, mirrors, high speed computers, and audio components, with other assorted miscellaneous uses (Cunningham, 1998, as cited in ATSDR, 2000). In 1998, the use of beryllium (as an alloy, metal, or oxide) in the electronic and electrical components, aerospace, and applications accounted for more than 80% of its consumption (Cunningham, 1999, as cited in ATSDR, 2000).

Beryllium oxide is used in high technology ceramics, electronic heat sinks, electrical insulators, microwave oven components, gyroscopes, military vehicle armor, rocket nozzle crucibles, thermocouple tubing, laser structural components, and substrates. Beryllium is also used for high-density electrical circuits, automotive ignition systems, and radar electronic countermeasure systems (Cunningham, 1998, as cited in ATSDR, 2000).

Beryllium-copper alloys are useful in a wide variety of applications because of their electrical and thermal conductivity, high strength and hardness, good corrosion and fatigue resistance, and non magnetic properties. Beryllium-copper alloys are manufactured into springs, electrical connectors and relays, precision instruments, brushings and bearings in aircraft and heavy machinery, non sparking tools, submarine cable housing and pivots, wheels and pinions, switches in automobiles, molds for injection molded plastics, radar, telecommunications, factory automation, computers, home appliances, instrumentation and control systems, tubing in oil and drilling equipment, connectors for fiber optics, and integrated circuits, as well as many other uses (Cunningham, 1998, as cited in ATSDR, 2000).

Both anthropogenic and natural processes result in emissions of beryllium to the atmosphere. In addition to ore processing, beryllium is also released into the atmosphere during the production and use of beryllium alloys and chemicals. Beryllium is released into the atmosphere from anthropogenic sources including the combustion of coal and fuel oil, the incineration of municipal and solid waste, the production, use, and recycling of beryllium alloys and chemicals, and, to a minor extent, the burning of solid rocket fuel. Emissions from coal and fuel oil combustion account for a majority of the United States beryllium emissions from natural and anthropogenic sources. Natural emission sources include windblown dusts and volcanic particles. However, the amount of beryllium released to the atmosphere from these sources is small compared with anthropogenic sources.

Anthropogenic sources of beryllium release to water include industrial waste water effluents. Beryllium concentrations are highest in waste waters from electric utility industries. Deposition of atmospheric beryllium is also a source in surface waters. Beryllium also enters water from the weathering of rocks and soils. Since coal contains beryllium, it is also likely that beryllium will enter surface water via leaching of coal piles.

Beryllium is naturally present in soils and sediments. The majority of beryllium and beryllium compound releases to land are by facilities that manufacture or process beryllium. Coal fly ash and municipal solid waste containing beryllium are disposed of in landfills and used in building materials. This contributes to beryllium concentrations in soil. About 100 million tons of coal fly ash containing various levels of beryllium are generated each year. Land application of sewage sludge containing higher than background concentrations of beryllium can be a source of beryllium contamination of soil. Deposition of atmospheric aerosols on terrestrial surfaces is another source of beryllium in soil.

Table 2.1-1: Imports of Beryllium to the United States (thousand metric tons, gross weight)

Imports For Consumption	**1995**	**1996**	**1997**	**1998**	**1999**
Beryllium Ore and Metal	32	20	20	50	20

Source: USGS, 2000

Table 2.1-2: Beryllium and Beryllium Compound Manufacturers and Processors by State

State[a]	Number of facilities	Range of maximum amounts on site in thousands of pounds[b]	Activities and uses[c]
AL	6	1,000-99,999	1,3,4,5,6,9,10,13
AZ	4	10,000-9,999,999	1,3,4,5,6,8,9,10
FL	2	1,000-9,999	1,4,5,6,10,13
GA	5	10,000-99,999	1,3,4,5,6,10,13
IL	1	1,000-9,999	1,5,10
IN	5	1,000-999,999	1,5,9,10
KY	4	0-99,999	1,5,6,10,13
MI	3	0-99,999	1,5,9,10
MO	1	1,000-9,999	8,10
MT	1	10,000-99,999	1,3,4,5,6,10,13
NC	4	10,000-99,999	1,3,4,5,6,9,10,13
NM	6	0-99,999	1,3,4,5,6,10,13
OH	8	1,000-99,999	1,3,4,5,6,10,13
OK	2	100-99,999	1,5,9
PA	5	100-999,999	1,2,3,4,5,6,7,9,10
SC	1	0-99	13
TN	3	10,000-99,999	1,5,8,9
TX	2	10,000-99,999	1,3,4,5,6,10,13
UT	4	100-49,999,999	1,4,7,8,10,13
WI	8	1,000-99,999	8,9
WV	1	1,000-99,999	1,3,4,5,6,10,13
WY	2	1,000-99,999	1,5,6,10,13

[a] Post office State abbreviations used

[b] Range represents maximum amounts on site reported by facilities in each State

[c] Activities/Uses

1. Produce
2. Import
3. For on-site use/processing
4. For sale/distribution
5. As a byproduct
6. As an impurity
7. As a reactant
8. As a formulation component
9. As an article component
10. For repackaging only
11. As a chemical processing aid
12. As a manufacturing aid
13. Ancillary or other uses

[c] Number of facilities reporting "no data" regarding maximum amount of the substance on site

Source: ATSDR, 2000 compilation of 1998 TRI data

2.1.2 Environmental Release

Beryllium and beryllium compounds are listed as Toxics Release Inventory (TRI) chemicals (see Tables 2.1-3 and 2.1-4). For both beryllium and beryllium compounds, releases to land constitute most of the on-site releases. Beryllium compounds have a gradual increase in releases to land until 1992, then decrease from 1993 through 1999, while releases of beryllium decrease until 1993 and then increase in 1994. It is unclear whether these sharp beryllium decreases are real or a function of changes in TRI reporting requirements in the late 1980s and early 1990s (see discussion in Introduction). Air emissions are also an important mode of on-site release. Though the first several years of record for air emissions of beryllium are markedly higher for certain years, no trend is apparent for the remainder. Also, air emissions of beryllium compounds have fluctuated modestly with no trend evident. Surface water discharges of beryllium and beryllium compounds are less significant on-site releases, with low levels continuing until the present and no other trends apparent. There are no releases by underground injection of either beryllium or beryllium compounds until 1999, where a high percentage of on-site releases of beryllium compounds are attributed to underground injection.

Increases in releases to land have contributed to increases in total on- and off-site releases in recent years. Off-site releases of beryllium and beryllium compounds are considerable. Off-site releases of beryllium are a large component of total releases. Though there is a large drop in beryllium releases in 1992 when compared to the previous year, the late 1990s show a steady increase in pounds released. Off-site releases of beryllium compounds fluctuate throughout the years, with highest releases in 1988 and 1998, although no other trends are apparent. These TRI data for beryllium were reported from 21 States, with only 3 States reporting data for all years (USEPA, 2000). Eight of these 21 States that reported TRI data for beryllium are contained in the 16-State cross-section (used for analyses of beryllium occurrence in drinking water; see Section 2.1.4). The TRI data for beryllium compounds were reported from 17 States, with only two States reporting data for all years (USEPA, 2000). Six of the 17 States that reported TRI data for beryllium compounds are contained in the 16-State cross-section. (For a map of the 16-State cross-section, see Figure 1.3-1.)

Table 2.1-3: Environmental Releases (in pounds) for Beryllium in the United States, 1988-1999

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1999	769	57	--	53,271	20,081	74,178
1998	799	26	--	57,818	20,404	79,047
1997	816	27	--	56,123	5,741	62,707
1996	1,114	36	--	31,245	4,852	37,247
1995	1,087	31	--	21,255	7,595	29,968
1994	899	36	--	22,860	9,632	33,427
1993	903	24	--	14,594	5,142	20,663
1992	1,868	39	--	21,358	14,774	38,039
1991	1,378	101	--	29,023	117,582	148,084
1990	1,375	42	--	6,517	1,371	9,305
1989	1,895	122	--	31,522	1,199	34,738
1988	2,763	74	--	37,000	3,160	42,997

Source: USEPA, 2000

Table 2.1-4: Environmental Releases (in pounds) for Beryllium Compounds in the United States, 1988-1999

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1999	473	27	4,100	19	5,028	9,647
1998	383	6	--	--	6,754	7,143
1997	365	1	--	96	4,602	5,064
1996	395	1	--	16,188	2,333	18,917
1995	360	2	--	23,000	2,391	25,753
1994	610	2	--	17,000	2,901	20,513
1993	363	4	--	8,087	3,055	11,509
1992	511	5	--	48,000	4,618	53,134
1991	242	9	--	30,000	2,180	32,431
1990	212	88	--	40,000	972	41,272
1989	962	25	--	36,000	5,085	42,072
1988	862	17	–	12,000	8,261	21,140

Source: USEPA, 2000

2.1.3 Ambient Occurrence

Beryllium is an analyte for both surface and ground water NAWQA studies, with a method detection limit (MDL) of 0.001 mg/L. Additional information on analytical methods used in the NAWQA study units, including method detection limits, are described by Gilliom and others (1998).

Beryllium was never detected in groundwater. A possible explanation for the higher detection frequencies in surface water is its greater sensitivity to anthropogenic releases. Both the median and 99th percentile concentrations of beryllium are below the MCL (0.001 mg/L and 0.002 mg/L, respectively). Beryllium detection frequencies in surface water greater than the MCL (0.004 mg/L) are approximately 10 times less than the percentage of all beryllium detections in surface water.

Table 2.1-5: Beryllium Detections and Concentrations in Surface Water and Ground Water

	Detection frequency > MDL*		**Detection frequency > MCL***		**Concentration percentiles (all samples; mg/L)**	
	% samples	% sites	% samples	% sites	median	99th
surface water	0.64%	3.83%	0.06%	0.55%	0.001	0.002
ground water	0.00%	0.00%	0.00%	0.00%	N/A	N/A

** The Method Detection Limit (MDL) for beryllium in water is 0.001 mg/L and the Maximum Contaminant Level (MCL) is 0.004 mg/L.*

2.1.3.2 Additional Ambient Occurrence Data

A summary document entitled "Beryllium in Water: An Assessment of Occurrence and Exposure" (Ciccone & Associates, 1984), was previously prepared for past USEPA assessments of beryllium. This document included various studies and information are presented regarding levels of beryllium in ambient water on both the regional and national level. The following information is taken directly from "Beryllium in Water: An Assessment of Occurrence and Exposure" (Ciccone & Associates, 1984).

2.1.3.2.1 National Surveys

Since 1967, no new information on beryllium concentrations in naturally occurring waters in the U.S. has been cited in the literature. However, no drastic changes would be expected. A study by Kopp and Kroner (1969, as cited in Ciccone & Associates, 1984) suggests a minimum beryllium concentration to be 0 µg/L in raw surface water with a maximum positive value of 1.22 µg/L and a mean positive value of 0.19 µg/L (Table 2.1-6). It should be noted, however, that the authors used only positive values for beryllium in calculating the average level of beryllium occurrence. Further, the frequency of occurrence of beryllium in this study was only 5.4%. Thus, the average concentration of beryllium in raw water suggested by Kopp and Kroner may be artificially inflated.

In a 1970 USGS survey of 143 surface water samples, beryllium levels were found to be mostly less than 1.0 µg/L (Table 2.1-6). The highest level detected was less than 40 µg/L in California Gulch of Malton, Colorado. No detection limits were reported for this study. Therefore, the meaning of less than 1 or less than 40 µg/L is unclear. Of the few actual numerical values reported by the USGS for beryllium, all were in New Jersey. These values ranged from 0.1 - 2.4 µg/L (mean 0.65 µg/L), the highest value being detected in the Delaware River of Trenton, NJ.

Durum and Haffty (1961, as cited in Ciccone & Associates, 1984) monitored 15 rivers in the U.S. and Canada for the presence of beryllium (Table 2.1-6). At 13 sites, beryllium was below detection limits in all samples examined. Beryllium was detected in 1 of 4 samples from the Apalachicola River, FL (<0.058 µg/L) and in 2 of 4 samples from the Atchafalaya River, LA (for one sample no numerical value reported; for the other, <0.22 µg/L). Detection limits for beryllium in this survey were not given. The national surveys described above all indicate that beryllium occurrence is very low in naturally occurring raw surface waters.

Table 2.1-6: Beryllium Occurrence in Raw Water - National Surveys

Survey	Sampling Site	# Samples/ Site	Mean Concentration (Range) µg/L	System Size	Survey Area	Notes
Trace Metals in Waters of the United States. Oct. 1, 1962- Sept. 30, 1967	130 R, S	Weekly samples composited for 3 months (occasionally 1 month). Composite samples taken twice yearly.	0.19 (0 - 1.22)	U; U.S. divided into 15 major river basins.	Nationwide	1,577 samples taken. 5.4% frequency of occurrence

Survey	Sampling Site	# Samples/ Site	Mean Concentration (Range) µg/L	System Size	Survey Area	Notes
Quality of Surface Waters in the United States. USGS, 1970	181 R, S	Samples collected daily and monthly at 143 locations.	0.65 (0.1 - 2.4)	U; U.S. divided into 16 major river basins.	Nationwide	Highest concentrations of Be detected in the Delaware River, Trenton, NJ. No limits of detection given.
Occurrence of Minor Elements in Water. Durum and Haffty, 1961	15 R, S	Variable, 2 to 7 samples/site.	<0.22 - <0.058	U, U.S. and Canada 15 sampling sites	Nationwide and Canada	Apalachicola River, FL: 1 of 4 samples positive at < 0.058 µg/L. Atchafalaya River, LA: 2 of 4 samples positive at <0.22 µg/L. No detection limits given.
Public Water Supplies of the 100 Largest Cities in the United States, 1962. Durfor and Becker, 1962	100 G, S	Variable	ND - 0.75	U	Nationwide	

2.1.3.2.2 State and Regional Surveys

Regional studies of the occurrence of beryllium in natural waters show a spectrum of results (Table 2.1-7). Silvey (1967, as cited in Ciccone & Associates, 1984) found no detectable beryllium in water samples from the State of California in a study of groundwater, surface water, ocean water and oil wells. On the other hand, Page (1981, as cited in Ciccone & Associates, 1984) found beryllium in all 1,064 groundwater samples and all 590 surface water samples obtained from New Jersey. The highest concentration of beryllium found by Page was 84 µg/L in groundwater. This same study showed that, in surface water, the highest concentration of beryllium was 1 µg/L. For both surface and ground water, the median level of beryllium was 1 µg/L. No detection limits were specified in this study.

Table 2.1-7: Beryllium Occurrence in Raw Water - Regional Surveys

Survey	Sampling Site	# Samples/ Site	Mean Concentration (Range) µg/L	System Size	Survey Area	Notes
Occurrence of Selected Minor Elements in the Waters of California. Silvey, 1967.	72 Springs 63 Water Wells 19 Oil Wells	One (3.51)	ND	U	State of California	Be limit of detection was 0.3 µg/L. No Be found at any sampling site.

Survey	Sampling Site	# Samples/ Site	Mean Concentration (Range) µg/L	System Size	Survey Area	Notes
Comparison of Ground Water and Surface Water for Patterns and Levels of Contamination by Toxic Substances, 1977-1979. Page, 1981.	1064 U, G 590 U, S	Usually one grab sample, sometimes more.	1-84	U	State of New Jersey	Median data reported. No limits of detection reported. 84 µg/L highest concentration found in groundwater (median 1 µg/L). 1 µg/L highest concentration found in surface water (median 1 µg/L). Be detected in all samples.

2.1.4 Drinking Water Occurrence Based on the 16-State Cross-Section

The analysis of beryllium occurrence presented in the following section is based on State compliance monitoring data from the 16 cross-section States. The 16-State cross-section is the largest and most comprehensive compliance monitoring data set compiled by EPA to date. These data were evaluated relative to several concentration thresholds of interest: 0.004 mg/L; 0.01 mg/L; and 0.001 mg/L.

All sixteen cross-section State data sets contained occurrence data for beryllium. These data represent approximately 48,000 analytical results from more than 19,000 PWSs during the period from 1983 to 1998 (with most analytical results from 1992 to 1997). The number of sample results and PWSs vary by State, although the State data sets have been reviewed and checked to ensure adequacy of coverage and completeness. The overall modal detection limit for beryllium in the 16 cross-section States is equal to 0.001 mg/L. (For details regarding the 16-State cross-section, please refer to Section 1.3.5 of this report.)

2.1.4.1 Stage 1 Analysis Occurrence Findings

Table 2.1-8 illustrates the Stage 1 analysis of beryllium occurrence in drinking water for the public water systems in the 16-State cross-section relative to three thresholds: 0.01 mg/L, 0.004 mg/L (the current MCL), and 0.001 mg/L (the modal MRL). A total of 18 ground water and surface water PWSs (approximately 0.0951%) had at least one analytical result exceeding 0.01 mg/L; 0.217% of systems (41 systems) had at least one analytical result exceeding the MCL (0.004 mg/L); and 1.28% of systems (243 systems) had at least one analytical result exceeding 0.001 mg/L.

Approximately 0.0971% of ground water systems (17 systems) had at least one analytical result greater than 0.01 mg/L. About 0.223% of ground water systems (39 systems) had at least one analytical result above the MCL (0.004 mg/L). The percentage of ground water systems with at least one result greater than 0.001 mg/L was equal to 1.27% (223 systems).

Only 1 (0.0702% of) surface water systems had at least one analytical result greater than 0.01 mg/L. A total of 2 (0.140% of) surface water systems had at least one analytical result greater than the MCL (0.004 mg/L). Twenty surface water systems (1.40%) had at least one analytical result exceeding 0.001 mg/L.

Table 2.1-8: Stage 1 Beryllium Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Ground Water	0.01	0.0971%	17
	0.004	0.223%	39
	0.001	1.27%	223
Surface Water	0.01	0.0702%	1
	0.004	0.140%	2
	0.001	1.40%	20
Combined Ground & Surface Water	0.01	0.0951%	18
	0.004	0.217%	41
	0.001	1.28%	243

Reviewing beryllium occurrence in the 16 cross-section States by PWS population served (Table 2.1-9) shows that approximately 0.0683% of the population (over 71,000 people) was served by PWSs with at least one analytical result of beryllium greater than 0.01 mg/L. A total of 649,000 (0.621% of) people were served by systems with an exceedance of the MCL. Approximately 3.2 million people (3.09%) were served by systems in the 16-State cross-section with at least one analytical result greater than 0.001 mg/L.

The percentage of population served by ground water systems with analytical results greater than 0.01 mg/L was equal to 0.150% (almost 68,800 people). When evaluated relative to 0.004 mg/L and 0.001 mg/L, the percent of population exposed was equal to 1.38% (635,000 people) and 4.25% (almost 2 million people), respectively.

The percentage of population served by surface water systems with exceedances of 0.01 mg/L was equal to 0.00441% (2,600 people). Approximately 0.0240% (about 14,100 people) of the population served by surface water systems in the 16-State cross-section was exposed to beryllium concentrations greater than 0.004 mg/L. When evaluated relative to 0.001 mg/L, the percent of population exposed was equal to 2.18% (over 1.2 million people).

Table 2.1-9: Stage 1 Beryllium Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Ground Water	0.01	0.150%	68,800
	0.004	1.38%	635,000
	0.001	4.25%	1,954,500

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Surface Water	0.01	0.00441%	2,600
	0.004	0.0240%	14,100
	0.001	2.18%	1,277,600
Combined Ground & Surface Water	0.01	0.0683%	71,400
	0.004	0.621%	649,000
	0.001	3.09%	3,232,100

2.1.4.2 Stage 2 Analysis Occurrence Findings

The Stage 2 occurrence findings, based on the cross-section data, are presented in Tables 2.1-10 and 2.1-11. The statistically generated best estimate values, as well as the ranges around the best estimate value, are presented. (For a review of the Stage 2 analytical approach, please refer to Section 1.4 of this report. For complete details regarding the Stage 2 analyses, please refer to *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT* (USEPA, 2002)).

A total of 2 (0.00809%) ground water and surface water PWSs in the 16 States had an estimated mean concentration of beryllium exceeding 0.01 mg/L. Approximately 15 (0.0781% of) PWSs in the 16 States had an estimated mean concentration exceeding 0.004 mg/L, and 203 (1.07%) had an estimated mean concentration exceeding 0.001 mg/L.

An estimated 2 ground water PWSs in the 16 cross-section States (0.00870%) had a mean concentration greater than 0.01 mg/L, 15 (0.0833%) had a mean concentration greater than 0.004 mg/L, and 192 (1.10%) had a mean concentration greater than 0.001 mg/L. Approximately 1 (0.000562%), 1 (0.014%), and 10 (0.731%) surface water PWSs in the 16 States had estimated mean concentrations exceeding 0.01 mg/L, 0.004 mg/L, and 0.001 mg/L, respectively.

Table 2.1-10: Stage 2 Estimated Beryllium Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	**Range**	**Best Estimate**	**Range**
Ground Water	0.01	0.00870%	0.000% - 0.0229%	2	0 - 4
	0.004	0.0833%	0.0400% - 0.137%	15	7 - 24
	0.001	1.10%	0.908% - 1.29%	192	159 - 225
Surface Water	0.01	0.000562%	0.000% - 0.000%	1	0 - 0
	0.004	0.0140%	0.000% - 0.0702%	1	0 - 1
	0.001	0.731%	0.351% - 1.19%	10	5 - 17
Combined Ground & Surface Water	0.01	0.00809%	0.000% - 0.0211%	2	0 - 4
	0.004	0.0781%	0.0370% - 0.127%	15	7 - 24
	0.001	1.07%	0.882% - 1.25%	203	167 - 237

Reviewing beryllium occurrence by PWS population served (Table 2.1-11) shows that an estimate of approximately 2,000 people (approximately 0.0019%) of population served by all PWSs in the 16 cross-section States were potentially exposed to beryllium levels above 0.01 mg/L. The percentage of population served by PWSs in the 16 States with levels of beryllium above 0.004 mg/L and 0.001 mg/L was 0.0208% (an estimated 21,800 people) and 0.699% (over 731,000 people), respectively.

When the percent of population served by ground water systems was evaluated relative to a threshold of 0.01 mg/L, 0.004 mg/L, and 0.001 mg/L, the percentage of population exposed in the 16 cross-section States was equal to 0.00403% (an estimated 1,900 people), 0.0430% (an estimated 19,800 people) and 1.17% (an estimated 538,500 people), respectively.

The percentage of population served by surface water systems in the 16 States with levels above 0.01 mg/L was equal to 0.000227% (an estimated 100 people), while the percentage of population served with levels above 0.004 mg/L was 0.00341% (an estimated 2,000 people). The percentage of the population served by surface water systems in the 16 States with levels above 0.001 mg/L was 0.330% (almost 193,000 people).

Table 2.1-11: Stage 2 Estimated Beryllium Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.01	0.00403%	0.000% - 0.0255%	1,900	0 - 11,700
	0.004	0.0430%	0.00586% - 0.174%	19,800	2,700 - 79,900
	0.001	1.17%	0.595% - 1.96%	538,500	273,800 - 903,400
Surface Water	0.01	0.000227%	0.000% - 0.000%	100	0 - 0
	0.004	0.00341%	0.000% - 0.0427%	2,000	0 - 25,000
	0.001	0.330%	0.0558% - 0.911%	192,900	32,600 - 533,200
Combined Ground & Surface Water	0.01	0.00190%	0.000% - 0.0128%	2,000	0 - 13,400
	0.004	0.0208%	0.00278% - 0.0781%	21,800	2,900 - 81,700
	0.001	0.699%	0.356% - 1.18%	731,300	372,400 - 1,237,100

2.1.4.3 Estimated National Occurrence

Based on the Stage 2 estimated percent of systems (and population served by systems) exceeding each threshold, an estimated 5 PWSs nationally serving approximately 4,100 people could be exposed to beryllium concentrations above 0.01 mg/L. About 51 systems serving 44,400 people had estimated mean concentrations greater than 0.004 mg/L. Approximately 696 systems serving about 1.5 million people nationally were estimated to have beryllium concentrations greater than 0.001 mg/L. (See Section 1.4 for a description of how Stage 2 16-State estimates are extrapolated to national values.)

For ground water systems, an estimated 5 PWSs serving about 3,500 people nationally had mean concentrations greater than 0.01 mg/L. Approximately 50 systems serving about 36,800 people nationally had estimated mean concentration values that exceeded 0.004 mg/L. About 653 ground water systems serving just over 1 million people had estimated mean concentrations greater than 0.001 mg/L.

Approximately 1 surface water system serving 300 people was estimated to have a mean concentration of beryllium above 0.01 mg/L. An estimated 1 surface water system serving 4,300 people had an estimated mean concentration greater than 0.004 mg/L. An estimated 41 surface water systems serving approximately 419,500 people had mean concentrations greater than 0.001 mg/L.

Table 2.1-12: Estimated National Beryllium Occurrence - Systems and Population Served

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.01	5	0 - 14	3,500	0 - 21,900
	0.004	50	24 - 81	36,800	5,000 - 148,700
	0.001	653	540 - 764	1,002,500	509,700 - 1,681,900
Surface Water	0.01	1	0 - 0	300	0 - 0
	0.004	1	0 - 4	4,300	0 - 54,400
	0.001	41	20 - 67	419,500	71,000 - 1,159,600
Combined Ground & Surface Water	0.01	5	0 - 14	4,100	0 - 27,200
	0.004	51	24 - 82	44,400	5,900 - 166,300
	0.001	696	574 - 814	1,489,600	758,500 - 2,519,900

2.1.5 Additional Drinking Water Occurrence Data

Several additional data sources regarding the occurrence of beryllium in drinking water are also reviewed. Beryllium data contained in the National Inorganics and Radionuclides Survey (NIRS) database are summarized below. Previously compiled occurrence information, from an OGWDW summary document entitled “Beryllium in Water: An Assessment of Occurrence and Exposure” (Ciccone & Associates, 1984), is presented in Section 2.1.5.2. In that review, a literature search was conducted and knowledgeable sources within the Office of Water were contacted. Only one study was found that addressed the occurrence of beryllium in finished water. (All information in Section 2.1.5.2 is taken directly from “Beryllium in Water: An Assessment of Occurrence and Exposure” (Ciccone & Associates, 1984).) Note that the study presented in the following section does not provide the quantitative analytical results or comprehensive coverage that would enable direct comparison to the occurrence findings estimated with the cross-section occurrence data presented in Section 2.1.4. These additional studies, however, do enable a broader assessment of the Stage 2 occurrence estimates presented for this Six-Year Review.

2.1.5.1 National Inorganics and Radionuclides Survey (NIRS)

In 1981, the USEPA's Office of Drinking Water (ODW) initiated the National Inorganics and Radionuclides Survey (NIRS) to characterize the occurrence of various contaminants in community drinking water supplies. The survey focused on the presence of 36 inorganics, including beryllium, and four radionuclides in ground water supplies from throughout the United States. Implementation of the survey and sampling were accomplished by ODW's Technical Support Division (TSD) between July 1984 and October 1986.

The NIRS sampling program was designed to reflect the national distribution of community ground water supplies by size of population served as inventoried by the Federal Reporting Data System (FRDS). The

FRDS data was stratified into the following four population-size categories: very small (serving 25-500), small (serving 501-3,300), medium (serving 3,301-10,000), and large/very large (serving >10,000). A total of 1,000 sites were selected randomly from the FRDS data in proportion to the four size categories. Approximately 2.1% of the supplies in each size category were chosen for sampling. Of the 1,000 targeted sites, 990 were actually sampled in the NIRS.

Sample collection and location within each supply were designed to reflect the quality of water actually received by the consumer. Samples were collected after three minutes of flushing in order to represent the finished water in the distribution system. To the extent possible, the sampling location was chosen at a point of maximum use in the distribution system. The method used to analyze for beryllium was not reported. The minimum reporting limit (MRL) for beryllium was 0.001 mg/L.

Beryllium results are available for all of 989 sites sampled in the NIRS. The mean of the analytical detections was 0.04 mg/L. The maximum value detected was 0.21 mg/L. Table 2.1-13 presents the estimated percentages of beryllium exceedances and the total number of systems to exceed the given threshold level. Table 2.1-14 shows the estimated percentages of beryllium exceedances and the total number of population to exceed the given threshold level.

Table 2.1-13: Estimated Beryllium Exceedance as Reported in the NIRS - Systems

Threshold	Percent of Systems That Exceed Threshold	Number of Systems Estimated to Exceed Threshold
0.01 mg/L	0.101%	60
0.004 mg/L	0.101%	60
0.001 mg/L	0.506%	301

Table 2.1-14: Estimated Beryllium Exceedance as Reported in the NIRS - Population

Threshold	Percent of Population Served by Systems That Exceed Threshold	Total Population Served by Systems Estimated to Exceed Threshold
0.01 mg/L	0.038%	33,000
0.004 mg/L	0.038%	33,000
0.001 mg/L	0.106%	91,000

2.1.5.2 100 Largest Cities - Finished Water Survey

Only one study was identified which examined the concentration of beryllium in finished water from treatment plants (Table 2.1-15). Durfor and Becker (1962, as cited in Ciccone & Associates, 1984) studied the occurrence of beryllium in raw and finished water from the 100 largest U.S. cities (1960 census). No detectable beryllium (detection limits 0.0001% of dissolved solids) was found in finished water in any of the cities. However, beryllium was detected in raw water from the Lock Raven Reservoir, Baltimore, MD at a concentration of 0.75 µg/L. The treatment process yielded finished water that contained no detectable beryllium.

Table 2.1-15: Beryllium Occurrence in 100 Largest U.S. Cities

Survey	Sampling Site	# Samples/ Site	Mean Concentration (Range) µg/L	System Size	Survey Area	Notes
Public Water Supplies of the 100 Largest Cities in the U.S., 1962. Durfur and Becker, 1962.	100 G, S	Variable	ND	U	Nationwide	1 sample of raw water from Lock Raven Reservoir, Baltimore, MD contained 0.75 µg/L. No Be detected (detection limits: 0.0001% of dissolved solids) following treatment, plain sedimentation, prechlorination, coagulation with alum, sedimentation, rapid sand filtration and adjustment of pH to 7.8 with lime.

2.1.6 Conclusion

Beryllium and many of its compounds are naturally occurring and found at low levels in soil, water, and air. Beryllium metal has a wide range of uses in nuclear weapons and reactors. Beryllium alloys are used in making electrical and electronic parts. Industrial releases of beryllium and beryllium compounds have been reported to TRI since 1988 from 21 States and 28 States, respectively. Releases to land, such as spills or leaks within the boundaries of the reporting facility, constitute the greatest proportion of the total on- and off-site releases of beryllium and beryllium compounds. Beryllium is also a national NAWQA analyte. Only 4% of all surface water sites had analytical detections of beryllium, compared to 0% of ground water sites. The percentage of surface water sites with analytical detections of beryllium greater than the MCL (0.004 mg/L) was equal to 0.55%. The Stage 2 analysis, based on the 16-State cross-section, estimated that approximately 0.0781% of combined ground water and surface water systems serving 0.0208% of the population had estimated mean concentrations of beryllium greater than the MCL of 0.004 mg/L. Based on this estimate, approximately 51 PWSs nationally serving about 44,400 people are expected to have estimated mean concentrations of beryllium greater than 0.004 mg/L.

Beryllium is a naturally occurring element. Therefore, the balanced geographic distribution of the 16-State cross-section should adequately cover the range of natural occurrence of beryllium from low to high. The 16-State cross-section also contains a substantial proportion of the States with reported TRI releases. Based on this use and release evaluation, the 16-State cross-section appears to adequately represent beryllium occurrence nationally.

2.1.7 References

Agency for Toxic Substances and Disease Registry (ATSDR). 1993. *ToxFAQs for Beryllium*. U.S. Department of Health and Human Services, Public Health Service. Available on the Internet at: http://atsdr.cdc.gov/tfacts4.html

Agency for Toxic Substances and Disease Registry (ATSDR). 2000. *Toxicological Profile for Beryllium*. U.S. Department of Health and Human Services, Public Health Service. 239 pp. + Appendices. Available on the Internet at: http://www.atsdr.cdc.gov/toxprofiles/tp4.pdf

Ciccone, V.J & Associates. 1984. *Beryllium in Water: An Assessment of Occurrence and Exposure*. Prepared for and submitted to EPA on August 8, 1984.

Cunningham, L.D. 1998. *Beryllium, Mineral Yearbook.* U.S. Geological Survey, pp. Kl-K4.

Cunningham, L.D. 1999. *Beryllium, Mineral Commodity Summary.* U.S. Geological Survey, pp. 34-35.

Gilliom, R.J., D.K. Mueller, and L.H. Nowell. 1998. *Methods for comparing water-quality conditions among National Water-Quality Assessment Study Units, 1992-95*. U.S. Geological Survey Open-File Report 97-589. Available on the Internet at: http://ca.water.usgs.gov/pnsp/rep/ofr97589/, last updated October 9, 1998.

USEPA. 2000. *TRI Explorer: Trends*. Available on the Internet at: http://www.epa.gov/triexplorer/trends.htm, last updated May 5, 2000.

USEPA. 2002. *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT*. EPA Report/815-D-02-005, Office of Water, 55 pp.

USGS. 2000. *Mineral Commodity Summaries, February, 2000 - Beryllium*. Available on the Internet at: http://minerals.usgs.gov/minerals/pubs/commodity.

Need references for: Kopp and Kroner; Duram and Haffty; Silvey; Page; Durfor and Decker

2.2 Chromium

Table of Contents

Tables and Figures

2.2.1 Introduction, Use and Production

Chromium (Cr) is a member of Group VIA of the periodic table. It is a naturally occurring element found in rocks, animals, plants, soil, and in volcanic dust and gases. Elemental chromium is a hard blue-white metal that is generally obtained through reduction of the chromite ore ($FeO\text{-}Cr_2O_3$). Chromium is present in the environment in several different forms. The primary valence states of chromium are +3 and +6, which are generally the only ones found in natural waters (Battelle, 1984; USEPA, 1979, as cited in Wade Miller, 1990). Chromium(III) occurs naturally in the environment and is an essential nutrient. Chromium(VI) and chromium(0) are generally produced by industrial processes (ATSDR, 2001). No taste or odor is associated with chromium compounds.

The major source of chromium in ground water is through leaching from rocks, mineral deposits, and mining and mill wastes. The major sources of chromium in surface waters are leaching from rocks, mineral deposits, soil runoff, industrial effluents, and deposition/precipitation of airborne particulates (Wade Miller, 1990).

Chromium has a wide range of uses in metals, chemicals, and refractories. Chromium is one of the United States' most important strategic and critical materials. Chromium use in iron, steel, and nonferrous alloys enhances hardenability and resistance to corrosion and oxidation. The use of chromium to produce stainless steel and nonferrous alloys are two of its more important applications. Chromium is also used in bricks in furnaces, dyes and pigments, and for chrome plating, leather tanning, and wood preserving. Other applications are in making pigments, leather processing, catalysts, surface treatments, and refractories (USGS, 2001).

In the United States, most chromite ore is smelted to produce stainless steel and non-ferrous alloy (ATSDR, 2000). The latter is used primarily in the production of steel to improve stiffness, hardness, and strength. Almost all of the chromite ore used in steel production in the United States is imported (see Table 2.2-1; USGS, 2001). Table 2.2-2 provides further information by State of the widespread manufacture and processing of chromium (ATSDR, 2000).

Drinking water generally contains the same chromium levels as the surface and ground waters, which serve as its source. Although some piping materials contain significant levels of chromium (corrosion resistant steel, 8-14%; cement, 5-120 ppm chromium), little is leached into the water. However, it should be noted that chromium (III) may be oxidized to chromium (VI) during the chlorination process (NLM, 2001).

The two largest sources of chromium emission in the atmosphere are from the chemical manufacturing industry and combustion of natural gas, oil, and coal. Other sources include wind transport from road dust, cement producing plants (since cement contains chromium), the wearing down of asbestos brake linings from automobiles or similar sources of wind carried asbestos (since asbestos contains chromium), incineration of municipal refuse and sewage sludge, exhaust emission from automotive catalytic converters, emissions from cooling towers that use chromium compounds as rust inhibitors, waste waters from electroplating, leather tanning, and textile industries when discharged into surface waters, and solid wastes from chemical manufacture of chromium compounds or from municipal incineration when disposed of improperly in landfill sites (NLM, 2001).

Table 2.2-1: Imports of Chromium to the United States (thousand metric tons, gross weight)

Import for Consumption	**1995**	**1996**	**1997**	**1998**	**1999**
chromite ore	416	362	350	381	476

Source: USGS, 2001

Table 2.2-2: Chromium and Chromium Compound Manufacturers and Processors by State

State[a]	Number of facilities	Range of maximum amounts on site in thousands of pounds[b]	Activities and uses[c]
AK	1	0-99,999	11
AL	87	1,000-999,999	1,2,3,5,6,7,8,9,10,11,12,13
AR	49	100-999,999	1,2,3,4,5,8,9,11,12,13
AZ	31	100-999,999	1,2,3,4,5,6,8,9,11,12,13
CA	147	0-999,999,999	1,2,3,4,5,6,7,8,9,10,11,12,13
CO	33	100-999,999	1,2,3,4,5,7,8,9,11,12
CT	66	100-9,999,999	1,2,3,4,5,7,8,9,10,11,12,13
DE	6	1,000-999,999	1,2,3,4,5,7,8,9
FL	45	100-9,999,999	5,7,8,9,10,11,13
GA	90	0-49,999,999	1,2,3,4,5,6,7,8,9,10,11,12,13
HI	2	0-99,999	8
IA	55	100-9,999,999	1,2,3,5,7,8,9,10,12,13
ID	6	100,000-49,999,999	1,5,7,9
IL	212	0-9,999,999	1,2,3,4,5,6,7,8,9,10,11,12,13
IN	199	0-99,999,999	1,2,3,4,5,6,7,8,9,10,11,12,13
KS	38	0-999,999	2,3,7,8,9,11,12,13
KY	72	0-9,999,999	1,2,3,4,5,6,7,8,9,10,11,12,13
LA	34	100-9,999,999	1,2,3,4,5,7,8,9,10,11,12
MA	79	100-999,999	1,2,3,4,5,7,8,9,10,11,12,13
MD	32	100-49,999,999	1,2,3,4,5,6,7,8,9,10,11
ME	18	1,000-999,999,999	1,3,5,7,8,9,12,13
MI	162	0-9,999,999	1,2,3,4,5,6,7,8,9,10,11,12,13
MN	49	100-9,999,999	1,3,5,7,8,9,10,12,13
MO	74	100-99,99,999	1,2,5,7,8,9,10,11,12,13
MS	49	1,000-999,999	1,5,7,8,9,11,12,13
MT	4	10,000-99,999	7,8,13
NC	91	0-999,999,999	1,2,3,4,5,6,7,8,9,10,12,13
ND	5	1,000-999,999	2,3,9
NE	22	1,000-999,999	1,2,3,5,8,9,11,12,13
NH	20	1,000-99,999	8,9,11,12
NJ	48	100-9,999,999	1,2,3,4,5,7,8,9,10,11,12,13
NM	7	1,000-999,999	1,2,3,5,6,8,9,12
NV	6	10,000-99,999	4,8,9,10
NY	94	0-9,999,999	1,2,3,4,5,6,7,8,9,10,11,12,13
OH	333	0-999,999,999	1,2,3,4,5,6,7,8,9,10,11,12,13
OK	67	100-49,999,999	1,2,3,4,5,6,8,9,10,11,12,13
OR	37	1,000-999,999	1,2,3,5,8,9,10,12,13
PA	316	0-999,999,999	1,2,3,4,5,6,7,8,9,10,11,12,13
PR	4	0-99,999	1,5,9,11
RI	14	1,000-999,999	1,2,3,8,9,10,13
SC	72	0-999,999,999	1,2,3,4,5,7,8,9,10,11,12,13
SD	8	1,000-99,999	2,3,8,9
TN	81	0-9,999,999	1,2,3,4,5,6,7,8,9,10,11,12,13
TX	177	0-99,999,999	1,2,3,4,5,6,7,8,9,10,11,12,13
UT	28	0-999,999	1,2,3,4,5,7,8,9,11,13
VA	51	0-9,999,999	1,2,4,5,7,8,9,10,12,13
VT	4	0-999,999	3,4,9
WA	39	100-9,999,999	1,2,3,6,7,8,9,12,13

State[a]	Number of facilities	Range of maximum amounts on site in thousands of pounds[b]	Activities and uses[c]
WI	197	0-9,999,999	1,2,3,4,5,6,7,8,9,10,11,12,13
WV	27	100-9,999,999	1,2,3,5,6,7,8,9,10,12,13
WY	3	0-99,999	1,6,9

[a] Post office State abbreviations used

[b] Range represents maximum amounts on site reported by facilities in each State

[c] Activities/Uses

1. Produce
2. Import
3. For on-site use/processing
4. For sale/distribution
5. As a byproduct
6. As an impurity
7. As a reactant
8. As a formulation component
9. As an article component
10. For repackaging only
11. As a chemical processing aid
12. As a manufacturing aid
13. Ancillary or other uses

Source: ATSDR, 2000 compilation of 1997 TRI data

2.2.2 Environmental Release

Chromium and chromium compounds are listed as Toxics Release Inventory (TRI) chemicals. Table 2.2-3 illustrates the environmental releases of chromium from 1988 to 1999. (There are only chromium data for these years.) Releases to land, constituting most of the on-site releases of chromium, gradually decreased from 1988 to 1995 and then dropped dramatically in 1996. It is unclear whether these sharp chromium decreases are real or a function of changes in TRI reporting requirements in the late 1980s and early 1990s (see discussion in the Introduction). Since 1995, land releases have fluctuated modestly for chromium with no apparent trend. Air emissions are also an important mode of on-site release. Though the first several years are markedly higher for air emissions of chromium, no trend is apparent for the remaining years. Surface water discharges and underground injection of chromium are less significant on-site releases. Off-site releases of chromium, a large component of total releases, are considerable. Though there was a large drop in total chromium releases in 1991 when compared to previous years, the late 1990s show a steady increase in pounds released. The TRI data for chromium were reported from 49 States with the exception of Hawaii and included Puerto Rico (USEPA, 2000). All 16 of the cross-section States (used for analyses of chromium occurrence in drinking water; see Section 2.2.4) reported releases of chromium. (For a map of the 16-State cross-section, see Figure 1.3-1.)

Table 2.2-3: Environmental Releases (in pounds) for Chromium in the United States, 1988-1999

Year	**On-Site Releases**				**Off-Site Releases**	**Total On- & Off-site Releases**
	Air Emissions	**Surface Water Discharges**	**Underground Injection**	**Releases to Land**		
1999	300,814	11,236	56	715,100	15,773,121	16,800,327
1998	478,733	13,112	9	685,766	12,938,825	14,116,445
1997	305,113	11,914	1	514,449	5,552,216	6,383,693
1996	434,107	574,456	7	535,711	6,022,527	7,566,808
1995	418,408	17,266	33	1,109,958	5,771,254	7,316,919
1994	622,337	20,566	48	1,176,881	5,877,781	7,697,613
1993	599,014	24,246	269	1,063,935	7,901,753	9,589,217
1992	492,851	23,341	333	1,138,756	6,047,944	7,703,225
1991	427,901	17,857	531	1,209,587	6,576,924	8,232,800
1990	434,330	41,265	95	2,738,681	10,585,379	13,799,750

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1989	945,625	69,681	693	3,369,485	9,865,483	14,250,967
1988	566,498	75,442	2,249	9,282,766	11,710,612	21,637,567

Source: USEPA, 2000

Table 2.2-4 illustrates the environmental releases for chromium compounds. Releases to land, ranging from about 20 to 30 million pounds, constitute most of the on-site releases of chromium compounds from 1988 to 1999. Though the first several years of recorded air emissions of chromium compounds are slightly higher, no real trend is apparent. Surface water discharges and underground injection of chromium compounds are less significant on-site releases. Surface water discharges of chromium compounds have gradually decreased since 1988. Underground injections of chromium compounds showed no discernable trend besides a sharp increase from 1995 to 1997. Off-site releases of chromium compounds fluctuate throughout the years, with highest releases in 1995 and 1997, although no other trends are apparent. The TRI data for chromium compounds were reported from 49 States with the exception of Vermont and included Puerto Rico (USEPA, 2000). All 16 of the cross-section States (used for analyses of chromium occurrence in drinking water; see Section 2.2.4) reported releases of chromium compounds. (For a map of the 16-State cross-section, see Figure 1.3-1.)

Table 2.2-4: Environmental Releases (in pounds) for Chromium Compounds in the United States, 1988-1999

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1999	467,071	97,379	816,717	29,591,378	14,203,028	45,175,573
1998	347,629	112,520	874,795	30,241,083	16,206,382	47,782,409
1997	382,843	100,082	1,131,559	29,271,102	21,003,330	51,888,916
1996	420,051	138,591	1,193,808	26,463,701	14,685,755	42,901,906
1995	650,311	138,551	1,084,747	22,090,165	20,389,031	44,352,805
1994	547,907	159,655	38,061	22,185,322	16,029,364	38,960,309
1993	405,083	230,548	42,493	24,634,864	12,975,431	38,288,419
1992	515,820	276,401	32,137	25,085,551	12,749,479	38,659,388
1991	606,278	343,298	34,603	26,267,556	13,735,176	40,986,911
1990	721,150	409,916	83,147	23,445,165	15,898,149	40,557,527
1989	1,398,526	475,850	59,110	31,081,444	18,526,178	51,541,108
1988	764,851	326,027	52,653	30,938,106	14,898,699	46,980,336

Source: USEPA, 2000

2.2.3 Ambient Occurrence

Chromium is an analyte for both surface and ground water NAWQA studies, with a method detection limit (MDL) of 0.01 mg/L. Additional information on analytical methods used in the NAWQA study units, including method detection limits, are described by Gilliom and others (1998).

Typical of many inorganic contaminants, chromium occurrence in ambient surface waters is high (Table 2.2-5). This is not surprising, considering that chromium and its compounds are used in many products. Contrary to occurrence of chromium in surface waters, no chromium was detected in ground waters. This is not surprising, however, considering the bonding tendencies of chromium with organic matter in soil particles and the low tendency for chromium to be found in leachate because of its low mobility in soil. Detection frequencies are also greater for surface water than for ground water, possibly because surface waters are more sensitive to anthropogenic releases. For all surface water samples, the median concentration is 0.001 mg/L and the 99th percentile concentration is 0.006 mg/L. However, chromium detection frequencies exceeding the MCL (0.1 mg/L) do not occur for surface water samples. This could be expected because surface waters subject to large anthropogenic inputs of chromium are more easily diluted by waters integrated from other parts of the watershed where chromium concentrations may be lower.

Table 2.2-5: Chromium Detections and Concentrations in Surface Water and Ground Water

	Detection frequency > MDL*		**Detection frequency > MCL***		**Concentration percentiles (all samples; mg/L)**	
	% samples	% sites	% samples	% sites	median	99th
surface water	27.4%	66.0%	0.0%	0.0%	0.001	0.006
ground water	0.0%	0.0%	0.0%	0.0%	N/A	N/A

** The Minimum Reporting Level (MRL) for chromium in water is 0.01 mg/L and the Maximum Contaminant Level (MCL) is 0.1 mg/L.*

2.2.3.2 Additional Ambient Occurrence Data

A summary document entitled "Occurrence and Exposure Assessment for Chromium in Public Drinking Water Supplies" (Wade Miller, 1990), was previously prepared for past USEPA assessments of chromium. However, no information on the ambient occurrence of chromium was included in that document. (The document did include information regarding chromium occurrence in drinking water, which is discussed in Section 2.2.5 of this report.)

2.2.4 Drinking Water Occurrence Based on the 16-State Cross-Section

The analysis of chromium occurrence presented in the following section is based on State compliance monitoring data from the 16 cross-section States. The 16-State cross-section is the largest and most comprehensive compliance monitoring data set compiled by EPA to date. These data were evaluated relative to several concentration thresholds of interest: 0.1 mg/L; 0.07 mg/L; 0.05 mg/L; 0.02 mg/L; and 0.01 mg/L.

All sixteen cross-section State data sets contained occurrence data for chromium. These data represent over 65,000 analytical results from approximately 20,000 PWSs during the period from 1983 to 1998 (with most analytical results from 1992 to 1997). The number of sample results and PWSs vary by State, although the State data sets have been reviewed and checked to ensure adequacy of coverage and completeness. The overall modal detection limit for chromium in the 16 cross-section States is equal to 0.01 mg/L. (For details regarding the 16-State cross-section, please refer to Section 1.3.5 of this report.)

2.2.4.1 Stage 1 Analysis Occurrence Findings

Table 2.2-6 illustrates the Stage 1 analysis of chromium occurrence in drinking water for the public water systems in the 16-State cross-section relative to five thresholds: 0.1 mg/L (the current MCL), 0.07 mg/L, 0.05 mg/L, 0.02 mg/L, and 0.01 mg/L (the modal MRL). A total of 25 ground water and surface water PWSs (approximately 0.127%) had at least one analytical result exceeding the MCL (0.1 mg/L); 0.513% (101 systems) of PWSs had at least one analytical result exceeding 0.05 mg/L; and 2.83% (557 systems) of PWSs had at least one analytical result exceeding 0.01 mg/L.

Approximately 0.110% (20 systems) of ground water PWSs had at least one analytical result greater than the MCL (0.1 mg/L). About 0.484% (88 systems) of ground water PWSs had at least one analytical result above 0.05 mg/L. The percentage of ground water systems with at least one result greater than 0.01 mg/L was equal to 2.81% (511 systems).

Only 5 (0.328% of) surface water systems had at least one analytical result greater than the MCL (0.1 mg/L). A total of 13 (0.852% of) surface water systems had at least one analytical result greater than 0.05 mg/L. Forty-six surface water systems (3.01%) had at least one analytical result exceeding 0.01 mg/L.

Table 2.2-6: Stage 1 Chromium Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Ground Water	0.1	0.110%	20
	0.07	0.352%	64
	0.05	0.484%	88
	0.02	1.33%	242
	0.01	2.81%	511
Surface Water	0.1	0.328%	5
	0.07	0.524%	8
	0.05	0.852%	13
	0.02	1.57%	24
	0.01	3.01%	46
Combined Ground & Surface Water	0.1	0.127%	25
	0.07	0.366%	72
	0.05	0.513%	101
	0.02	1.35%	266
	0.01	2.83%	557

Reviewing chromium occurrence in the 16 cross-section States by PWS population served (Table 2.2-7) shows that approximately 0.666% (over 702,000 people) of the population was served by PWSs with at least one analytical result of chromium greater than the MCL. Almost 10.5 million people (9.95%) were served by systems with an exceedance of 0.05 mg/L. Approximately 14 million people (13.3%) were served by systems with at least one analytical result greater than 0.01 mg/L.

The percentage of population served by ground water systems with analytical results greater than 0.1 mg/L was equal to 0.543% (244,300 people). When evaluated relative to 0.05 mg/L or 0.01 mg/L, the percent of population exposed was equal to 1.76% (almost 789,000 people) and 8.83% (almost 4 million people), respectively.

The percentage of population served by surface water systems with exceedances of 0.1 mg/L was equal to 0.758% (about 458,000 people). The percentage of population served by surface water systems dramatically increased to 16.1% (approximately 9.7 million people) when evaluated relative to 0.05 mg/L. The percentage of population exposed to concentrations greater than 0.01 mg/L was equal to 16.6% (over 10 million people).

Table 2.2-7: Stage 1 Chromium Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Ground Water	0.1	0.543%	244,300
	0.07	1.03%	462,500
	0.05	1.76%	789,000
	0.02	4.49%	2,020,400
	0.01	8.83%	3,967,200
Surface Water	0.1	0.758%	457,800
	0.07	13.0%	7,876,700
	0.05	16.1%	9,699,800
	0.02	16.2%	9,804,900
	0.01	16.6%	10,055,100
Combined Ground & Surface Water	0.1	0.666%	702,100
	0.07	7.91%	8,339,100
	0.05	9.95%	10,488,800
	0.02	11.2%	11,825,300
	0.01	13.3%	14,022,300

2.2.4.2 Stage 2 Analysis Occurrence Findings

The Stage 2 occurrence findings, based on the cross-section data, are presented in Tables 2.2-8 and 2.2-9. The statistically generated best estimate values, as well as the ranges around the best estimate value, are presented. (For a review of the Stage 2 analytical approach, please refer to Section 1.4 of this report. For complete details regarding the Stage 2 analyses, please refer to *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT* (USEPA, 2002)).

One (0.00424%) PWS in the 16 States was estimated to have a mean concentration of chromium above 0.1 mg/L (the current MCL). Approximately 7 (0.0366% of) PWSs in the 16-State cross-section are estimated to have mean concentrations greater than 0.05 mg/L. The percentage of PWSs in the 16 States with estimated mean concentrations exceeding 0.01 mg/L (the modal detection limit) was about 1.56% (307) PWSs nationally.

A significantly greater proportion of ground water systems, as compared to surface water systems, were estimated to exceed each threshold. Approximately 1 (0.00459% of) ground water system in the 16 States had an estimated mean concentration of chromium above 0.1 mg/L, compared to zero surface water systems. About 0.0393% (an estimated 7 PWSs) of the 16 States' ground water systems had estimated mean concentrations greater than 0.05 mg/L. This compares with about 0.00406% (about 1 system) of the surface water systems with estimated mean concentrations greater than 0.05 mg/L. The estimated mean concentration values for approximately 299 (1.65% of) ground water PWSs in the 16-State cross-section exceed 0.01 mg/L, compared to only 7 (0.474% of) surface water systems with estimated mean concentrations exceeding the modal detection limit.

Table 2.2-8: Stage 2 Estimated Chromium Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.1	0.00459%	0.000% - 0.0165%	1	0 - 3
	0.07	0.0144%	0.000% - 0.0385%	3	0 - 7
	0.05	0.0393%	0.011% - 0.0716%	7	2 - 13
	0.02	0.396%	0.292% - 0.501%	72	53 - 91
	0.01	1.65%	1.4% - 1.89%	299	255 - 343
Surface Water	0.1	0.000%	0.000% - 0.000%	0	0 - 0
	0.07	0.000786%	0.000% - 0.000%	1	0 - 0
	0.05	0.00406%	0.000% - 0.0655%	1	0 - 1
	0.02	0.0696%	0.000% - 0.262%	1	0 - 4
	0.01	0.474%	0.131% - 0.786%	7	2 - 12

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Combined Ground & Surface Water	0.1	0.00424%	0.000% - 0.0152%	1	0 - 3
	0.07	0.0133%	0.000% - 0.0355%	3	0 - 7
	0.05	0.0366%	0.0152% - 0.0660%	7	3 - 13
	0.02	0.371%	0.274% - 0.467%	73	54 - 92
	0.01	1.56%	1.33% - 1.78%	307	262 - 350

Reviewing chromium occurrence by PWS population served (Table 2.2-9) shows that approximately 0.00139% (an estimate of approximately 1,500 people) of the population served by PWSs in the 16 States were potentially exposed to chromium levels above 0.1 mg/L. When evaluated relative to a threshold of 0.05 mg/L, the percent of the population exposed estimated about 0.0108% (over 11,000 people served by systems in the 16 cross-section States). The percentage of population served by PWSs with estimated mean concentrations greater than 0.01 mg/L was approximately 0.431% (approximately 453,700 people).

About 1,500 people (0.00325% of the population served by ground water systems in the 16 States) were served by systems with estimated mean concentrations of chromium above 0.1 mg/L. An estimated 0.0248% (over 11,000 people) of the 16-State population were served by ground water systems whose mean concentration value exceeded 0.05 mg/L. The percentage of population served by ground water PWSs with estimated mean concentration values exceeding 0.01 mg/L was approximately 0.893% (about 401,300 people).

Zero surface water PWSs (therefore, none of the population served by surface water systems) had estimated mean concentrations of chromium above 0.1 mg/L. About 0.000336% (approximately 200 people in the 16 States) of the population served by surface water PWSs had mean concentrations greater than 0.05 mg/L. An estimated 52,300 (0.0866% of) people served by surface water in the 16-State cross-section were served by systems with estimated mean concentrations of chromium above 0.01 mg/L. The percentage (and estimated number) of population served by surface water systems that exceeded each threshold was always less than the percentage of ground water systems that exceeded the threshold.

Table 2.2-9: Stage 2 Estimated Chromium Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.1	0.00325%	0.000% - 0.0186%	1,500	0 - 8,400
	0.07	0.00987%	0.000% - 0.113%	4,400	0 - 50,700
	0.05	0.0248%	0.00124% - 0.130%	11,100	600 - 58,600

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
	0.02	0.228%	0.0959% - 0.357%	102,600	43,100 - 160,500
	0.01	0.893%	0.635% - 1.32%	401,300	285,500 - 592,500
Surface Water	0.1	0.000%	0.000% - 0.000%	0	0 - 0
	0.07	0.000104%	0.000% - 0.000%	100	0 - 0
	0.05	0.000336%	0.000% - 0.00182%	200	0 - 1,100
	0.02	0.00667%	0.000% - 0.0532%	4,000	0 - 32,100
	0.01	0.0866%	0.00604% - 0.358%	52,300	3,700 - 216,100
Combined Ground & Surface Water	0.1	0.00139%	0.000% - 0.00793%	1,500	0 - 8,400
	0.07	0.00427%	0.000% - 0.0481%	4,500	0 - 50,600
	0.05	0.0108%	0.000580% - 0.0559%	11,300	600 - 58,900
	0.02	0.101%	0.0447% - 0.159%	106,600	47,100 - 167,700
	0.01	0.431%	0.298% - 0.649%	453,700	313,700 - 683,900

2.2.4.3 Estimated National Occurrence

Based on the Stage 2 estimated percent of systems (and population served by systems) exceeding each threshold (see Table 2.2-10), an estimated 3 PWSs serving approximately 3,000 people nationally could be exposed to chromium concentrations above 0.1 mg/L. About 24 systems serving almost 23,000 people had estimated mean concentrations greater than 0.05 mg/L. Approximately 1,013 systems serving about 917,000 people nationally were estimated to have chromium concentrations greater than 0.01 mg/L. (See Section 1.4 for a description of how Stage 2 16-State estimates are extrapolated to national values.)

For ground water systems, an estimated 3 PWSs serving about 2,800 people nationally had mean concentrations greater than 0.1 mg/L. Approximately 23 ground water systems serving about 21,200 people nationally had estimated mean concentration values that exceeded 0.05 mg/L. About 980 ground water systems serving almost 765,000 people had estimated mean concentrations greater than 0.01 mg/L.

Zero surface water systems were estimated to have mean concentrations of chromium above 0.1 mg/L. An estimated 1 surface water system serving 400 people had an estimated mean concentration greater than 0.05 mg/L. About 26 surface water systems serving approximately 110,200 people had estimated mean concentrations greater than 0.01 mg/L.

Table 2.2-10: Estimated National Chromium Occurrence - Systems and Population Served

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.1	3	0 - 10	2,800	0 - 15,900
	0.07	9	0 - 23	8,500	0 - 96,600
	0.05	23	7 - 43	21,200	1,100 - 111,600
	0.02	236	173 - 298	195,500	82,200 - 306,000
	0.01	980	834 - 1,122	764,900	544,200 - 1,129,300
Surface Water	0.1	0	0 - 0	0	0 - 0
	0.07	1	0 - 0	100	0 - 0
	0.05	1	0 - 4	400	0 - 2,300
	0.02	4	0 - 15	8,500	0 - 67,700
	0.01	26	7 - 44	110,200	7,700 - 455,400
Combined Ground & Surface Water	0.1	3	0 - 10	3,000	0 - 16,900
	0.07	9	0 - 23	9,100	0 - 102,400
	0.05	24	10 - 43	22,900	1,200 - 119,000
	0.02	241	178 - 304	215,600	95,200 - 338,900
	0.01	1,013	865 - 1,156	917,000	634,100 - 1,382,400

2.2.5 Additional Drinking Water Occurrence Data

Several additional data sources regarding the occurrence of chromium in drinking water are also reviewed. Previously compiled occurrence information, from an OGWDW summary document entitled "Occurrence and Exposure Assessment for Chromium in Public Drinking Water Supplies" (Wade Miller, 1990), is presented in this section. This variety of studies and information are presented regarding levels of chromium in drinking water, with the scope of the reviewed studies ranging from national to regional. Note that none of the studies presented in the following section provide the quantitative analytical results or comprehensive coverage that would enable direct comparison to the occurrence findings estimated with the cross-section occurrence data presented in Section 2.2.4. These additional studies, however, do enable a broader assessment of the Stage 2 occurrence estimates presented for this Six-Year Review. All the following information in Section 2.2.5 is taken directly from "Occurrence and Exposure Assessment for Chromium in Public Drinking Water Supplies" (Wade Miller, 1990).

2.2.5.1 National Inorganics and Radionuclides Survey (NIRS)

In 1981, the USEPA's Office of Drinking Water (ODW) initiated the National Inorganics and Radionuclides Survey (NIRS) to characterize the occurrence of various contaminants in community drinking water supplies. The survey focused on the presence of 36 inorganics, including chromium, and four radionuclides in ground water supplies from throughout the United States. Implementation of the survey and sampling were accomplished by ODW's Technical Support Division (TSD) between July 1984 and October 1986.

The NIRS sampling program was designed to reflect the national distribution of community ground water supplies by size of population served as inventoried by the Federal Reporting Data System (FRDS). The FRDS data was stratified into the following four population-size categories: very small (serving 25-500), small (serving 501-3,300), medium (serving 3,301-10,000), and large/very large (serving >10,000). A total of 1,000 sites were selected randomly from the FRDS data in proportion to the four size categories. Approximately 2.1% of the supplies in each size category were chosen for sampling. Of the 1,000 targeted sites, 990 were actually sampled in the NIRS.

Sample collection and location within each supply were designed to reflect the quality of water actually received by the consumer. Samples were collected after three minutes of flushing in order to represent the finished water in the distribution system. To the extent possible, the sampling location was chosen at a point of maximum use in the distribution system. The method used to analyze for chromium was not reported. The minimum reporting limit (MRL) for chromium was 0.002 mg/L.

Table 2.2-11 presents the NIRS results in terms of the cumulative number of systems exceeding the indicated concentrations for each of the population size strata. Chromium results are available for all of 990 sites sampled in the NIRS. Approximately 94 percent of the samples had chromium concentrations below the MRL of 0.002 mg/L. Six percent (63) of the samples contained chromium in concentrations equal to or greater than 0.002 mg/L. The mean of the positives was 0.007 mg/L. The maximum value detected was 0.041 mg/L which is below the current MCL of 0.05 mg/L and the proposed MCL of 0.1 mg/L. Table 2.2-12 presents the estimated percentages of chromium exceedances and the total number of systems to exceed the given threshold level. Table 2.2-13 shows the estimated percentages of chromium exceedances and the total number of population to exceed the given threshold level.

Table 2.2-11: Cumulative Occurrence of Chromium as Reported in NIRS

System size (population served)	Number of Systems Sampled	Cumulative Number of Supplies with Concentrations (mg/L) of:			
		≥ 0.002	> 0.05	> 0.1	> 0.2
Very Small					
25 - 100	338	27	0	0	0
101 - 500	337	21	0	0	0
Small					
501 - 1,000	113	2	0	0	0
1,001 - 3,300	120	4	0	0	0
Medium					
3,301 - 10,000	54	8	0	0	0
Large/Very Large					
10,001 - 25,000	22	1	0	0	0
25,001 - 50,000	3	0	0	0	0

System size (population served)	Number of Systems Sampled	Cumulative Number of Supplies with Concentrations (mg/L) of:			
		≥ 0.002	> 0.05	> 0.1	> 0.2
50,001 - 75,000	2	0	0	0	0
75,001 - 100,000	0	0	0	0	0
>100,000	1	0	0	0	0
Totals	990	63	0	0	0

Table 2.2-12: Estimated Chromium Exceedance as Reported in the NIRS - Systems

Threshold	Percent of Systems That Exceed Threshold	Number of Systems Estimated to Exceed Threshold
0.10 mg/L	0.00%	0
0.07 mg/L	0.00%	0
0.05 mg/L	0.00%	0
0.02 mg/L	0.51%	301
0.01 mg/L	0.81%	481

Table 2.2-13: Estimated Chromium Exceedance as Reported in the NIRS - Population

Threshold	Percent of Population Served by Systems That Exceed Threshold	Total Population Served by Systems Estimated to Exceed Threshold
0.10 mg/L	0.00%	0
0.07 mg/L	0.00%	0
0.05 mg/L	0.00%	0
0.02 mg/L	0.16%	137,876
0.01 mg/L	0.48%	411,201

2.2.5.2 Federal Survey Data

Several national-scale surveys, in addition to the NIRS Survey, have been conducted that provide data on chromium in public drinking water supplies. These include the 100 Largest Cities Study, the 1969 Community Water Supply Study, the 1978 Community Water Supply Survey, the Rural Water Survey, and the National Organic Monitoring Survey. The following sections describe those surveys and present the data on chromium levels in ground water and surface water supplies. It should be noted that none of the surveys differentiate between chromium in the (III) and (VI) valence states.

2.2.5.2.1 100 Largest Cities Study

Durfor and Becker (1964, as cited in Wade Miller, 1990) reported on the water quality, use, and treatment at public water supplies serving the 100 largest U.S. cities at the time of the 1960 census. Included were 66 cities that used only surface water, 20 that used only ground water, and 14 that used mixed surface and ground water sources. Both raw and finished water samples were taken for most of the locations.

Chromium was measured using a flame emission spectrographic technique. There was not sufficient information provided to discern the minimum detectable or minimum quantifiable concentration. Only very generalized results are available for chromium. Chromium concentrations ranged from undetectable to 0.035 mg/L. The majority of finished water samples with chromium present had concentrations below 0.005 mg/L.

2.2.5.2.2 1969 Community Water Supply Study (1969 CWSS)

The U.S. Public Health Service (USPHS) conducted the Community Water Supply Study (CWSS) in 1969 to assess the Nation's water supply facilities and drinking water quality (McCabe et al., 1970; USPHS, 1970; both as cited in Wade Miller, 1990). Finished water from 969 community supplies located in 9 geographically distributed areas was studied. These areas were Vermont; New York, New York; Charleston, West Virginia; Charleston, South Carolina; Cincinnati, Ohio; Kansas City, Missouri-Kansas; New Orleans, Louisiana; Pueblo, Colorado; and San Bernardino-Riverside-Ontario, California. Except for Vermont (in which all supplies in the State were sampled), the study locations are standard metropolitan statistical areas (SMSAs). Water samples were taken at randomly selected sites in the distribution system after flushing for several seconds.

Of the 969 systems studied, 678 were groundwater supplies; 109 were surface water supplies; and the remaining 182 were mixed sources, purchased water, or of unspecified source. Analytical results for chromium were provided for 676 ground water supplies and 109 surface water supplies.

Results were published in several volumes addressing each of the study areas and the national findings. The published report did not provide complete data on the water source, population served, or chromium level measured for each system sampled. However, a computer file with the requisite data was prepared by Science Applications International Corporation (SAIC, 1987, as cited in Wade Miller, 1990) using the published data, and additional information was provided by Dr. Rolf Deininger of the University of Michigan, and EPA staff.

The information does not specify a detection limit nor a minimum quantifiable concentration for chromium. The “negative” findings for individual supplies were reported as having a value of 0 mg/L.

Overall, chromium was observed in 107 of the 676 ground water supplies (16 percent) for which data are available. Chromium was also present in 35 of the 109 surface water supplies sampled (32 percent) at concentrations of 0.0005-0.21 mg/L.

2.2.5.2.3 1978 Community Water Supply Survey (1978 CWSS)

The 1978 Community Water Supply Survey (CWSS) was conducted by EPA to determine the occurrence of organic and inorganic compounds in public water supplies throughout the U.S. Drinking water samples were provided by approximately 500 supplies; however, due to analytical problems, reliable data for chromium were available for only 47 ground water and 12 surface water supplies (USEPA, 1983, as cited in Wade Miller, 1990).

Details on the analytical method used for chromium were not available; from the information provided by Glick (1984, as cited in Wade Miller, 1990) the minimum quantifiable concentration appeared to be 0.005 mg/L. Supplies provided one to five samples of raw, finished, and/or distribution water. However, Brass (1983, as cited in Wade Miller, 1990) indicated that reporting inconsistencies made it impossible to distinguish between finished and distribution samples. Therefore, distribution and finished sample results were averaged; raw water data were not used.

Chromium was not found above the (apparent) minimum quantifiable concentration of 0.005 mg/L in any of the 47 ground water or 12 surface water supplies for which analytical data are available.

2.2.5.2.4 Rural Water Survey (RWS)

The Rural Water Survey (RWS) conducted between 1978 and 1980 evaluated the status of drinking water in rural America as required by Section 3 of the Safe Drinking Water Act. More than 2,000 households served by 648 public water supplies (494 ground water, 154 surface water) were surveyed. Many of these households used private wells or very small systems serving fewer than 25 people, and only a subsample of the supplies evaluated included analyses for chromium (71 ground water and 21 surface water supplies). Results of the inorganic analyses were provided to Science Applications International Corporation (SAIC, 1987, as cited in Wade Miller, 1990) as a computer file by Brower (1983, as cited in Wade Miller, 1990).

A problem with the RWS was that the number of service connections associated with water systems was reported in lieu of the actual populations served by the systems. Dr. Bruce Brower of Cornell University, who collaborated in the National Statistical Assessment of Rural Water Conditions (based on the RWS data), provided a factor to convert the data from service connections to the number of people served, based on the average number of persons per household observed in the RWS. It must be noted, however, that these population values are only approximations. Details were not available on the sample collection nor the analytical methodology used. However, the minimum quantifiable concentration for chromium appeared to be 0.005 mg/L. Of the 71 ground water supplies studied, 4 (6 percent) contained chromium, all at levels of 0.005 mg/L.

For surface water supplies, 2 of the 21 supplies sampled had chromium present, also at levels of 0.005 mg/L.

2.2.5.2.5 National Organic Monitoring Survey (NOMS)

EPA conducted the National Organic Monitoring Survey (NOMS) in 1976 and 1977, primarily to provide data for establishing MCLs for organic compounds in drinking water. A substudy of NOMS analyzed samples for 27 trace elements in the 113 supplies sampled (91 surface water, 19 ground water, 3 mixed sources) (USEPA, 1980, as cited in Wade Miller, 1990). Chromium data are available for 90 surface water and 18 ground water supplies. Samples were taken of treated, finished water leaving the treatment plant; occasionally, samples were taken of distribution system water in close proximity to the treatment plant. The results of the inorganic analyses for NOMS were provided to SAIC by the Technical Support Division of EPA's Office of Drinking Water (USEPA, 1985, as cited in Wade Miller, 1990). No information on the analytical procedures used was available; the minimum quantifiable concentration appeared to be approximately 0.003 mg/L.

Chromium was found in 3 of the 18 ground water supplies sampled (17 percent) at concentrations ranging from 0.0045 to 0.0895 mg/L. Only one supply had a value exceeding the current MCL of 0.05 mg/L. Chromium was not detected in concentrations greater than the proposed MCL of 0.1 mg/L.

For surface water supplies, chromium was observed in 24 of the 90 supplies sampled (27 percent) at concentrations ranging from 0.0032 mg/L to 0.0522 mg/L. Only one supply had a value exceeding the current MCL of 0.05 mg/L and none of the concentrations were greater than the proposed MCL of 0.1 mg/L.

2.2.5.2.6 Compliance Monitoring Data

The Federal Reporting Data System (FRDS) provides information on public water supplies in violation of current MCLs as determined through compliance monitoring of all supplies performed by the States under the requirements of the National Interim Primary Drinking Water Regulations. Only violations of current MCLs (i.e., 0.05 mg/L for chromium) and approved variances and exemptions from the standards are recorded in FRDS. Monitoring is required annually for surface water supplies and every three years for ground water supplies.

The FRDS database (FRDS, 1990, as cited in Wade Miller, 1990) was searched for ground water violations reported during the three year period from 1987 through 1989. The data indicate that there are 5 public water supplies providing drinking water having chromium levels above the current MCL of 0.05 mg/L. As summarized in Table 2.2-14, all of those supplies have a ground water source and are in the very small size categories. Four of the supplies in violation had chromium levels in the range of 0.05 to 0.075 mg/L and the fifth supply reported a value of 0.15 mg/L. No violations were reported for supplies having a surface water source. Also, no variances or exemptions from the current chromium MCL of 0.05 mg/L have been granted.

Table 2.2-14: National Summary of Chromium Violations in Ground Water Systems

System size (population served)	Unspecified Concentration	Number of Supplies in Violation by Concentration Range (mg/L):					
		> 0.05 - 0.075	> 0.075 - 0.1	> 0.1 - 0.125	> 0.125 - 0.15	> 0.15	Totals
Very Small							
25 - 100	0	1	0	0	0	0	1
101 - 500	0	3	0	0	1	0	4
Small							
501 - 1,000	0	0	0	0	0	0	0
1,001 - 3,300	0	0	0	0	0	0	0
Medium							
3,301 - 10,000	0	0	0	0	0	0	0
Large/Very Large							
10,001 - 25,000	0	0	0	0	0	0	0
25,001 - 50,000	0	0	0	0	0	0	0
50,001 - 75,000	0	0	0	0	0	0	0

System size (population served)	Unspecified Concentration	Number of Supplies in Violation by Concentration Range (mg/L):					
		> 0.05 - 0.075	> 0.075 - 0.1	> 0.1 - 0.125	> 0.125 - 0.15	> 0.15	Totals
75,001 - 100,000	0	0	0	0	0	0	0
>100,000	0	0	0	0	0	0	0
Totals	0	4	0	0	1	0	5

Source: FRDS 1990

2.2.5.3 Results of Survey Data

2.2.5.3.1 Estimated National Occurrence in Public Water Supplies

The preceding sections presented the results of several studies that provide information on the occurrence of chromium in public drinking water supplies, as reported by Wade Miller (1990). This section presents national estimates of chromium occurrence in public drinking water supplies based on those study results. A document entitled *Overview of methodology used to estimate national occurrence and exposure to inorganic drinking water contaminants*, describes the methodology used to estimate chromium occurrence in drinking water (USEPA, 1986, as cited in Wade Miller, 1990).

In general, national survey data (presented in section 2.2.5.2) are used as the basis for the national estimates. The most representative data sets are selected and combined, stratified appropriately by water source and system size sampled, and applied to a "delta-lognormal" distribution model. Using that model, the probability of contaminant occurrence above any given concentration is determined for each source/size category of supplies and applied to the total number of water supplies in those groups. The resulting national occurrence estimates are presented in tables that show the number of public water supplies within various water source and size categories expected to have contaminant levels falling within certain concentration ranges. Tables are also provided that show the cumulative number of supplies, by source and size category, expected to exceed certain concentrations. The cumulative estimates also include upper and lower bounds based on the 95 percent confidence intervals.

The chromium occurrence estimates are based on the results of the NIRS survey for ground water supplies and the combined results of the 1969 CWSS, the 1978 CWSS, the RWS, and the NOMS for surface water supplies. The NIRS data were the most current ground water data available at the time of the study, and the analytical results are considered to be highly reliable because of the extensive quality assurance program employed. None of the surveys that analyzed surface water supplies could be shown to be any more or less representative of the universe of water supplies than the other surveys, and it was therefore determined to be most appropriate to combine the results from all of the surveys to form the basis of the national occurrence estimates. (There were insufficient details for the 100 Largest Cities Survey to permit inclusion in the national estimates.)

Table 2.2-15 shows the estimated cumulative number of public ground water supplies, by system size, having chromium levels exceeding various concentrations. It is estimated that more than 93 percent of the water supplies have chromium levels below 0.002 mg/L. Because 0.002 mg/L was the minimum quantifiable concentration for chromium, it is not known whether those supplies are free of chromium or have chromium present at very low levels.

Table 2.2-15 indicates that two supplies, both serving small populations, are expected to have chromium present at levels exceeding both the proposed MCL and MCLG of 0.1 mg/L. The FRDS compliance data, given in Section 2.2.5.2.6, reported only one ground water supply as having chromium levels above 0.1 mg/L. The supply was listed as serving 200 people with a concentration of 0.15 mg/L chromium.

Table 2.2-15: Estimated Cumulative National Occurrence of Chromium in Community Ground Water Supplies Based on the Delta Lognormal Distribution Model

System size (population served)	Number of Systems Sampled	Cumulative Number of Supplies with Concentrations (mg/L) of:			
		≥ 0.002	> 0.05	> 0.1	> 0.2
Very Small					
25 - 100	17,079	1,216	2	0	0
101 - 500	15,354	1,093	2	0	0
Small					
501 - 1,000	5,038	130	5	1	0
1,001 - 3,300	5,185	134	5	1	0
Medium					
3,301 - 10,000	2,308	253	0	0	0
Large/Very Large					
10,001 - 25,000	823	90	0	0	0
25,001 - 50,000	278	31	0	0	0
50,001 - 75,000	77	8	0	0	0
75,001 - 100,000	17	2	0	0	0
>100,000	43	4	0	0	0
Totals	46,202	2,961	14	2	0

** Number of systems in the United States includes those that purchase water.*

Table 2.2-16 provides the national cumulative occurrence estimates for chromium from surface water supplies. These estimates, based on the combined results of the 1969 CWSS, 1975 CWSS, NOMS and RWS indicate that zero surface water supplies have chromium levels above the proposed MCL of 0.1 mg/L. This estimate is consistent with the FRDS data which also shows no supplies exceeding the 0.1 mg/L MCL.

It should be noted that the values shown in Tables 2.2-15 and 2.2-16 are rounded to the nearest whole number. Because they are based on probabilities of occurrence at various concentrations, some partial probability of occurrence may exist even when the value in the table indicates "0" systems in a particular size category at or above a given concentration.

Table 2.2-16: Estimated Cumulative Occurrence of Chromium in Surface Water Supplies Based on the Delta Lognormal Distribution Model

System size (population served)	Number of Systems Sampled	Cumulative Number of Supplies with Concentrations (mg/L) of:			
		≥ 0.002	> 0.05	> 0.1	> 0.2
Very Small					
25 - 100	833	208	2	0	0
101 - 500	779	195	2	0	0
Small					
501 - 1,000	754	189	2	0	0
1,001 - 3,300	1,040	260	2	0	0
Medium					
3,301 - 10,000	1,156	289	3	0	0
Large/Very Large					
10,001 - 25,000	569	142	1	0	0
25,001 - 50,000	328	82	1	0	0
50,001 - 75,000	157	39	0	0	0
75,001 - 100,000	108	27	0	0	0
>100,000	233	59	0	0	0
Totals	5,957	1,490	13	0	0

** Number of systems in the United States includes those that purchase water.*

2.2.5.3.2 Estimated National Exposure from Public Water Supplies

The previous section noted that a separate methodology document has been prepared to describe the approach used to estimate national occurrence of inorganic contaminants in public water supplies. That document also addresses the approach to estimating the population exposed to contaminant levels in public drinking water supplies. In summary, the occurrence probability density functions obtained from the national survey data on supplies contaminated at various levels are applied to the number of people using water supplies in the various size categories. The results of the population exposed estimates are presented in tables similar to those in section 2.2.5.3.1 presenting the national occurrence estimates.

Table 2.2-17 presents the population exposed to chromium from ground water supplies exceeding the current MCL of 0.05 mg/L as reported in FRDS (1990, as cited in Wade Miller, 1990). The data show that 1,060 people are exposed to chromium at levels exceeding the current MCL of 0.05 mg/L. Of the 1,060 people, 806 are exposed to levels ranging from 0.05 to 0.075 mg/L and an additional 200 people are exposed to chromium in ground water at levels above 0.1 mg/L. Table 2.2-18 gives the estimated cumulative population exposed to chromium from ground water systems exceeding various concentrations. This table indicates that 3,000 people are expected to be exposed to chromium at levels above the proposed MCL of 0.1 mg/L.

National cumulative population exposure estimates based on the national survey data for chromium from surface water supplies are shown in Table 2.2-19. An estimated 20,000 people are expected to be exposed to chromium levels above the proposed MCL of 0.1 mg/L.

The apparent inconsistency between the estimate in Section 2.2.5.3.1 that there are no surface water supplies exceeding the proposed MCL of 0.1 mg/L and the estimate here that 20,000 people using surface water supplies are exposed to levels above this is a result of the application of the probability of occurrence and exposure derived from the delta-lognormal distribution and applied to the universe of water supplies and populations using those supplies. In the case of estimating supplies, the numbers are rounded to the nearest whole number, whereas the population estimates are rounded to the nearest thousand. Where very small probabilities of occurrence exist, the number of supplies may be rounded to 0, whereas the number of people exposed is rounded to some number greater than 0.

Using a drinking water consumption rate of 2 liters/day, the intake of chromium for an adult at the proposed MCL is 0.200 mg/day. As indicated above from the national estimates, 23,000 people are estimated to have an intake of that amount or more from drinking water. Typically, however, exposure to chromium in drinking water is at levels below 0.002 mg/L, which would contribute less than 0.004 mg/day to chromium intake.

Table 2.2-17: Population Exposed to Chromium at Levels Exceeding the Current MCL in Ground Water Supplies as Reported in FRDS

System size (population served)	Unspecified Concentration	Number of Supplies in Violation by Concentration Range (mg/L):					
		> 0.05 - 0.075	> 0.075 - 0.1	> 0.1 - 0.125	> 0.125 - 0.15	> 0.15	Totals
Very Small							
25 - 100	0	40	0	0	0	0	40
101 - 500	0	820	0	0	200	0	1,020
Small							
501 - 1,000	0	0	0	0	0	0	0
1,001 - 3,300	0	0	0	0	0	0	0
Medium							
3,301 - 10,000	0	0	0	0	0	0	0
Large/Very Large							
10,001 - 25,000	0	0	0	0	0	0	0
25,001 - 50,000	0	0	0	0	0	0	0
50,001 - 75,000	0	0	0	0	0	0	0
75,001 - 100,000	0	0	0	0	0	0	0
>100,000	0	0	0	0	0	0	0
Totals	0	860	0	0	200	0	1,060

Source: FRDS 1990

Table 2.2-18: Estimated Cumulative Population (in thousands) Exposed to Chromium in Drinking Water Exceeding the Indicated Concentrations from Community Ground Water Supplies

System size (population served)	Number of Systems Sampled	Cumulative Number of Supplies with Concentrations (mg/L) of:			
		≥ 0.002	> 0.05	> 0.1	> 0.2
Very Small					
25 - 100	950	68	0	0	0
101 - 500	3,850	274	0	0	0
Small					
501 - 1,000	3,910	101	4	1	0
1,001 - 3,300	10,000	258	10	2	0
Medium					
3,301 - 10,000	13,310	1,461	0	0	0
Large/Very Large					
10,001 - 25,000	13,110	1,439	0	0	0
25,001 - 50,000	9,540	1,047	0	0	0
50,001 - 75,000	4,770	524	0	0	0
75,001 - 100,000	1,360	149	0	0	0
>100,000	10,360	1,137	0	0	0
Totals	71,160	6,458	14	3	0

** Number of systems in the United States includes those that purchase water.*

Table 2.2-19: Estimated Cumulative Population (in thousands) Exposed to Chromium in Drinking Water Exceeding the Indicated Concentrations from Community Surface Water Supplies

System size (population served)	Number of Systems Sampled	Cumulative Number of Supplies with Concentrations (mg/L) of:			
		≥ 0.002	> 0.05	> 0.1	> 0.2
Very Small					
25 - 100	90	23	0	0	0
101 - 500	570	143	1	0	0
Small					
501 - 1,000	1,280	320	3	0	0
1,001 - 3,300	4,330	1,083	10	1	0
Medium					
3,301 - 10,000	10,200	2,550	24	1	0

System size (population served)	Number of Systems Sampled	Cumulative Number of Supplies with Concentrations (mg/L) of:			
		≥ 0.002	> 0.05	> 0.1	> 0.2
Large/Very Large					
10,001 - 25,000	12,640	3,160	30	2	0
25,001 - 50,000	15,910	3,978	37	2	0
50,001 - 75,000	10,310	2,578	24	1	0
75,001 - 100,000	10,090	2,523	24	1	0
>100,000	89,240	22,311	210	12	0
Totals	154,660	38,669	363	20	0

** Number of systems in the United States includes those that purchase water.*

2.2.6 Conclusion

Chromium and many of its compounds are naturally occurring and found at low levels in soil, water, and air. Furthermore, chromium compounds are produced in the United States from chromite ore and are in widespread use. Chromium has a wide range of uses in metals, chemicals, and refractories. Chromium use in iron, steel, and nonferrous alloys enhances hardenability and resistance to corrosion and oxidation. Recent statistics regarding import for consumption indicate production and use are robust. Industrial releases of chromium and chromium compounds have been reported to TRI since 1988 from 49 of the 50 States. Off-site releases constitute a considerable amount of total releases, with releases to land the most significant on-site releases. Chromium is also a national NAWQA analyte. Approximately 66% of all surface water sites had analytical detections of chromium, compared to 0% of ground water sites. No surface or ground water had any analytical detections of chromium greater than the MCL (0.1 mg/L). The Stage 2 analysis, based on the 16-State cross-section, estimated that approximately 0.00424% of combined ground water and surface water systems serving 0.00139% of the population had estimated mean concentrations of chromium greater than the MCL of 0.1 mg/L. Based on this estimate, approximately 3 PWSs nationally serving about 3,000 people are expected to have estimated mean concentrations of chromium greater than 0.1 mg/L.

Chromium is a naturally occurring element. Therefore, the balanced geographic distribution of the 16-State cross-section should adequately cover the range of natural occurrence of chromium from low to high. Fifteen of the 16 cross-section States, excluding Vermont, have reported TRI releases. Based on this use and release evaluation, the 16-State cross-section appears to adequately represent chromium occurrence nationally.

2.2.7 References

Agency for Toxic Substances and Disease Registry (ATSDR). 2000. *Toxicological Profile for Chromium*. U.S. Department of Health and Human Services, Public Health Service. 419 pp. + Appendices. Available on the Internet at: http://www.atsdr.cdc.gov/toxprofiles/tp7.pdf

Agency for Toxic Substances and Disease Registry (ATSDR). 2001. *ToxFAQs for Chromium*. U.S. Department of Health and Human Services, Public Health Service. Available on the Internet at: http://atsdr.cdc.gov/tfacts7.html

Battelle. 1984. Battelle, Pacific Northwest Laboratories. Chemical attenuation rates, coefficients, and constants in leachate migration. Volume 1: A critical review. Prepared for the Electric Power Research Institute. Research Project 2198-1.

Brass, H. 1983. U.S. Environmental Protection Agency, Office of Drinking Water, Technical Support Division, Cincinnati, OH. Personal communication to author of SAIC, 1987.

Brower, B. 1983. Computer data file of analytical results for public water supplies sampled in the Rural Water Survey. Cornell University, Department of Rural Sociology.

Durfor, C.N., and E. Becker. 1964. Public water supplies of the 100 largest cities in the United States, 1962. U.S. Geological Survey Water Supply Paper 1812. Washington, DC: U.S. Government Printing Office.

Federal Reporting Data System (FRDS). 1990. Computer file extracts of compliance monitoring data for the Safe Drinking Water Act.

Gilliom, R.J., D.K. Mueller, and L.H. Nowell. 1998. *Methods for comparing water-quality conditions among National Water-Quality Assessment Study Units, 1992-95*. U.S. Geological Survey Open-File Report 97-589. Available on the Internet at: http://ca.water.usgs.gov/pnsp/rep/ofr97589/, last updated October 9, 1998.

Glick, E. 1984. U.S. Environmental Protection Agency, Office of Drinking Water, Technical Support Division, Cincinnati, OH. Personal communication to author of SAIC, 1987.

McCabe, L.J., J.M. Symons, R.D. Lee, and G.G. Robeck. 1970. Survey of community water supply systems. *Journal of the American Water Works Association.* v. 62, no. 9, pp. 670-687.

Morel, F.M. 1983. *Principles of aquatic chemistry.* John Wiley and Sons, Inc.

National Library of Medicine (NLM). 2001. NLM Hazardous Substances Data Base Toxicology Data Network. Available on the Internet at: http://toxnet.nlm.nih.gov/, last updated May 16, 2001.

Science Applications International Corporation (SAIC). 1987. *Estimated National Occurrence and Exposure to Chromium in Public Drinking Water Supplies (Revised Draft).*

USEPA. 1979. Water-related environmental fate of 129 priority pollutants. Volume 1. Office of Water Planning and Standards, USEPA. EPA-440/4-79-029a.

USEPA. 1980. *Trace Elements in 113 U.S. Drinking Waters.* A substudy of the National Organics Monitoring Survey. Cincinnati, OH: Technical Support Division, Office of Drinking Water, USEPA. January, 1980.

USEPA. 1983. Data on inorganics from the Community Water Supply Survey. Provided by E.M. Glick, Drinking Water Quality Assessment Branch, Technical Support Division, Office of Drinking Water, USEPA, Cincinnati, OH.

USEPA. 1985. Computerized listing of inorganics data for the National Organics Monitoring Survey (NOMS). Provided to Science Applications International Corporation by E.B. Dotson, Water Supply Technology Branch, Technical Support Division, Office of Drinking Water, USEPA, Cincinnati, OH. November 12, 1985.

USEPA. 1986. *Overview of methodology used to estimate national occurrence and exposure to inorganic drinking water contaminants (Draft)*. Prepared by Science Applications International Corporation for Science and Technology Branch, Office of Drinking Water, USEPA. October 30, 1986.

USEPA. 2000. *TRI Explorer: Trends*. Available on the Internet at: http://www.epa.gov/triexplorer/trends.htm, last updated May 5, 2000.

USEPA. 2002. *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT*. EPA Report/815-D-02-005, Office of Water, 55 pp.

USGS. 2001. *Mineral Commodity Summaries, January, 2001 - Chromium*. Available on the Internet at: http://minerals.usgs.gov/minerals/pubs/commodity/chromium/180300.pdf.

USPHS. 1970. Community water supply study. Analysis of national survey findings. Bureau of Water Hygiene, Environmental Health Service, Department of Health, Education, and Welfare.

Wade Miller Associates, Inc. 1990. *Occurrence and Exposure Assessment for Chromium in Public Drinking Water Supplies*. Prepared for and submitted to EPA on July 24, 1990.

2.3 Fluoride

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Tables and Figures

2.3.1 Introduction, Use and Production

Fluorine (F), the element, is a pale, yellow-green, irritating gas that has a strong, sharp odor. Because it is so chemically reactive, it is almost always found naturally combined with metals as a salt. The term "fluorides" is used to refer to the common salts of the element fluorine, with the most common salts being sodium fluoride and calcium fluoride. Because toxic effects are due to the fluoride ion, the term fluoride is most commonly used in discussing health effects and regulations.

Fluorides occur naturally in a variety of geologic settings (for example, in sedimentary and volcanic rocks) in coal, clay, and certain minerals, and also are found in sea water. Ground water levels of fluoride are typically higher than surface water levels because their content is influenced more by the mineral and rock through which they flow (WHO, 1984, as cited in ATSDR, 1993). The biggest natural source of fluorides released to the air is volcanic eruptions. Although the greatest total volume of fluorides in the environment is released from natural sources (e.g., volcanoes and oceans), the highest concentrations are found near anthropogenic point sources related to steel, aluminum, and glass production.

Fluoride compounds are used in a wide range of industrial and other applications. The steel industry is the largest consumer of fluorides, followed by the chemical industry and the glass and ceramics industry (ATSDR, 1993).

In the United States, more than 80% of fluorspar, the primary source of fluorine and its compounds, is imported (ATSDR, 1993). Fluorspar (a term sometimes used to refer to calcium fluoride) is used directly or indirectly to manufacture products such as aluminum, gasoline, insulating foams, refrigerants, steel, and uranium fuel. Byproduct fluorosilicic acid production from some phosphoric acid producers supplements fluorspar as a domestic source of fluorine, but is not included in fluorspar production or consumption calculations. The imports originate primarily from China, the Republic of South Africa, and Mexico (USGS, 2000).

Table 2.3-1: Imports of Fluorspar to the United States (thousand metric tons, gross weight)

Imports For Consumption	1994	1995	1996	1997	1998	1999
Acid grade	434	470	474	485	462	419
Metallurgical grade	59	88	39	51	41	59
Fluorspar equivalent from hydrofluoric acid plus cryolite	108	114	131	175	204	192

Source: USGS, 2000

Usage of fluoride compounds are varied, implying potentially widespread environmental release. Molecular fluorine has been used as an oxidizer in rocket fuels, in the production of metallics and other fluorides, and in glass, enamel, and brick production. Currently, molecular fluorine is used by most manufacturers for the production of various inorganic fluorides. The main use of another fluoride compound, sodium fluoride, is as a drinking water additive for prevention of dental caries (tooth decay). It is also used as a disinfectant for fermentation apparatus in breweries and distilleries, in wood preservation, and in rimmed steel manufacturing. Calcium fluoride, the primary compound used by the fluoride chemical industry, has been used as a flux in steel manufacturing. Other uses are frosting glass and enamels, coating welding rods, fluoridation of drinking water, paint pigment, and as a catalyst in wood preservation. Prior to 1930, hydrogen fluoride was used mainly for glass etching and polishing, foundry scale removal, and minor production of metal fluorides. Other uses include uranium processing, petroleum alkylation, and stainless steel pickling. A sharp decrease in demand for hydrogen fluoride occurred in 1978 when the United States prohibited the use of chlorofluorocarbon gases in pressure packaging (ATSDR, 1993).

Table 2.3-2 shows the number of facilities in each State that manufacture and process hydrogen fluoride, the intended uses of the product, and the range of maximum amounts derived from the Toxics Release Inventory (TRI) of EPA (ATSDR, 1993). Because only certain types of facilities are required to report, this is not an exhaustive list. Neither sodium fluoride nor any other fluoride salts are listed on TRI.

Table 2.3-2: Hydrogen Fluoride Manufacturers and Processors by State

State[a]	Number of facilities	Range of maximum amounts on site in thousands of pounds[b]	Activities and uses[c]
AL	5	1-999	3,7,12
AR	1	100-999	7
AZ	8 (1) [d]	0.1-999	7,11,12,13
CA	60 (6) [d]	0-49,999	2,3,4,7,8,9,10,11,12,13
CO	6 (1) [d]	1-99	11,12,13
CT	9	0.1-99	1,5,8,11,12,13
DE	1	10-99	7,8
FL	11	0-999	1,3,5,6,7,12,13
GA	13 (1) [d]	0.1-999	8,9,11,12,13
HI	2	1-9	12
IA	3	0-99	3,7,9,11,13
ID	2 (1) [d]	0.1-0.9	1,5,12,13
IL	13	0-999	2,3,4,7,8,9,11,12
IN	14 (2) [d]	0-999	5,7,8,11,12,13
KS	8	1-9,999	7,10,11
KY	8 (1) [d]	0-9,999	1,2,3,4,5,7,10,11,12
LA	11	10-9,999	1,2,3,4,5,7,11,12,13
MA	15	0.1-99	8,11,12,13
MD	6 (1) [d]	1-999	5,11,12
ME	1	10-99	12
MI	12	0.1-9,999	2,7,8,11,12,13
MN	1	100-999	7,13
MO	12 (1) [d]	0-99	5,7,8,11,12,13
MS	1	1-9	13
MT	5	0-999	1,3,5,11
NC	13	0-99	1,5,7,11,12,13
ND	1	1-9	11
NJ	17 (2) [d]	0-999	1,2,3,4,5,7,8,10,11,12,13
NM	4 (1) [d]	0.1-99	11,12,13
NV	1	1-99	2,7
NY	21 (2) [d]	0-9,999	1,2,5,6,7,10,11,12,13
OH	38 (6) [d]	0-999	1,2,3,5,7,8,11,12,13
OK	8 (1) [d]	10-999	1,2,3,7,11,12
OR	8	0.1-999	1,5,11,12,13
PA	48 (2) [d]	0.1-9,999	2,5,7,8,10,11,12,13

State[a]	Number of facilities	Range of maximum amounts on site in thousands of pounds[b]	Activities and uses[c]
PR	7 (1) [d]	1-99	5,11,12,13
RI	3 (1) [d]	0.1-99	11,12
SC	6	0-999	5,7,11,12,13
TN	8 (1) [d]	0-9,999	1,3,4,5,6,7,11,12
TX	42	0-49,999	1,2,3,4,5,7,11,12,13
UT	7	0-999	2,3,5,8,11,12,13
VA	3	0-99	5,11,12
VT	1	100-999	12
WA	16 (1) [d]	0-999	1,5,7,11,12,13
WI	11	0.1-99	9,10,11,12,13
WV	3	0-9	2,5,12
WY	4 (1) [d]	10-99	5,11

[a] Post office State abbreviations used

[b] Data in TRI are maximum amounts on site at each facility

[c] Activities/Uses include:

1. Produce
2. Import
3. For on-site use/processing
4. For sale/distribution
5. As a byproduct
6. As an impurity
7. As a reactant
8. As a formulation component
9. As an article component
10. For repackaging only
11. As a chemical processing aid
12. As a manufacturing aid
13. Ancillary or other uses

[d] Number of facilities reporting “no data” regarding maximum amount of the substance on site

Source: ATSDR, 1993 compilation of 1989 TRI data

2.3.2 Environmental Release

Fluorine and hydrogen fluoride are both listed as Toxics Release Inventory (TRI) chemicals. Table 2.3-3 illustrates the environmental releases for fluorine from 1995 - 1999. (There are only fluorine data for these years.) Air emissions constitute most of the on-site releases, with a steady increase over the years. The increase in air emissions, as well as in surface water discharges, have solely contributed to increases in fluorine total on- and off-site releases in recent years. No underground injection, releases to land (such as spills or leaks within the boundaries of the reporting facility), or off-site releases (including metals or metal compounds transferred off-site) were reported for fluorine. These TRI release data for fluorine were reported from 14 States and Puerto Rico (USEPA, 2000). Of the 14 States that reported TRI data, 4 are contained within the 16-State cross-section (used for analyses of fluoride occurrence in drinking water; see Section 2.3.4). (For a map of the 16-State cross-section, see Figure 1.3-1.)

Table 2.3-3: Environmental Releases (in pounds) for Fluorine in the United States, 1995-1999

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1999	86,302	54,153	--	--	--	140,455
1998	81,938	49,857	--	--	--	131,795
1997	30,091	54,200	--	--	--	84,291
1996	25,460	48,300	--	--	--	73,760
1995	18,319	15,000	--	--	--	33,319

Source: USEPA, 2000

Table 2.3-4 illustrates the environmental releases for hydrogen fluoride between 1988 and 1999. Air emissions constitute most of the on-site releases, with a moderate fluctuation over the years. No real trend is suggested in the data. Surface water discharges have also fluctuated since 1988, but have stayed considerably lower than the high levels observed in 1988. Underground injection and releases to land are less significant on-site releases, with underground injections sharply decreasing to zero in 1998 after its 5-year long peak between 1993 and 1997. Off-site releases of hydrogen fluoride are considerable. From 1988 to 1998 there has been a general decrease in off-site releases, but in 1999 there was a large increase in pounds released. The TRI data for hydrogen fluoride data were reported from 49 States and do not include Alaska or Puerto Rico (USEPA, 2000). All 16 of the cross-section States (used for analyses of fluoride occurrence in drinking water; see Section 2.3.4) reported releases of hydrogen fluoride. (For a map of the 16-State cross-section, see Figure 1.3-1.)

Table 2.3-4: Environmental Releases (in pounds) for Hydrogen Fluoride in the United States, 1988-1999

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1999	14,434,432	16,983	0	5,353	522,159	14,978,927
1998	15,612,197	23,194	0	12,740	72,358	15,720,489
1997	13,235,977	31,680	2,879	15,047	110,848	13,396,431
1996	13,696,720	10,691	2,620	36,604	167,240	13,913,875
1995	11,616,575	8,702	3,845	24,078	1,020,034	12,673,234
1994	8,901,538	14,989	2,174	33,443	736,747	9,688,891
1993	9,388,840	10,340	3,520	33,260	856,706	10,292,666
1992	11,577,121	3,400	1	27,886	1,269,429	12,877,837
1991	11,345,059	5,469	1	25,259	1,080,205	12,455,993
1990	11,577,926	13,868	25	8,329	1,658,769	13,258,917
1989	13,066,004	35,918	0	10,943	1,398,278	14,511,143
1988	14,732,294	189,928	250	13,002	3,467,471	18,402,945

Source: USEPA, 2000

2.3.3 Ambient Occurrence

Fluoride is an analyte for both surface and ground water NAWQA studies, with a method detection limit (MDL) of 0.1 mg/L. Additional information on analytical methods used in the NAWQA study units, including method detection limits, is described by Gilliom and others (1998).

Typical of many inorganic contaminants, fluoride occurrence in ambient surface and ground waters is common (Table 2.3-5). This is not surprising, considering that the element and its compounds are used in many products. Significantly, fluoride compounds are used in drinking water treatment.

Detection frequencies are consistently greater for surface water than for ground water, possibly because surface waters are more sensitive to anthropogenic releases. Median concentrations are also generally higher for surface water (median concentration is 0.2 mg/L in surface water and 0.1 mg/L in ground water). However, fluoride detection frequencies greater than the MCL (4 mg/L) are higher in ground water, and 99th percentile ground water concentrations are two times larger than corresponding 99th percentile surface water concentrations. Locally high concentrations in ground water, higher than any seen in surface water, are not surprising given the possibility of long contact times between ground water and rocks enriched in fluoride at a given location. Contact times between surface waters and naturally occurring fluoride are orders of magnitude shorter, hence concentrations are lower. Furthermore, surface waters subject to large anthropogenic inputs of fluoride are more easily diluted by waters integrated from other parts of the watershed, where fluoride concentrations may be lower.

Table 2.3-5: Fluoride Detections and Concentrations in Surface Water and Ground Water

	Detection frequency > MDL*		**Detection frequency > MCL***		**Concentration percentiles (all samples; mg/L)**	
	% samples	% sites	% samples	% sites	median	99^{th}
surface water	65.7 %	69.0 %	0.02 %	0.05 %	0.2	1.3
ground water	60.3 %	67.0 %	0.4 %	0.5 %	0.1	2.6

** The Method Detection Limit (MDL) for fluoride in water is 0.1 mg/L and the Maximum Contaminant Level (MCL) is 4.0 mg/L.*

2.3.3.1 Additional Ambient Occurrence Data

A summary document entitled "Occurrence of Fluoride in Drinking Water, Food, and Air" (JRB Associates, 1984), was previously prepared for past USEPA assessments of fluoride. However, no information on the ambient occurrence of fluoride was included in that document. (The document did include information regarding fluoride occurrence in drinking water, which is discussed in Section 2.3.5 of this report.)

2.3.4 Drinking Water Occurrence Based on the 16-State Cross-Section

Fluoride is unique as a drinking water constituent in that there are both a MCL to limit levels in drinking water to protect the public from the adverse effects of fluoride, and a recommended Optimum Level for protection against dental caries. A number of drinking water systems achieve the Optimum Level by the addition of fluoride during the drinking water treatment process. The recommended optimum level ranges from 0.7 mg/L for warmer climates to 1.2 mg/L for cooler climates. The current MCL of 4 mg/L was promulgated by EPA in 1986. At the same time, a National Secondary Drinking Water Regulation (NSDWR) was promulgated, establishing a Secondary Maximum Contaminant Level (SMCL) of 2.0 mg/L. (The SMCL was based upon the finding that a 2.0 mg/L concentration of fluoride in drinking water would be protective against dental decay while preventing the majority of cases of water-related dental fluorosis which is cosmetically objectionable.)

The analysis of fluoride occurrence presented in the following section is based on State compliance monitoring data from the 16 cross-section States. The 16-State cross-section is the largest and most comprehensive compliance monitoring data set compiled by EPA to date. Fluoride occurrence in drinking water was assessed relative to several concentration thresholds of interest: 4 mg/L; 3 mg/L; 2 mg/L; 1.5 mg/L; 1.2 mg/L; 0.7 mg/L; 0.5 mg/L; and 0.1 mg/L.

All sixteen cross-section State data sets contained occurrence data for fluoride. These data represent more than 93,000 analytical results from approximately 21,000 PWSs during the period from 1983 to 1998 (with most analytical results from 1992 to 1997). The number of sample results and PWSs vary by State, although the State data sets have been reviewed and checked to ensure adequacy of coverage and completeness. The overall modal detection limit for fluoride in the 16 cross-section States is equal to 0.1 mg/L. (For details regarding the 16-State cross-section, please refer to Section 1.3.5 of this report.)

2.3.4.1 Stage 1 Analysis Occurrence Findings

The percentage of systems indicates the proportion of systems (or population served by systems) with any analytical results exceeding the specified threshold of concern. Table 7 illustrates the Stage 1 analysis of fluoride occurrence in drinking water for the public water systems in the 16-State cross-section. The percentage of total ground and surface water PWSs with at least one analytical result exceeding the MCL (4 mg/L) was equal to 1.28% (266 systems). Approximately 4.45% of total ground and surface water systems (925 systems) had any analytical results greater than the ½ MCL (2 mg/L). Over 74.1% of PWSs (15,414 systems) had at least one analytical result greater than 0.1 mg/L (the modal detection limit for fluoride).

Table 2.3-6: Stage 1 Fluoride Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Ground Water	4	1.26%	243
	3	2.26%	434
	2	4.51%	867
	1.5	7.41%	1,424
	1.2	10.7%	2,062
	0.7	23.3%	4,475
	0.5	31.1%	5,980
	0.1	73.7%	14,164
Surface Water	4	1.44%	23
	3	2.00%	32
	2	3.64%	58
	1.5	7.03%	112
	1.2	15.6%	249
	0.7	44.8%	713
	0.5	50.4%	803
	0.1	78.5%	1,250
Combined Ground & Surface Water	4	1.28%	266
	3	2.24%	466

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
	2	4.45%	925
	1.5	7.38%	1,536
	1.2	11.1%	2,311
	0.7	24.9%	5,188
	0.5	32.6%	6,783
	0.1	74.1%	15,414

Reviewing fluoride occurrence in the 16 cross-section States by PWS population served (Table 2.3-7) shows over 4.56% of the total population (over 4.8 million people) was served by PWSs with at least one analytical result greater than the MCL. Approximately 6.76% of the population served by all systems (about 7.2 million people) had any analytical results greater than the ½ MCL. More than 93.5% of the population (over 100 million people) was served by PWSs with analytical detections of fluoride greater than 0.1 mg/L.

Table 2.3-7: Stage 1 Fluoride Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Ground Water	4	3.84%	1,685,400
	3	5.29%	2,323,400
	2	8.06%	3,539,100
	1.5	12.2%	5,362,200
	1.2	21.3%	9,363,800
	0.7	52.5%	23,069,200
	0.5	62.4%	27,432,700
	0.1	93.0%	40,839,200
Surface Water	4	5.06%	3,195,800
	3	5.09%	3,213,800
	2	5.86%	3,700,100
	1.5	9.34%	5,894,600
	1.2	15.7%	9,921,200
	0.7	62.4%	39,421,200
	0.5	66.6%	42,022,900
	0.1	93.9%	59,262,900

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Combined Ground & Surface Water	4	4.56%	4,881,200
	3	5.17%	5,537,200
	2	6.76%	7,239,200
	1.5	10.5%	11,256,800
	1.2	18%	19,285,000
	0.7	58.4%	62,490,400
	0.5	64.9%	69,455,600
	0.1	93.5%	100,102,100

2.3.4.2 Stage 2 Analysis Occurrence Findings

The Stage 2 occurrence findings, based on the cross-section data, are presented in Tables 2.3-8 and 2.3-9. The statistically generated best estimate values, as well as the ranges around the best estimate value, are presented. (For a review of the Stage 2 analytical approach, please refer to Section 1.4 of this report. For complete details regarding the Stage 2 analyses, please refer to *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT* (USEPA, 2002)).

Approximately 106 (ground water and surface water) PWSs in the 16-State cross-section (0.511%) are estimated to have mean concentrations of fluoride above 4 mg/L (the current MCL). Approximately 603 (2.90% of) PWSs in the 16 States are estimated to have mean concentrations greater than 2 mg/L. The percentage of PWSs in the 16 States with estimated mean concentrations exceeding 0.1 mg/L (the modal detection limit) was about 82.2% (17,098 PWSs).

A significantly greater proportion of ground water systems, as compared to surface water systems, was estimated to exceed each threshold. Approximately 106 ground water systems in the 16-State cross-section (0.550%) had estimated mean concentrations of fluoride above 4 mg/L, compared to approximately 1 surface water system (0.0491%). About 3.05% of ground water systems (an estimated 586 systems in the 16 States) had estimated mean concentrations greater than 2 mg/L. This compares with about 1.11% of the surface water systems (about 18 systems) with estimated mean concentrations greater than 2 mg/L. The estimated mean concentration values for approximately 15,846 ground water PWSs in the 16 States (82.5%) exceed 0.1 mg/L. Approximately 1,251 surface water systems in the 16 States (78.6%) had estimated mean concentrations exceeding the modal detection limit.

Table 2.3-8: Stage 2 Estimated Fluoride Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	4	0.550%	0.469% - 0.635%	106	90 - 122
	3	1.20%	1.07% - 1.33%	230	205 - 255
	2	3.05%	2.85% - 3.23%	586	547 - 621
	1.5	5.55%	5.29% - 5.78%	1,066	1,017 - 1,110
	1.2	8.54%	8.24% - 8.80%	1,640	1,583 - 1,691
	0.7	19.8%	19.4% - 20.2%	3,804	3,729 - 3,875
	0.5	29.3%	28.8% - 29.7%	5,619	5,540 - 5,702
	0.1	82.5%	82.1% - 82.9%	15,846	15,769 - 15,925
Surface Water	4	0.0491%	0.000% - 0.188%	1	0 - 3
	3	0.193%	0.000% - 0.377%	3	0 - 6
	2	1.11%	0.691% - 1.51%	18	11 - 24
	1.5	3.91%	3.08% - 4.77%	62	49 - 76
	1.2	9.37%	8.22% - 10.5%	149	131 - 167
	0.7	30.2%	29.0% - 31.3%	481	462 - 499
	0.5	39.6%	38.6% - 40.6%	631	615 - 646
	0.1	78.6%	77.4% - 79.9%	1,251	1,233 - 1,272
Combined Ground & Surface Water	4	0.511%	0.437% - 0.591%	106	91 - 123
	3	1.12%	1.01% - 1.23%	233	209 - 256
	2	2.90%	2.72% - 3.08%	603	566 - 640
	1.5	5.42%	5.19% - 5.63%	1,128	1,079 - 1,172
	1.2	8.60%	8.32% - 8.89%	1,789	1,730 - 1,849
	0.7	20.6%	20.2% - 21.0%	4,283	4,208 - 4,358
	0.5	30.0%	29.7% - 30.5%	6,249	6,170 - 6,337
	0.1	82.2%	81.8% - 82.6%	17,098	17,017 - 17,177

Reviewing fluoride occurrence by PWS population served (Table 2.3-9) shows that approximately 96,000 (0.0897% of) the PWS population in the 16-State cross-section were served by systems with mean fluoride concentrations above 4 mg/L. When evaluated relative to a threshold of 2 mg/L, the percent of population exposed increased significantly to about 0.929% (about 994,600 people served in the 16 States). The percentage of population served by PWSs with estimated mean concentrations greater than 0.1 mg/L was approximately 89.4% (almost 96 million people).

For ground water systems, about 91,300 people in the 16 States (0.208% of the population served by ground water systems) were served by systems with estimated mean concentrations of fluoride above 4 mg/L. An estimated 1.68% of the 16-State population (approximately 736,800 people) were served by ground water systems whose mean concentration value exceeded 2 mg/L. The percentage of population served by ground water PWSs with estimated mean concentration values exceeding 0.1 mg/L was approximately 90.4% (almost 40 million people).

Approximately 0.00754% (about 4,800 people) of the population served by surface water PWSs in the 16-State cross-section were served by systems with an estimated mean concentration of fluoride above 4 mg/L. About 0.408% (about 257,800 people) of the population served by surface water PWSs were served by systems with mean concentrations greater than 2 mg/L. Over 56 million people in the 16 States (88.7%) were served by PWSs with mean fluoride concentrations above 0.1 mg/L. The percentage of population served by surface water systems that exceeded each threshold was generally always less than the percentage of ground water systems that exceeded the threshold (except greater than 0.7 mg/L). However, the total population served by systems estimated to exceed each threshold was much greater for surface water systems for thresholds less than 1.5 mg/L.

Table 2.3-9: Stage 2 Estimated Fluoride Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems in the 16 States Estimated to Exceed Threshold		Total Population served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	4	0.208%	0.131% - 0.314%	91,300	57,400 - 137,900
	3	0.556%	0.393% - 0.771%	244,100	172,400 - 338,800
	2	1.68%	1.35% - 2.04%	736,800	594,400 - 896,300
	1.5	3.52%	2.87% - 4.18%	1,545,600	1,261,800 - 1,836,500
	1.2	6.51%	5.59% - 7.57%	2,858,000	2,455,500 - 3,325,000
	0.7	24.6%	20.8% - 27.4%	10,825,500	9,151,600 - 12,042,500
	0.5	40.1%	38.3% - 42.0%	17,613,500	16,844,600 - 18,461,400
	0.1	90.4%	89.6% - 91.3%	39,730,300	39,361,200 - 40,108,100
Surface Water	4	0.00754%	0.000% - 0.0687%	4,800	0 - 43,300
	3	0.0400%	0.000% - 0.175%	25,300	0 - 110,300
	2	0.408%	0.130% - 1.44%	257,800	81,800 - 908,600
	1.5	1.92%	0.961% - 3.41%	1,212,900	606,900 - 2,153,100
	1.2	5.59%	3.55% - 8.41%	3,527,700	2,244,000 - 5,309,500
	0.7	28.3%	25.6% - 30.9%	17,837,300	16,189,300 - 19,491,600
	0.5	37.8%	35.4% - 41.1%	23,892,500	22,364,500 - 25,938,300
	0.1	88.7%	85.5% - 92.5%	56,012,300	53,953,900 - 58,392,700

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems in the 16 States Estimated to Exceed Threshold		Total Population served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Combined Ground & Surface Water	4	0.0897%	0.0555% - 0.141%	96,000	59,400 - 151,300
	3	0.252%	0.169% - 0.36%	269,400	181,000 - 387,300
	2	0.929%	0.707% - 1.55%	994,600	756,600 - 1,655,400
	1.5	2.58%	1.96% - 3.46%	2,758,300	2,093,300 - 3,707,000
	1.2	5.96%	4.61% - 7.64%	6,384,900	4,937,300 - 8,179,500
	0.7	26.8%	24.3% - 28.8%	28,664,200	26,040,800 - 30,837,800
	0.5	38.8%	37.1% - 40.9%	41,502,600	39,671,600 - 43,794,000
	0.1	89.4%	87.4% - 91.6%	95,736,400	93,573,500 - 98,102,800

2.3.4.3 Estimated National Occurrence

Based on the Stage 2 estimated percent of systems (and population served by systems) exceeding each threshold (Table 2.3-10), an estimated 332 PWSs serving approximately 191,000 people nationally could be exposed to fluoride concentrations above 4 mg/L. About 1,885 systems serving almost 2 million people had estimated mean concentrations greater than 2 mg/L. Approximately 53,448 systems serving over 190 million people nationally were estimated to have fluoride concentrations greater than 0.1 mg/L. (See Section 1.4 for a description of how Stage 2 16-State estimates are extrapolated to national values.)

For ground water systems, an estimated 327 PWSs serving about 178,000 people nationally had mean concentrations greater than 4 mg/L. Approximately 1,812 ground water systems serving about 1.4 million people nationally had estimated mean concentration values that exceeded 2 mg/L. About 49,032 ground water systems serving over 77 million people had estimated mean concentrations greater than 0.1 mg/L.

Three surface water systems serving 9,600 people were estimated to have mean concentrations of fluoride above 4 mg/L. An estimated 62 surface water systems serving 519,900 people had estimated mean concentrations greater than 2 mg/L. An estimated 4,392 surface water systems serving almost 113 million people had mean concentrations greater than 0.1 mg/L.

Table 2.3-10: Estimated National Fluoride Occurrence - Systems and Population Served

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	4	327	278 - 378	178,000	112,000 - 268,900
	3	711	634 - 789	476,000	336,300 - 660,800
	2	1,812	1,692 - 1,922	1,436,900	1,159,300 - 1,747,900
	1.5	3,297	3,147 - 3,434	3,014,300	2,460,800 - 3,581,500

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
	1.2	5,076	4,898 - 5,233	5,573,600	4,788,700 - 6,484,400
	0.7	11,769	11,537 - 11,989	21,112,000	17,847,500 - 23,485,400
	0.5	17,386	17,142 - 17,642	34,349,800	32,850,400 - 36,003,400
	0.1	49,032	48,794 - 49,276	77,482,000	76,762,200 - 78,218,800
Surface Water	4	3	0 - 11	9,600	0 - 87,400
	3	11	0 - 21	51,000	0 - 222,400
	2	62	39 - 84	519,900	164,900 - 1,832,200
	1.5	219	172 - 267	2,445,900	1,223,900 - 4,341,800
	1.2	524	460 - 586	7,113,700	4,525,200 - 10,706,900
	0.7	1,688	1,621 - 1,751	35,969,700	32,646,500 - 39,305,700
	0.5	2,213	2,158 - 2,267	48,180,300	45,099,000 - 52,305,700
	0.1	4,392	4,327 - 4,464	112,951,300	108,800,500 - 117,751,500
Combined Ground & Surface Water	4	332	284 - 385	191,000	118,200 - 301,000
	3	728	654 - 801	535,900	360,000 - 770,500
	2	1,885	1,769 - 2,000	1,978,600	1,505,100 - 3,293,100
	1.5	3,526	3,373 - 3,664	5,487,100	4,164,300 - 7,374,300
	1.2	5,594	5,408 - 5,780	12,701,700	9,821,800 - 16,271,700
	0.7	13,390	13,156 - 13,624	57,022,300	51,803,600 - 61,346,400
	0.5	19,535	19,288 - 19,808	82,562,000	78,919,500 - 87,120,300
	0.1	53,448	53,195 - 53,695	190,450,600	186,147,900 - 195,158,100

2.3.5 Additional Drinking Water Occurrence Data

Several additional data sources regarding the occurrence of fluoride in drinking water are also reviewed. A preliminary comparison of the Stage 2 model findings to MCL violation records in SDWIS/FED was conducted. The Stage 2 occurrence estimates for fluoride were also compared to fluoride occurrence findings reported in the CDC *Fluoridation Census 1992*. Previously compiled occurrence information, from an OGWDW summary document entitled "Occurrence of Fluoride in Drinking Water, Food, and Air" (JRB Associates,1984), is presented in Sections 2.3.5.3 - 2.3.5.8. This variety of studies and information are presented regarding levels of fluoride in drinking water, with the scope of the reviewed studies ranging from national to regional. (All the information in Sections 2.3.5.3 - 2.3.5.8 is taken directly from "Occurrence of Fluoride in Drinking Water, Food, and Air" (JRB Associates,1984).) Note that none of the studies presented in the following section provide the quantitative analytical results or comprehensive coverage that would enable direct comparison to the occurrence findings estimated with the cross-section occurrence data presented in Section 2.3.4. These additional studies, however, do enable a broader assessment of the Stage 2 occurrence estimates presented for this Six-Year Review.

2.3.5.1 SDWIS/FED Comparison

A preliminary comparison of Stage 2 model findings to MCL violation records in the Safe Drinking Water Information System (SDWIS) was conducted. Due to many qualifying factors, this must be regarded as a very general, indirect comparison. A primary reason inhibiting a direct comparison is the somewhat incomplete State reporting to the SDWIS database over the time frame of interest (roughly 1993-1999). Also, the method for calculating a contaminant's concentration in a system is somewhat different for the Stage 2 analysis as compared to MCL violation determinations. A brief description of some key topics related to MCL compliance information is presented below to provide background on SDWIS MCL violation data.

For systems that monitor more frequently than annually, compliance with the MCL is determined by a running annual average of results from all samples taken at each sampling point. If this contaminant mean concentration exceeds the MCL, then the system is out of compliance. For systems that monitor annually or less frequently, if the level of a contaminant at any sampling point exceeds the MCL, the system is out of compliance with the MCL.

More systems have MCL exceedances than actual MCL violations. A system with an MCL violation always has an MCL exceedance. However, a system with an MCL exceedance may not always incur an MCL violation. For example, if a system on quarterly monitoring has one quarter in which the concentration is above the MCL, but the running annual average of this high sample result and the three preceding quarters are below the MCL, the system would have an MCL exceedance but not an MCL violation. Also, if the State requires a confirmation sample, compliance with the MCL is calculated using the average of the routine and confirmation sample. If the average is below the MCL, the system would have an exceedance but not an MCL violation.

Many States experienced delays in implementation of the Phase II/V rule. In some cases, approval of State primacy took many years. Laboratory capacity, resource and staffing levels, and waivers were recurring issues. States are required to report MCL violations to SDWIS. However, delays in determining MCL violations and reporting them to SDWIS were commonplace. States had to create new databases or modify existing databases for Phase II/V compliance tracking and reporting. As a result, many States had delays in reporting chemical violation data to SDWIS. Underreporting of violations for chemicals may still be an issue for some States. SDWIS has the capability of storing data on MCL exceedances; however, reporting of these is optional.

When comparing the modeled national occurrence estimates to the SDWIS MCL violation data, one must also consider the different time frames at hand. The SDWIS MCL violation data are roughly from 1993-1999. The Stage 2 estimate is based on compliance monitoring analytical results predominantly between 1992 and 1997. (Potentially more than five years of monitoring results are used to estimate a single system mean concentration). The Stage 2 estimated number of systems with a mean concentration greater than the MCL (based on data for many years) is an approximation of, though not directly comparable to, the number of SDWIS MCL violations for a single year.

Approximately 247 PWSs reported MCL violations to SDWIS/FED between January 1, 1993 and December 31, 1999. The Stage 2 analysis estimated that approximately 332 PWSs nationally had mean concentrations of fluoride greater than the MCL (See Table 2.3-10). (The Stage 2 estimate is based on compliance monitoring analytical results predominantly between 1992 and 1997. Potentially more than five years of monitoring results are used to estimate a single system mean concentration). Based on the qualifying factors described above, it is not surprising that the Stage 2 estimates are higher than the reported SDWIS MCL violations. Even given the inherent differences between the SDWIS MCL violation records and the Stage 2 analytical findings measured relative to the MCL, the comparison between the two assessments of occurrence are quite comparable, providing additional measures that suggest a validation of the Stage 2 modeling approach.

2.3.5.2 Centers for Disease Control and Prevention *Fluoridation Census*

This section provides a general comparative assessment between the Six-Year Review's Stage 2 national fluoride occurrence estimates (based on the 16-State national cross-section) primarily with public water system fluoridation findings reported in the Centers for Disease Control and Prevention (CDC) *Fluoridation Census 1992* (CDC, 1992) as well as with findings provided by CDC staff from the unpublished *Fluoridation Census 2000* (CDC, 2002). A rigorous and direct comparison cannot be made between the CDC *Fluoridation Census 1992* (or *2000*) findings and the EPA-OGWDW's Six-Year Review statistical model estimations. The CDC census findings report the voluntary provision of qualitative/semi-quantitative information from public drinking water systems that identify if a particular system is operating as a fluoridating system (with either natural or "adjusted" concentrations of fluoride within the optimum range of fluoride). The OGWDW Six-Year Review Stage 2 findings are quantitative, parametric statistical estimations of fluoride occurrence based on compliance monitoring analytical results of fluoride concentrations in public drinking water systems from the 16-State cross-section (with the results from the 16-State cross-section then extrapolated to national occurrence estimates).

Despite the significant differences in the underlying sources of fluoride occurrence information, the comparison between the CDC and OGWDW Stage 2 findings is informative. The comparison suggests that the Stage 2 modeled national estimates are valid, broadly reflecting and correlating with the general fluoride concentrations implied by the fluoridation census findings when considering details of the differences between the census and statistical estimation approaches. Details of the comparative assessment are included below.

The CDC periodically conducts a national fluoridation census which records the total national number of public water systems, and population served by those systems, that operate with natural or adjusted levels of fluoride in drinking water at optimum levels. The "optimum range" of fluoride in drinking water (regarding prevention of dental cavities) is from 0.7 mg/L to 1.2 mg/L (although a system can be considered to be operating as a fluoridating system if it operates within the broader "control range" of fluoride concentrations from 0.6 mg/L to 1.7 mg/L)[1]. To complete the fluoridation census, States voluntarily report: the name, location, and public water system identification number of each fluoridated water system; the population served by each system; whether the system operates with adjusted, or natural, levels of fluoride; the chemical used for fluoridation, if adjusted; and whether or not the system purchased water. However, no quantitative analytical results are presented, no information is provided for systems with fluoride occurrence less than 0.7 mg/L (the low end of the optimum range), and the source water type is not specified. Therefore, the implication is that all systems that reported as fluoridating (i.e., allsystemslisted in the CDC census) are considered for comparison purposes to have a minimum (average) fluoride concentration of 0.7 mg/L, the low end of the optimum fluoridation range.

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[1] The optimum amount of fluoride in drinking water at PWSs is the range of fluoride that assists in the prevention of dental cavities. The specific optimum level of fluoride for a given PWS is generally inversely proportional to temperature. It is assumed that individuals drink more water in warmer climates and higher temperatures. The ingestion of fluoride via drinking water is directly related to the volume of water consumed. Therefore, since high temperatures result in consumption of higher volumes of water, the amount of fluoride considered optimal is at the low end of the optimal range (0.7 mg/L) in warmer regions (or warmer seasons) and at the high end of the optimum range (1.2 mg/L) in cooler regions (or cooler seasons). For example, the optimum level of fluoride for PWSs in southern Florida is 0.7 mg/L and for PWSs in Maine is 1.2 mg/L. The "control range" recommended by CDC for the optimum concentration is 0.1 mg/L below to 0.5 mg/L above the optimum.

Table VI.J.1.a shows a comparison between the quantitative results based on the 16-State cross-section data and the qualitative reported findings of the CDC *Fluoridation Census 1992* and the unpublished CDC *Fluoridation Census 2000*. The table specifically presents the Stage 2 modeled estimates based on the Six-Year Review 16-State cross-section compared to the number of fluoridating systems (and population served by those systems) as reported to the CDC.

Table VI.J.1.a. Comparison of the National Extrapolations of the Stage 2 Modeled Estimates with the CDC Fluoridation Census Findings

Stage 2 Modeled Estimates based on Compliance Monitoring Results of the 16-State Cross-Section					**CDC Fluoridation Census 1992 and unpublished 2000 [1] Findings**	
Fluoride Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold		Total Number of Systems Fluoridating	Total Population Served by Systems Fluoridating
	Best Estimate	Range	Best Estimate	Range		
4	332	284 - 385	191,000	118,200 - 301,000	145 [1]	152,527 [1]
2	1,885	1,769 - 2,000	1,978,600	1,505,100 - 3,293,100	746 [1]	849,591 [1]
0.7	13,390	13,156 - 13,624	57,022,300 [2]	51,803,600 - 61,346,400 [2]	14,496 [3]	141,107,164 [3]

For a summary of how the Stage 2 modeled estimations are derived, please refer to Section 1.4 of this report. For a detailed description of the Stage 2 method estimations, please refer to *Occurrence Estimation Methodology and Occurrence Findings Report For Six-Year Review of National Primary Drinking Water Regulations*, EPA-815-D-02-005, March 2002.

1. The number of systems and population-served by systems with reported fluoride concentrations greater than 2 mg/L and 4 mg/L were provided by the CDC from the unpublished *Fluoridation Census 2000*. (These measures of fluoride occurrence relative to these specific fluoride thresholds are not included in the 1992 or earlier census publications.)
2. There were no compliance monitoring records for fluoride for the Chicago Water System in the State of Illinois' compliance monitoring data set. Therefore, since Illinois is one of the states in the 16-state cross-section and the Chicago Water System is known to fluoridate, the Stage 2 modeled estimates presented here do not reflect the population served by the fluoridated water provided by the Chicago Water System (and its consecutive systems). (The Chicago Water System fluoride were requested, but were received after the Stage 2 modeled estimates were generated for this draft report.)
3. This estimate includes public water systems that operate within the "control range" of optimum fluoride concentrations. Therefore, this estimate includes systems that maintain fluoride concentrations as low as 0.6 mg/L while the Stage 2 model estimates are based on the 0.7 mg/L fluoride concentration values which is the low end of the optimum (rather than control) range.

The CDC *Fluoridation Census 1992* indicates that a total of 14,496 public water systems, serving 141,107,164 people, report that they operate as a fluoridated system[2]. In comparison, the Stage 2 national occurrence estimates based on the 16-State cross-section indicate a total of 13,390 systems, serving 57,022,300 people, with estimated mean concentrations of fluoride greater than 0.7 mg/L. (For a detailed presentation of Stage 2 modeled estimations of fluoride occurrence, please refer to Appendix C, Tables C.16.f and C.16.n). A system with a mean concentration of fluoride greater than 0.7 mg/L is approximately equivalent to a "fluoridated" system (in the CDC census) that reports operation at optimum fluoride levels, though systems are included in the CDC census as fluoridating if systems operate within the broader control range and above 0.6 mg/L fluoride.

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[2] The system and population totals listed here are equal to the exact system and population summations of the 50 States. These total sums do not equal the sums presented in the CDC *Fluoridation Census 1992*, in part due to the inclusion of the District of Columbia.

The differences between the national estimates for fluoridating systems (CDC–14,496 PWSs and national cross-section–13,390 PWSs) and population served by fluoridating systems (CDC–141,107,164 people and national cross-section–57,022,300 people) appear to relate to several factors. First, the lack of fluoride occurrence data from the Chicago Water System certainly results in an underestimate for the model estimated number of systems, and population served by those systems. (Fluoride data for Chicago were not included in the original compliance monitoring data sets obtained directly from the state of Illinois. Fluoride compliance monitoring data are reported to the state's public health agency. These fluoride data were subsequently requested, but were received after the Stage 2 estimations prepared for this draft report.)

The size distribution of fluoridating systems (based on population served size categories) is a second factor influencing the difference in population served between the State data and the CDC census data. Table VI.J.1.b illustrates the distribution of fluoridating systems based on six population served size categories. Although the number of systems serving 1,000 people or less is similar in the State data and CDC data (2,824 and 2,540 respectively), this equals a much larger percentage of the smallest systems in the cross-section data set (66%) than are represented in the CDC census (only 42%). Therefore, the cross-section data set (comprised of compliance monitoring data records acquired directly from the States) has a proportionately larger amount of the smallest systems than does the CDC census (based on voluntary reporting of which systems fluoridate). This differing system size profile can result in a smaller population served by a similar number of systems (as is the case for the national extrapolations based on the cross-section data).

Table VI.J.1.b. Distribution of Fluoridating Systems in the 16 Cross-Section States and the CDC Fluoridation Census 1992

Population Served	Number of Systems that Fluoridate - State Data [1]	Percent of State Total Number of Fluoridating Systems	Number of Systems that Fluoridate - CDC Data [2]	Percent of CDC Total Number of Fluoridating Systems
≤ 1,000	2,824	66%	2,540	42%
1,001 - 5,000	750	18%	1,983	33%
5,001 - 10,000	244	6%	578	10%
10,001 - 50,000	347	8%	716	12%
50,001 - 100,000	54	1%	103	2%
> 100,000	42	1%	79	1%
Total	**4,261**	**100%**	**5,999**	**100%**

1. The State data results of "number of systems that fluoridate" are derived by using the cross-section data, calculating a simple arithmetic mean fluoride concentration for each system in a particular population served system size category, and then counting all systems with a mean concentration greater than 0.7 mg/L (which represents the low end of the range of optimum fluoride concentration for fluoridation).
2. CDC "number of systems that fluoridate" are derived from qualitative reported findings of the CDC 1992 *Fluoridation Census*.

A third factor influencing the system number and population differences between the CDC and national cross-section estimates relates to systems that report as "fluoridated systems." In the CDC *Fluoridation Census 1992*, systems that operate within the control range (of optimum fluoride concentration) of 0.6 mg/L and 1.7 mg/L are considered to fluoridate. The Stage 2 statistical estimations and related national extrapolations were based on a fluoride concentration threshold of 0.7 mg/L (the low end of the optimum, not the control, range of fluoride levels). Therefore, the Six-Year Review Stage 2 estimates of systems with estimated mean concentrations of fluoride greater than 0.7 mg/L will likely be lower the CDC census number of systems reporting to operate within the control range (between 0.6 mg/L and 1.7 mg/L fluoride).

Other factors relate to the type of systems included in EPA's Six-Year Review and the CDC fluoridation census. The Six-Year Review, based on compliance monitoring, does not include analytical results for consecutive systems. Because consecutive systems compliance monitoring requirements are at the discretion of the individual States, the consecutive system compliance monitoring record is not uniform from state to state. Therefore, systems identified as consecutive (or, synonymously, as "purchased") were removed in the raw data sets prior to Stage 2 estimations. The CDC fluoridation census does include consecutive systems. (CDC estimates that there may be approximately 1,696 consecutive systems serving a population of 12,850,000 in the 16 states that comprise the 16-State cross-section used in this Six-Year Review analysis.) Also, while the Six-Year Review 16-State cross-section (compliance monitoring) data does include monitoring results from non-transient non-community water systems (NTNCWSs), the CDC does not include NTNCWs in the fluoridation census.

In summary, given the differences between the CDC census numbers and the EPA model estimates, rigorous and systematic comparisons cannot be directly made between the two assessments of fluoride occurrence in public water systems. However, general comparisons suggest that the EPA Six-Year Stage 2 modeling approach is valid in that it tracks relatively closely to CDC voluntarily reported qualitative census findings. These comparisons are closer still when the underlying differences between the CDC census findings and the Six-Year Review model estimates are considered.

The comparison of the number of systems estimated by the Six-Year model to have an estimated mean fluoride concentration greater than 0.7 mg/L compared to the number of systems reporting to the CDC census as fluoridating exhibits the largest difference between the two fluoride occurrence assessments. However, the two differing estimates are likely much closer when considering that: the CDC fluoridating systems include systems operating with the "control range" (as low as 0.6 mg/L); the Six-Year Review estimates did not have data for the Chicago Water System, and; the Six-Year Review estimates generally do not include systems considered to be "consecutive" (or purchasing water).

The comparison between the Six-Year Review model estimates and the unpublished 2000 Census numbers for systems with fluoride concentrations above 2 mg/L and 4 mg/L are generally good. For example, relative to 4 mg/L, the Six-Year Review model estimates are not dramatically higher than the CDC estimates, especially when comparing the total population served. The EPA system numbers are modeled estimates, and therefore, it is appropriate to consider the estimated range of results rather than the single "best estimate." The modeled estimates indicate that from 118,200 people to 301,000 people could be served by systems with a mean fluoride concentration greater than 4 mg/L. The CDC estimate (of approximately 153,000 people) falls into this range. The other comparisons with the unpublished 2000 CDC census findings, while not within the statistical model estimate ranges, are relatively similar (not orders of magnitude apart) given the differences between the two (CDC and EPA) sources of information/data. The differences in hundreds of systems or hundreds of thousands of population served by systems can be interpreted as somewhat close when considered relative to the total US population or the total US population served by fluoridated water.

2.3.5.3 1969 Community Water Supply Study

The U.S. Public Health Service (USPHS) conducted a Community Water Supply Study (CWSS) in 1969 to assess the status of the nation's water supply facilities and drinking water quality (USPHS 1970b, as cited in JRB Associates,1984). Finished water from a total of 969 community supplies in nine geographically distributed areas were studied. Except for the State of Vermont (in which all supplies were sampled), the study locations were standard metropolitan statistical areas (SMSAs). Water samples were reported to have been taken at various places in the distribution system of each supply studied. Of the 969 systems, 678 were groundwater supplies, 109 were surface water supplies, and the remaining 182 were mixed sources, purchased water, or of unspecified source. A shortcoming in the 1969 CWSS data file is that no distinction can be made between those systems for which fluoride was found not to be present at the detection limit of 0.1 mg/L and those having an actual measured value of 0.1 mg/L. Therefore, all systems in the 1969 CWSS reporting a value of 0.1 mg/L were treated as though fluoride were present at that level.

Of the 678 groundwater supplies sampled, 628 (92.6%) had fluoride levels reported to be at or below 1.0 mg/L. Of the 50 supplies with higher levels, 34 (5.0 %) were found to have fluoride between 1.0 and 2.0 mg/L, 7 (1.0%) between 2.0 and 3.0 mg/L, and 9 (1.3%) between 3.0 and 4.0 mg/L. No groundwater systems were observed in the 1969 CWSS to have fluoride levels exceeding 4.0 mg/L. Of the 16 groundwater systems exceeding 2.0 mg/L, 13 were small systems serving fewer than 500 people. The mean value of fluoride levels in groundwater systems sampled in the 1969 CWSS was 0.39 mg/L; the median was 0.17 mg/L.

In surface water, 102 (93.6%) of the 109 systems sampled had fluoride levels at or below 1.0 mg/L. Of the remaining 7 systems, 6 (5.5%) were between 1.0 and 2.0 mg/L, and 1 (0.9%) was between 2.0 and 3.0 mg/L. The mean value of fluoride levels in surface water systems sampled in the 1969 CWSS was 0.30 mg/L; the median value was 0.18 mg/L.

These 1969 survey findings are generally consistent with the Stage 2 occurrence findings estimated for this report. However, the different scopes of the two studies do not enable a direct comparison.

2.3.5.4 1978 Community Water Supply Survey

The 1978 CWSS, conducted by the USEPA, provided data on fluoride levels in a total of 157 surface water and 345 groundwater supplies dispersed throughout the United States (USEPA, 1978, as cited in JRB Associates,1984). The survey examined systems ranging in size from 25 people served to more than 100,000 people served. One to five samples were taken from each system. Water samples classified as raw, finished (i.e., treated water sampled at the supply), and distribution (i.e., water sampled at a user's tap) were all included. However, for the purpose of this analysis, distribution sample data were used when available. When data for distribution samples were not available, data for finished water samples were used. Data on raw water were not included in the analysis.

Of the 345 groundwater supplies sampled, 310 (89.9%) had fluoride levels reported to be at or below 1.0 mg/L. Of the remaining 35 systems, 23 (6.7%) were found to have fluoride levels between 1.0 and 2.0 mg/L, 5 (1.4%) between 2.0 and 3.0 mg/L, 3 (0.9%) between 3.0 and 4.0 mg/L, 2 (0.6%) between 4.0 and 5.0 mg/L, and 2 (0.6%) between 5.0 and 6.0 mg/L. Of the 12 groundwater systems exceeding 2.0 mg/L, seven were small systems serving fewer than 500 people; the remaining five systems served between 500 and 2,500 people. The mean fluoride concentration in groundwater systems sampled in the 1978 CWSS was 0.58 mg/L; the median value was 0.33 mg/L.

In surface water, 134 (85.4%) of the 157 systems sampled had fluoride levels at or below 1.0 mg/L. Of the remaining 23 systems, 22 (14.0%) were between 1.0 and 2.0 mg/L, and 1 (0.6%) was reported to be at 5.0 mg/L. This latter supply was a small system serving between 101-500 people. The mean fluoride concentration in surface water systems in the 1978 CWSS was 0.69 mg/L; the median value was 0.79 mg/L.

These 1978 survey findings are generally consistent with the Stage 2 occurrence findings estimated for this report. However, the different scope and coverage of the two studies prohibits a more direct comparison.

2.3.5.5 Rural Water Survey

The Rural Water Survey (RWS) (USEPA, 1982, as cited in JRB Associates,1984) was conducted between 1978 and 1980 to evaluate the status of drinking water in rural America as required by Section 3 of the Safe Drinking Water Act. Although the RWS examined drinking water from over 2,000 households in rural areas for a variety of water quality parameters, samples from only 91 public water supplies were examined for fluoride levels (the sources of water for the remaining households were private wells or very small systems serving fewer than 25 people). A second limitation regarding the RWS was that the number of service connections associated with water systems was reported in lieu of the actual population served by the systems. Dr. Bruce Brower of Cornell University, who collaborated in the National Statistical Assessment of Rural Water Conditions (based on the RWS data) provided a factor to convert the data from service connections to the number of people served, based on the average number of persons per household observed in the RWS. It must be noted, however, that these population values are only approximations.

Of the 70 groundwater supplies sampled, 62 (88.6%) had fluoride levels at or below 1 mg/L. Of the remaining 8 systems, 6 (8.6%) had fluoride levels between 1.0 and 2.0 mg/L and 2 (2.9%) had fluoride levels between 2.0 and 3.0 mg/L. The two systems with levels between 2.0 and 3.0 mg/L served between 501 and 2,500 people. The mean value of the fluoride levels in systems sampled in the RWS was 0.45 mg/L.

Of the 21 surface water systems sampled in the RWS, 19 (90.5%) had fluoride levels at or below 1.0 mg/L. The remaining 2 (9.5%) systems were reported to have fluoride between 1.0 and 2.0 mg/L. The mean value of fluoride in surface water systems in the RWS was 0.67 mg/L.

2.3.5.6 Federal Reporting Data System

The Federal Reporting Data System (FRDS) was developed to provide information on public water supplies with MCL violations as determined through monitoring of all supplies performed under the requirements of the National Interim Primary Drinking Water Regulations. The FRDS was the forerunner of the Safe Drinking Water Information System (SDWIS) database. The Wentworth (1983, as cited in JRB Associates,1984) study on MCL violations recorded in the FRDS was conducted prior to the 1986 Fluoride Rule that set the MCL at 4 mg/L. Therefore, the Wentworth (1983, as cited in JRB Associates,1984) study assessed violations in a different regulatory context, but the results are summarized here for historical perspective.

An estimated 558 groundwater supplies and 29 surface water supplies were delivering drinking water with fluoride levels exceeding the MCL in place prior to the 1986 fluoride rule (Wentworth, 1983, as cited in JRB Associates,1984). Because of the several different temperature-dependent standards (ranging from 1.4-2.4 mg/L) for fluoride that were in place throughout the U.S. prior to 1986, Wentworth's results should be interpreted with caution. For example, in the fluoride concentration ranges of 1.0-2.0 mg/L and 2.0-3.0 mg/L, the number of systems counted as exceeding the MCL is an estimate of the number of systems that by virtue of having fluoride levels in those ranges are in violation of the locally applicable fluoride standard. Other systems having fluoride concentrations in those ranges, but not in violation of the local standard, are not included in the FRDS data. For the concentration ranges greater than 3.0 mg/L, however, the FRDS data were considered to be a reasonably accurate reflection of the total number of systems nationally, since fluoride present at such levels would always be in violation of the MCL regardless of the local air temperature as based on the standards in place in 1983.

2.3.5.7 U. S. Public Health Service Reports on Optimum Levels

Two reports produced by the USPHS discuss fluoride in drinking water supplies, both of which deal with systems operating at optimal fluoride levels. These two studies are earlier versions of the fluoridation census. (The CDC *Fluoridation Census 1992*, for example, was described in Section 2.3.5.2) Note that these studies are based on "communities" and "places" (see below) rather than on public water systems and the direct population served by those water systems. These differences should be considered when comparing the results of these two USPHS fluoridation studies to the results of the 1992 census and to the result of the Stage 2 16-State cross-section fluoride analyses. Note also that the USPHS (1970a, as cited in JRB Associates,1984) study is for communities served by natural fluoride levels at or above the minimum optimal level of 0.7 mg/L.

The study titled *National Fluoride Content of Community Water Supplies - 1969* (USPHS, 1970a, as cited in JRB Associates,1984) was conducted to identify the number and location of community water supplies in the United States that have natural fluoride levels at or above the minimum optimal level of 0.7 mg/L. This report provided the names of the communities, their populations, and the reported concentration in the community water supplies. However, no information was given on the source of the water (i.e., ground or surface) in those communities, nor was any information provided for communities having natural levels less than 0.7 mg/L.

The results of the survey summarized indicated that 2,630 communities with a combined population of 8,106,435 (based on 1960 U.S. Census data) had natural fluoride levels above 0.7 mg/L. Of these, 1,517 communities (57.7%) with a combined population of 5,752,628 had drinking water supplies with natural levels in the optimum range of 0.7-1.2 mg/L. There were 1,017 communities (38.7%) with a combined population of 2,172,706 reported to have natural fluoride levels at or above 1.4 mg/L, the lowest temperature based MCL value. Of these, 596 communities with 1,070,222 people were reported to have levels above 2.0 mg/L. Only 138 communities were reported to have fluoride levels of 4 mg/L or more and seven communities exceeded 8 mg/L.

The average community size in this survey was 3,082, ranging from less than 25 to one community of 313,900. Only eight communities had reported populations greater than 100,000; over 75% had fewer than 2,500. There is some trend toward smaller average community size for those communities with levels that exceed the current MCL. Communities reporting very high levels (e.g., 8 mg/L or more) all had populations of about 500 persons or less.

The USPHS (1970a, as cited in JRB Associates,1984) indicated that most (62%) of the communities having natural fluoride levels of 0.7 mg/L or more were located in the States of Arizona, Colorado, Illinois, Iowa, New Mexico, Ohio, Oklahoma, South Dakota, and Texas. These same States account for about 66% of the 1,017 communities exceeding the lowest MCL of 1.4 mg/L. Six States – Delaware, Hawaii, Massachusetts, Pennsylvania, Tennessee, and Vermont – as well as the District of Columbia were reported to have no communities with natural levels above 0.7 mg/L. Although this information indicates that there is a regional aspect to high natural fluoride levels in drinking water supplies, it is important to note that in all but one State (other than those listed above as having no natural fluoride of 0.7 mg/L or more), at least one community had 1.4 mg/L or more. (The one exception to this, New Hampshire, had one community at 1.3 mg/L.)

The second report by the U.S. Public Health Service that addressed optimum fluoride levels in drinking water supplies is the *1975 Fluoridation Census* (USPHS, 1977, as cited in JRB Associates,1984). This report is similar to the USPHS report discussed above, although it includes locations and population data for places having both natural and adjusted fluoride levels of 0.7 mg/L or more. However, this report presents no data on the concentration of fluoride in these systems. Bock (1982, as cited in JRB Associates,1984) indicates that, like the 1969 report, the 1975 census included all systems with levels above 0.7 mg/L, not just those in the optimum fluoride range. Again, like the 1969 study, no information was given on water source type nor for actual water sample analytical results.

The *1975 Fluoridation Census* reported that 9,425 places[3] with a total population of 105,338,343 (using 1970 U.S. Census data) have drinking water with natural or adjusted fluoride levels of 0.7 mg/L or more. Of these, 2,630 places having a population of 10,711,049 have natural fluoride levels at 0.7 mg/L or more. (The appearance of "2,630" in both the USPHS surveys is coincidental. The terms "community" used in the 1969 study and "place" used in the 1975 Census do not appear to be synonymous. Some States show significantly more "places" in the 1975 report than "communities" in the 1969 survey, while others show fewer; States showing the same number in both studies often list different locations.)

Although of limited value for this discussion of fluoride occurrence in drinking water, the *1975 Fluoridation Census* does indicate a higher population receiving natural fluoride levels of 0.7 mg/L or more as compared to the 1969 study. Also, the Fluoridation Census supports the 1969 study conclusion that the nine States listed earlier are responsible for most (60% in the 1975 fluoridation census) of the places having natural levels of 0.7 mg/L or more.

2.3.5.8 Estimated National Occurrence of Fluoride in Public Drinking Water Supplies Based on Survey Data

The JRB Associates (1984) study developed estimates of the number of drinking water supplies nationally within each of the source/size categories expected to have fluoride present within various concentration ranges. The study developed the national estimates using both Federal survey data and compliance monitoring data. The Public Health Service data (briefly reviewed above in Section 2.3.5.7) were reportedly not useful in the JRB Associates (1984) development of the national estimates for several reasons. Those data were for "places" or "communities" rather than supplies, and there was no indication as to the source of the water for those locations. The *1975 Fluoridation Census* provided no quantitative data on fluoride levels in the drinking water, indicating only whether the water had natural or adjusted levels of 0.7 mg/L or more; the 1969 USPHS study addressed only communities with natural levels at or above 0.7 mg/L.

The Federal survey data together with the compliance monitoring data provided information on water source and system size for extrapolating to all public water supplies. The compliance monitoring data is believed to provide a reasonably accurate picture of those supplies in the U.S. with high fluoride levels. However, because it addressed only supplies in violation of the current MCL, the compliance monitoring data provided no information on supplies with lower levels of fluoride. The Federal survey data, which

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[3] "Place" refers to a geographic entity listed in the Worldwide Geographic Location Codes prepared by the General Services Administration.

provides some information on supplies at all concentrations, is of limited value for estimating the number of systems nationally having high fluoride levels because of the small number of supplies sampled. That is, because there are relatively few supplies in the U.S. having high levels, the chances of observing them in the surveys is small. On the other hand, when a supply with a high fluoride level was observed in the surveys, extrapolating to the national level results in a questionably high national estimate. It was, therefore, decided that the compliance monitoring data would be used to describe national fluoride occurrence at the higher concentrations and the survey data would be used to estimate national fluoride occurrence at lower concentrations.

The estimates of supplies having > 3.0 mg/L are taken directly from the compliance monitoring data, since systems having levels > 3.0 would always be reported through FRDS as MCL violations (at the MCL in place prior to the 1986 fluoride rule). For lower levels (i.e., ≤ 3.0 mg/L), national estimates were calculated as follows. First, the results of the three surveys were combined for groundwater and surface water, respectively, to determine the total number of systems sampled with values ≤ 3.0 mg/l, as well as the number falling within each concentration range of interest. National estimates of supplies within each concentration range were then calculated in proportion to that observed in the combined Federal survey data.

For the > 2.0-3.0 mg/L range for groundwater, the estimates calculated from the Federal survey data were compared to the compliance monitoring data for each source/size category and the larger value was chosen for the national estimates. This choice was based on the recognition that the compliance monitoring data may underestimate the actual number of supplies in the > 2.0-3.0 mg/L range since not all supplies having fluoride in that range are necessarily in violation of the MCL and, therefore, would not be reported through FRDS. Higher estimates, computed from the survey data, were considered to be more conservative. On the other hand, in those instances where the compliance data showed more supplies in that range than the estimates from the survey data, the compliance data were considered more representative of actual occurrence, since the lower estimates from the survey data probably resulted from the small sample size. Specifically, for ground water in the > 2.0-3.0 mg/L ranges, the national estimates for supplies serving 5,000 or fewer people are based on the Federal survey data and on the compliance data for supplies serving more than 5,000 persons. For surface water, all values in the > 2.0-3.0 mg/L range are from the compliance monitoring data. All estimates of ground water and surface water supplies having ≤ 2.0 mg/L of fluoride are based on the Federal survey data.

The estimates indicate that 82.8% of all public water supplies in the U.S. in the mid-1980s using ground water had fluoride present in the range of 0.1 to 1.0 mg/L. About 8.6% of ground water supplies (4,214 total) were estimated to have fluoride levels > 1.0 mg/L, though most of these fall in the 1.0-2.0 mg/L range. Most of the estimated 1,324 groundwater supplies with fluoride levels exceeding 2.0 mg/L are expected to be small or medium sized supplies, while all of the supplies having very high levels (> 7.0 mg/L) are expected to be small systems serving fewer than 1,000 people.

For surface water, the majority of systems (78.5%) are also expected to have fluoride present in the 0.1-1.0 mg/L range. Of the 726 surface water supplies estimated to have levels above 1.0 mg/L, almost all (704) are estimated to be in the 1.0-2.0 mg/L range. As in the case of groundwater, most of the surface water supplies expected to have levels exceeding 2.0 mg/L are small and medium sized systems.

2.3.6 Conclusion

The record of use, production and release of fluoride and its compounds suggest it is found at low levels in soil, water, and air. Most fluorides are used in steel production, while other fluoride compounds are used in a variety of applications including drinking water additives. Recent statistics regarding import for consumption of fluorspar (the primary source of fluorine and its compounds) indicate production and use are robust. Industrial releases of fluorine have occurred since 1995 in 11 States and Puerto Rico, while releases of hydrogen fluoride have occurred since 1988 in 49 States. Air emissions constitute the greatest proportion of the total on- and off-site releases of fluorine and hydrogen fluoride. Fluoride is also a national NAWQA analyte. Fluoride occurrence in ambient surface and ground waters is high. Approximately 69.0% of all surface water sites had analytical detections of fluoride, compared to 67.0% of ground water sites. The percentage of sites with fluoride detections greater than the MCL (4 mg/L) drastically decreases, however, to 0.05% for surface water sites and 0.5% for ground water sites. The Stage 2 analysis, based on the 16-State cross-section, estimated that approximately 0.511% of combined ground water and surface water systems serving 0.0897% of the population had estimated mean concentrations of fluoride greater than the MCL of 4 mg/L. Based on this estimate, approximately 332 PWSs nationally serving about 191,000 people are expected to have estimated mean concentrations of fluoride greater than 4 mg/L.

Since fluoride and its compounds occur naturally occurring, the balanced geographic distribution of the 16-State cross-section should adequately cover the range of natural occurrence of fluoride from low to high. The 16-State cross-section also contains a substantial proportion of the States with reported TRI releases of fluorine and hydrogen fluoride. Based on this use and release evaluation, the 16-State cross-section appears to adequately represent fluoride occurrence nationally.

2.3.7 References

Agency for Toxic Substances and Disease Registry (ATSDR). 1993. *Toxicological Profile for Fluorides, Hydrogen Fluoride, and Fluorine (F)*. U.S. Department of Health and Human Services, Public Health Service. 244 pp. + Appendices. Available on the Internet at: http://www.atsdr.cdc.gov/toxprofiles/tp11.pdf

Bock, W. 1982. Census Program, Center for Disease Control, U.S. Public Health Service, Athens, GA. Private Communication with author of JRB Associates,1984.

CDC. 1992. *Fluoridation Census 1992.* Atlanta, GA: Centers for Disease Control and Prevention, Public Health Service, U.S. Department of Health and Human Services.

Gilliom, R.J., D.K. Mueller, and L.H. Nowell. 1998. *Methods for comparing water-quality conditions among National Water-Quality Assessment Study Units, 1992-95*. U.S. Geological Survey Open-File Report 97-589. Available on the Internet at: http://ca.water.usgs.gov/pnsp/rep/ofr97589/, last updated October 9, 1998.

JRB Associates. 1984. *Occurrence of Fluoride in Drinking Water, Food, and Air.* Prepared for and submitted to EPA on February 9, 1984.

USEPA. 1978. *Community Water Supply Survey.* Computer data files on inorganic contaminants.

USEPA. 1982. *Rural Water Survey.* Computer data provided by Department of Sociology, Cornell University.

USEPA. 2000. *TRI Explorer: Trends*. Available on the Internet at: http://www.epa.gov/triexplorer/trends.htm, last updated May 5, 2000.

USEPA. 2002. *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT.* EPA Report/815-D-02-005, Office of Water, 55 pp.

USGS. 2000. *Mineral Commodity Summaries, February, 2000 - Fluoride.* Available on the Internet at: http://minerals.usgs.gov/minerals/pubs/commodity.

USPHS. 1970a. *Natural Fluoride Content of Community Water Supplies; 1969.* Bethesda, MD: National Institutes of Health, Public Health Service, Department of Health, Education, and Welfare.

USPHS. 1970b. *Community Water Supply Survey.* Washington, DC: Bureau of Water Hygiene, Public Health Service, Department of Health, Education, and Welfare.

USPHS. 1977. *Fluoridation Census 1975.* Atlanta, GA: Center for Disease Control, Public Health Service, Department of Health, Education, and Welfare.

Wentworth, N. 1983. Summary of fluoride drinking water violations data derived from: (a) FRDS24 of FY82 (3/14/83); (b) FRDS Chemical Violation List of FY78-FY81; (c) Summary of Variances and Exemptions Issued FY82; (d) Report on “Defluoridation Study for Suffolk Area of VA,” (10/82); and (e) Region VIII report on “Solving Public Health Problems” (2/8/83). U.S. Environmental Protection Agency, Office of Drinking Water. Personal communication to author of JRB Associates, 1984 on March 24, 1983.

WHO. 1984. *Fluorine and Fluorides.* Geneve, Switzerland: World Health Organization, Distribution and Sales Service, EHC Number 36.

2.4 Mercury

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Tables and Figures

2.4.1 Introduction, Use and Production

Mercury (Hg) is a member of Group IIB of the periodic table. Mercury is a naturally occurring metal which has several forms. The principal valence states of mercury are +1 (mercurous) and +2 (mercuric), both of which are found in natural waters (USEPA, 1979, as cited in Wade Miller, 1990). The metallic mercury is a shiny, silver-white, odorless liquid. If heated, it is a colorless, odorless gas. Mercury combines with other elements, such as chlorine, sulfur, or oxygen, to form inorganic mercury compounds or "salts," which are usually white powders or crystals. Mercury also combines with carbon to make organic mercury compounds (ATSDR, 1999b).

The occurrence of mercury in surface and ground water is influenced by natural and anthropogenic sources. Although mercury occurs in the environment as a result of human activities, the major source of mercury in the environment results from geothermal activity, volatilization from mineral deposits, or volcanic activity (Wade Miller, 1990). Mercury in surface water may be the result of human activities or naturally occurring sources. Because mercury does not readily leach through soils, contamination of ground water is believed to be unlikely. Therefore, most mercury in ground water is considered to be natural in origin (Battelle, 1977; Perwak et al., 1980, all as cited in Wade Miller, 1990).

Like all elements, the same amount of mercury has existed on the planet since the Earth was formed. However, the amount of mercury mobilized and released into the environment has increased since the beginning of the industrial age. The human activities that are most responsible for causing mercury to enter the environment are the burning of materials (such as batteries), use of fuels (such as coal) that contain mercury, and certain industrial processes (USEPA, 2001).

Mercury has many applications in industry due to its unique properties, such as its fluidity, its uniform volume expansion over the entire liquid temperature range, its high surface tension, and its ability to alloy with other metals (ATSDR, 1999a). Mercury is used in its pure form in thermometers, barometers, and other consumer products (NSC, 2001). However, domestic consumption of mercury has demonstrated a downward trend since the early 1970s. In 1995, consumption was 102,000 pounds, down 10% from 1994. The largest commercial use of mercury in the United States was for electrolytic production of chlorine and caustic soda in mercury cells, accounting for 35% of domestic consumption. Manufacture of wiring devices and switches accounted for 19%, measuring and control instruments for 9%, dental equipment and supplies used 7%, electric lighting used 7%, and other uses amounted to 21% (USGS, 1997). Due to the high toxicity of mercury in most of its forms, many applications have been canceled as a result of attempts to limit the amount of exposure to mercury waste (ATSDR, 1999a).

The canceled uses of mercury include use of phenylmercuric acetate as a fungicide in interior latex paints and exterior paints. The former use was banned in 1990 and the latter in 1991. This occurred because the paint released mercury vapors as it degraded. Most agricultural applications of mercury compounds in bactericides and fungicides have been canceled due to the toxicity of mercury. Minor uses of mercury in the production of felt hats and as a wood preservative have also been terminated (ATSDR, 1999a).

In electrical applications, mercury is a critical element in alkaline batteries. Due to its toxicity, the amount of mercury in batteries is being reduced from 0.1% to 0.025%. Mercury vapors are used in discharge tubes of some electrical lamps because this makes the lamps efficient, long-lasting, and more energy efficient. In 1985, 64% of the mercury used in the U.S. was for electrical applications, and this amount had fallen to 29% in 1992 (ATSDR, 1999a).

Probably one of mercury's most familiar applications is in medicine in dental restorations. It is used in dentistry because of its ability to alloy with other metals. Estimates of annual mercury usage by U.S.

dentists range from approximately 220,500 pounds in the 1970s to 154,300 pounds in 1995. Until 30 years ago, mercury was also used in pharmaceuticals. Mercury salts were used in antiseptics, diuretics, skin lightening creams, and laxatives. Organic mercury compounds were used in antisyphilitic drugs and some laxatives. Phenylmercury acetate was used in contraceptive gels and foams and as a disinfectant. Almost all of these uses have now been replaced by others that are more effective and less toxic (ATSDR, 1999a).

In the chemical and mining industries, mercury is used as a catalyst in reactions to form polymers and in the preparation of chlorine and caustic soda from brines. In mining, mercury is used in gold mining to extract gold from ores through amalgamation (ATSDR, 1999a).

Organic mercury (especially methyl mercury and dimethyl mercury) can imperil human welfare because of its tendency to bioaccumulate in the flesh of certain fish. Low levels of mercury contamination in oceans and lakes can lead to toxic contamination of fish, making it hazardous for human consumption, especially for children and pregnant women (NSC, 2001).

The primary method of obtaining mercury is from mining. Ten percent of mercury mining is open pit mining and 90% is from underground mining techniques. There are currently 34 facilities that produce or process mercury in the U.S. (ATSDR, 1999a). U.S. production of mercury in 1985 was 1,254,000 pounds, and world production in 1986 was 13,376,000 pounds (NSC, 2001). As of 1995, eight mines in California, Nevada, and Utah produced mercury as a by-product from gold mining operations. Approximately 127,900 pounds of mercury were produced from eight mines in 1991 and 141,100 pounds were produced as a by-product from nine mines in 1992. Since then, production volumes have been withheld to avoid disclosing Bureau of Mines company proprietary data (ATSDR, 1999a).

Table 2.4-1 lists the facilities in each State that manufacture or process mercury, the intended use, and the range of maximum amounts of mercury that are stored on site derived from the Toxics Release Inventory (TRI) of EPA (ATSDR, 1999a).

Table 2.4-1: Facilities that Manufacture or Process Mercury

Facility	Location[a]	Range of maximum amounts on site in pounds	Activities and uses
Occidental Chemical	Muscle Shoals, AL	100,000-999,999	Chemical processing aid
Tuscaloosa Steel Corp.	Tuscaloosa, AL	0-99	Article component
Occidental Chemical	New Castle, DE	100,000-999,999	Chemical processing aid
Olin Chlor-Alkali Prods.	Augusta, GA	100,000-999,999	Chemical processing aid
Alexander Mfg. Co.	Mason City, IA	0-99	Import, On-site use/processing, Article component
Micro Switch	Freeport, IL	10,000-99,999	Article component
Valspar Corp.	Rockford, IL	10,000-99,999	Formulation component
Durakool Inc.	Elkhart, IN	10,000-99,999	Article component
Hermaseal Co.	Elkhart, IN	10,000-99,999	Article component
U.S. Steel	Gary, IN	10,000-99,999	Produce, Byproduct
United Techs.	Edinburgh, IN	10,000-99,999	Article component
Koch Sulfur Prods. Co.	De Soto, KS	0-99	Ancillary/other use
BF Goodrich Co.	Calvert City, KY	100,000-999,999	Chemical processing aid
Du Pont	Louisville, KY	not available	not available
Borden Chemicals &	Geismar, LA	100,000-999,999	Import, On-site use/processing, Chemical processing aid
Dow Chemical Co.	Plaquemine, LA	1,000-9,999	Produce, Byproduct
Pioneer Chlor Alkali Co.	Saint Gabriel, LA	100,000-999,999	Chemical processing aid
PPG Ind. Inc.	Lake Charles, LA	100,000-999,999	Chemical processing aid
Holtrachem Mfg.	Orrington, ME	100,000-999,999	Chemical processing aid

Facility	Location[a]	Range of maximum amounts on site in pounds	Activities and uses
Elm Plating Co.	Jackson, MI	0-99	Article component
Kerr Corp.	Romulus, MI	1,000-9,999	Repackaging
Holtrachem Mfg. Co.	Riegelwood, NC	100,000-999,999	Chemical processing aid
Mercury Refining Co.	Albany, NY	10,000-99,999	Produce, Sale/Distribution, Repackaging, Ancillary/other use
Ashta Chemicals Inc.	Ashtabula, OH	10,000-99,999	Chemical processing aid
Component Repair	Mentor, OH	not available	not available
Sinclair Oil Corp.	Tulsa, OK	100-999	Produce, Byproduct
Advanced Environmental	Allentown, PA	10,000-99,999	Produce, Sale/distribution
Bethlehem Apparatus	Hellertown, PA	100,000-999,999	Produce, Import, On-site use/processing, Sale/distribution,
Zinc Corp. of America	Monaca, PA	10,000-99,999	Produce, Impurity
Olin Corp.	Charleston, TN	100,000-999,999	Chemical processing aid
Occidental Chemical	Deer Park, TX	100,000-999,999	Chemical processing aid
Georgia-Pacific West	Bellingham, WA	100,000-999,999	Chemical processing aid
Vulcan Materials Co.	Port Edwards, WI	100,000-999,999	Chemical processing aid
PPG Ind. Inc.	New Martinsville,	100,000-999,999	Chemical processing aid

[a] Post office State abbreviations used

Source: ATSDR, 1999a compilation of TRI96 1998 data

2.4.2 Environmental Release

Mercury and mercury compounds are both listed as Toxics Release Inventory (TRI) chemicals. Table 2.4-2 illustrates the environmental releases for mercury from 1988 - 1999. (There are only mercury data for these years.) Air emissions constitute most of the on-site releases, with the amount released decreasing in earlier years and generally remaining constant in more recent years. The decrease in air emissions, as well as decreases in surface water discharges and off-site releases (including metals or metal compounds transferred off-site), have contributed to decreases in mercury total on- and off-site releases in previous years. Releases to land decreased until 1996, at which point they began to rise. No underground injection releases were recorded or reported for mercury. These TRI data for mercury were reported from 31 States and Puerto Rico with 12 States reporting all 12 years (USEPA, 2000). Of the 31 States, 10 are included in the 16 State cross-section (used for analyses of mercury occurrence in drinking water; see Section 2.4.4). (For a map of the 16-State cross-section, see Figure 1.3-1.)

Table 2.4-2: Environmental Releases (in pounds) for Mercury in the United States, 1988-1999

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1999	11,275	133	--	2,419	7,070	20,897
1998	12,591	134	--	3,069	15,721	31,515
1997	12,163	391	--	1,016	26,346	39,916
1996	14,286	468	--	537	13,012	28,303
1995	13,262	192	--	1,016	14,228	28,698
1994	11,277	175	--	1,351	14,097	26,900
1993	11,642	267	--	1,801	18,355	32,065
1992	14,222	273	--	3,122	43,854	61,471
1991	18,208	629	0	5,292	112,969	137,098
1990	22,391	751	0	4,184	177,015	204,341
1989	25,095	1,555	0	4,942	126,087	157,679
1988	22,905	1,397	0	13,279	258,718	296,299

Source: USEPA, 2000

Table 2.4-3 illustrates the environmental releases for mercury compounds between 1988 and 1999. Air emissions constitute most of the on-site releases, with some fluctuation over the years. Both surface water discharges and releases to land have also fluctuated, with releases to land dramatically increasing in 1998-1999. Underground injections contribute relatively little to total releases, and have not been registered since 1998. Off-site releases of mercury compounds are considerable. The levels of total on- and off-site releases have generally followed the highs and lows of the levels of off-site releases, with no discernible trend. These TRI data for mercury compounds were reported from 32 States with one State, Pennsylvania, reporting every year (USEPA, 2000). Of the 32 States, 12 are included in the 16 State cross-section (used for analyses of mercury occurrence in drinking water; see Section 2.4.4). (For a map of the 16-State cross-section, see Figure 1.3-1.)

Table 2.4-3: Environmental Releases (in pounds) for Mercury Compounds in the United States, 1988-1999

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1999	2,110	36	--	5,700	53,051	60,897
1998	2,372	34	--	2,550	19,858	24,814
1997	2,356	34	41	0	25,448	27,879
1996	2,916	73	9	0	29,437	32,435
1995	3,156	136	6	0	207,097	210,395
1994	2,716	151	7	0	26,166	29,040
1993	3,421	184	15	11	56,009	59,640
1992	3,249	307	9	17	191,945	195,527
1991	3,080	52	9	2	36,875	40,018
1990	1,158	58	21	15	36,041	37,293
1989	4,009	13	36	260	56,113	60,431
1988	2,376	9	27	0	17,916	20,328

Source: USEPA, 2000

2.4.3 Ambient Occurrence

The most comprehensive and nationally consistent data describing ambient water quality in the United States are being produced through the United States Geological Survey's (USGS) National Water Quality Assessment (NAWQA) program. However, no national NAWQA data are available for mercury.

Also, there are no other ambient data available for mercury. A summary document entitled "Occurrence and Exposure Assessment for Mercury in Public Drinking Water Supplies" (Wade Miller, 1990), was previously prepared for past USEPA assessments of mercury. However, no information on the ambient occurrence of mercury was included in that document. (The document did include information regarding mercury occurrence in drinking water, which is discussed in Section 2.4.5 of this report.)

2.4.4 Drinking Water Occurrence Based on the 16-State Cross-Section

The analysis of mercury occurrence presented in the following section is based on State compliance monitoring data from the 16 cross-section States. The 16-State cross-section is the largest and most comprehensive compliance monitoring data set compiled by EPA to date. These data were evaluated relative to several concentration thresholds of interest: 0.002 mg/L; 0.001 mg/L; and 0.0005 mg/L.

All sixteen cross-section State data sets contained occurrence data for mercury. These data represent more than 64,000 analytical results from approximately 19,000 PWSs during the period from 1984 to 1998 (with most analytical results from 1992 to 1997). The number of sample results and PWSs vary by State, although the State data sets have been reviewed and checked to ensure adequacy of coverage and completeness. The overall modal detection limit for mercury in the 16 cross-section States is equal to 0.001 mg/L. (For details regarding the 16-State cross-section, please refer to Section 1.3.5 of this report.)

2.4.4.1 Stage 1 Analysis Occurrence Findings

Table 2.4-4 illustrates the low occurrence of mercury in drinking water for the public water systems in the 16-State cross-section relative to three thresholds: 0.002 mg/L (the current MCL), 0.001 mg/L (the modal MRL), and 0.0005 mg/L. A total of 50 ground water and surface water PWSs (approximately 0.263%) had at least one analytical result exceeding the MCL; 0.900% (171 systems) of PWSs had at least one analytical result exceeding 0.001 mg/L; and 2.90% (551 systems) of PWSs had at least one analytical result exceeding 0.0005 mg/L.

Approximately 0.252% (44 systems) of ground water PWSs had at least one analytical result greater than the MCL. About 0.848% (148 systems) of ground water PWSs had at least one analytical result above 0.001 mg/L. The percentage of ground water systems with at least one result greater than 0.0005 mg/L was equal to 2.68% (467 systems).

Only 6 (0.387% of) surface water systems had at least one analytical result greater than the MCL. A total of 23 (1.48% of) surface water systems had at least one analytical result greater than 0.001 mg/L. Eighty-four surface water systems (5.42%) had at least one analytical result exceeding 0.0005 mg/L.

Table 2.4-4: Stage 1 Mercury Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Ground Water	0.002	0.252%	44
	0.001	0.848%	148
	0.0005	2.68%	467
Surface Water	0.002	0.387%	6
	0.001	1.48%	23
	0.0005	5.42%	84
Combined Ground & Surface Water	0.002	0.263%	50
	0.001	0.900%	171
	0.0005	2.90%	551

Reviewing mercury occurrence in the 16 cross-section States by PWS population served (Table 2.4-5) shows that approximately 0.276% of the population (almost 300,000 people) was served by PWSs with at least one analytical result of mercury greater than the MCL (0.002 mg/L). Approximately 4.5 million (4.33% of) people were served by systems with an exceedance of 0.001 mg/L. A total of 9,268,500 people (8.82%) were served by systems with at least one analytical result greater than 0.0005 mg/L.

The percentage of population served by ground water systems with analytical results greater than the MCL was equal to 0.538% (almost 232,000 people). When evaluated relative to 0.001 mg/L or 0.0005 mg/L, the percent of population exposed was equal to 4.18% (1,803,400 people) and 10.2% (approximately 4.4 million people), respectively.

The percentage of population served by surface water systems with exceedances of 0.002 mg/L was equal to 0.0937% (58,000 people). Approximately 4.43% (about 2.7 million people) of the population served by surface water systems were served by systems with estimated mean concentrations of mercury greater than 0.001 mg/L. When evaluated relative to 0.0005 mg/L, the percent of population exposed was equal to 7.84% (almost 4.9 million people).

Table 2.4-5: Stage 1 Mercury Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Ground Water	0.002	0.538%	231,900
	0.001	4.18%	1,803,400
	0.0005	10.2%	4,409,500
Surface Water	0.002	0.0937%	58,000
	0.001	4.43%	2,746,300
	0.0005	7.84%	4,859,000
Combined Ground & Surface Water	0.002	0.276%	290,000
	0.001	4.33%	4,549,700
	0.0005	8.82%	9,268,500

2.4.4.2 Stage 2 Analysis Occurrence Findings

The Stage 2 occurrence findings, based on the cross-section data, are presented in Tables 2.4-6 and 2.4-7. The statistically generated best estimate values, as well as the ranges around the best estimate value, are presented. (For a review of the Stage 2 analytical approach, please refer to Section 1.4 of this report. For complete details regarding the Stage 2 analyses, please refer to *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT* (USEPA, 2002)).

A total of 13 (0.0672%) ground water and surface water PWSs in the 16 States had an estimated mean concentration of mercury exceeding 0.002 mg/L. Approximately 73 (0.385% of) PWSs in the 16 States had an estimated mean concentration exceeding 0.001 mg/L, and 431 (2.27%) had an estimated mean concentration exceeding 0.0005 mg/L.

An estimated 13 ground water PWSs in the 16 cross-section States (0.0727%) had a mean concentration greater than 0.002 mg/L, 72 (0.411%) had a mean concentration greater than 0.001 mg/L, and 416 (2.38%) had a mean concentration greater than 0.0005 mg/L. Approximately 1 (0.00529%), 1 (0.0863%), and 16 (1.03%) surface water PWSs in the 16 States had estimated mean concentrations exceeding 0.002 mg/L, 0.001 mg/L, and 0.0005 mg/L, respectively.

Table 2.4-6: Stage 2 Estimated Mercury Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.002	0.0727%	0.0459% - 0.103%	13	8 - 18
	0.001	0.411%	0.321% - 0.504%	72	56 - 88
	0.0005	2.38%	2.13% - 2.62%	416	372 - 457
Surface Water	0.002	0.00529%	0.000% - 0.0645%	1	0 - 1
	0.001	0.0863%	0.000% - 0.258%	1	0 - 4
	0.0005	1.03%	0.581% - 1.55%	16	9 - 24
Combined Ground & Surface Water	0.002	0.0672%	0.0421% - 0.0948%	13	8 - 18
	0.001	0.385%	0.300% - 0.474%	73	57 - 90
	0.0005	2.27%	2.05% - 2.49%	431	390 - 473

Reviewing mercury occurrence by PWS population served (Table 2.4-7) shows that approximately 0.00627% (an estimate of approximately 6,600 people) of population served by all PWSs in the 16 cross-section States were potentially exposed to mercury levels above 0.002 mg/L. The percentage of population served by PWSs in the 16 States with levels of mercury above 0.001 mg/L and 0.0005 mg/L were 0.0987% (an estimated 103,700 people) and 1.56% (about 1.6 million people), respectively.

When the percent of population served by ground water systems was evaluated relative to a threshold of 0.002 mg/L, 0.001 mg/L, and 0.0005 mg/L, the percentage of population exposed in the 16 cross-section States was equal to 0.0147% (an estimated 6,300 people), 0.151% (an estimated 65,100 people) and 1.36% (an estimated 585,500 people), respectively.

The percentage of population served by surface water systems with levels above 0.002 mg/L was equal to 0.000429% (an estimated 300 people served by systems in the 16 States), and the percentage of population served with levels above 0.001 mg/L was 0.0624% (an estimated 38,700 people in the 16-State cross-section). The percentage of the population served by surface water systems with levels above 0.0005 mg/L was 1.70% (just over 1 million people).

Table 2.4-7: Stage 2 Estimated Mercury Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.002	0.0147%	0.00224% - 0.0535%	6,300	1,000 - 23,100
	0.001	0.151%	0.0661% - 0.288%	65,100	28,500 - 124,100
	0.0005	1.36%	0.923% - 2.26%	585,500	397,800 - 975,300
Surface Water	0.002	0.000429%	0.000% - 0.00921%	300	0 - 5,700
	0.001	0.0624%	0.000% - 1.36%	38,700	0 - 840,400
	0.0005	1.70%	0.473% - 2.27%	1,056,100	293,000 - 1,408,800
Combined Ground & Surface Water	0.002	0.00627%	0.000924% - 0.0223%	6,600	1,000 - 23,400
	0.001	0.0987%	0.0308% - 0.853%	103,700	32,300 - 896,900
	0.0005	1.56%	0.946% - 2.06%	1,641,600	994,500 - 2,166,000

2.4.4.3 Estimated National Occurrence

Based on the Stage 2 estimated percent of systems (and population served by systems) exceeding each threshold, an estimated 44 PWSs serving approximately 13,400 people nationally could be exposed to mercury concentrations above 0.002 mg/L. About 250 systems serving 210,200 people had estimated mean concentrations greater than 0.001 mg/L. Approximately 1,477 systems serving about 3.3 million people nationally were estimated to have mean mercury concentrations greater than 0.0005 mg/L. (See Section 1.4 for a description of how Stage 2 16-State estimates are extrapolated to national values.)

For ground water systems, an estimated 43 PWSs serving about 12,600 people nationally had mean concentrations greater than 0.002 mg/L. Approximately 244 systems serving about 129,300 people nationally had estimated mean concentration values that exceeded 0.001 mg/L. About 1,416 ground water systems serving over 1.1 million people had estimated mean concentrations greater than 0.0005 mg/L.

Approximately 1 surface water system serving 500 people was estimated to have a mean concentration of mercury above 0.002 mg/L. About 5 surface water systems serving 79,400 people had estimated mean concentrations greater than 0.001 mg/L. An estimated 58 surface water systems serving approximately 2,169,600 people had mean concentrations greater than 0.0005 mg/L.

Table 2.4-8: Estimated National Mercury Occurrence - Systems and Population Served

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.002	43	27 - 61	12,600	1,900 - 45,900
	0.001	244	191 - 300	129,300	56,700 - 246,600
	0.0005	1,416	1,267 - 1,557	1,163,600	790,600 - 1,938,100
Surface Water	0.002	1	0 - 4	500	0 - 11,700
	0.001	5	0 - 14	79,400	0 - 1,726,500
	0.0005	58	32 - 87	2,169,600	601,900 - 2,894,100
Combined Ground & Surface Water	0.002	44	27 - 62	13,400	2,000 - 47,400
	0.001	250	195 - 308	210,200	65,500 - 1,817,800
	0.0005	1,477	1,335 - 1,619	3,327,200	2,015,700 - 4,390,100

2.4.5 Additional Drinking Water Occurrence Data

Several additional data sources regarding the occurrence of mercury in drinking water are also reviewed. Previously compiled occurrence information, from an OGWDW summary document entitled "Occurrence and Exposure Assessment for Mercury in Public Drinking Water Supplies" (Wade Miller, 1990), is presented in this section. This variety of studies and information are presented regarding levels of mercury in drinking water, with the scope of the reviewed studies ranging from national to regional. Note that none of the studies presented in the following section provide the quantitative analytical results or comprehensive coverage that would enable direct comparison to the occurrence findings estimated with the cross-section occurrence data presented in Section 2.4.4. These additional studies, however, do enable a broader assessment of the Stage 2 occurrence estimates presented for this Six-Year Review. All the following information in Section 2.4.5 is taken directly from "Occurrence and Exposure Assessment for Mercury in Public Drinking Water Supplies" (Wade Miller, 1990).

2.4.5.1 Reported Occurrence in Drinking Water

This section presents information on measured mercury levels in drinking water from public water supplies. Section 2.4.5.1.1 provides the results from several national-scale surveys in which mercury levels were measured in drinking water. Section 2.4.5.1.2 provides the most current information from the U.S. Environmental Protection Agency's Federal Reporting Data System (FRDS) on the status of drinking water supplies reported to be in violation of the current standard of 2 µg/L for mercury.

2.4.5.1.1 Federal Survey Data

Several national-scale surveys have been conducted that provide data on mercury in public drinking water supplies. These include the 1978 Community Water Supply Survey, the Rural Water Survey, the National Organic Monitoring Survey, and the National Inorganics and Radionuclides Survey. The following sections describe these surveys and present the data on mercury levels in ground water and surface water supplies.

1978 Community Water Supply Survey (1978 CWSS)

The 1978 Community Water Supply Survey (CWSS) was conducted by the USEPA to determine the occurrence of organic and inorganic compounds in public water supplies. Drinking water samples were provided by approximately 500 supplies; however, due to analytical problems, reliable data for mercury were available for only 35 ground water and 10 surface water supplies (USEPA, 1983, as cited in Wade Miller, 1990).

Details on the analytical method used for mercury were not available; from the information provided by Glick (1984, as cited in Wade Miller, 1990) the minimum quantifiable concentration appeared to be 0.5 µg/L. Supplies provided one to five samples of raw, finished, and/or distribution water. However, Brass (1983, as cited in Wade Miller, 1990) indicated that reporting inconsistencies made it impossible to distinguish between finished and distribution samples. Therefore, distribution and finished sample results were averaged; raw water data were not used.

Of the 35 ground water supplies sampled, nine (26 percent) contained mercury at concentrations ranging from 0.5 to 175 µg/L. Except for the one high value of 175 µg/L, none of the samples exceeded 2 µg/L. None of the 10 surface water supplies sampled contained mercury above the minimum quantifiable concentration of 0.5 µg/L.

Rural Water Survey (RWS)

The Rural Water Survey (RWS) conducted between 1978 and 1980 evaluated the status of drinking water in rural America as required by Section 3 of the Safe Drinking Water Act. More than 2,000 households served by 648 public water supplies (494 ground water, 154 surface water) were surveyed. Many of these households used private wells or very small systems serving fewer than 25 people, and only a subsample of the supplies evaluated included analyses for mercury (71 ground water and 21 surface water supplies). Results of the inorganic analyses were provided to Science Applications International Corporation (SAIC) as a computer file by Brower (1983, as cited in Wade Miller, 1990).

A problem with the RWS was that the number of service connections associated with water systems was reported in lieu of the actual populations served by the systems. Dr. Bruce Brower of Cornell University, who collaborated in the National Statistical Assessment of Rural Water Conditions (based on the RWS data) provided a factor to convert the data from service connections to the number of people served, based on the average number of persons per household observed in the RWS. It must be noted, however, that these population values are only approximations.

Details were not available on the sample collection or analytical methodology used. However, the minimum quantifiable concentration for mercury appeared to range from 0.2 to 0.5 µg/L. Of the 71 ground water supplies studied, 24 (34 percent) contained mercury at levels ranging from 0.3 to 12.3 µg/L. For surface water supplies, 11 of the 21 supplies sampled (52 percent) had mercury present at concentrations ranging from 0.3 to 16.0 µg/L.

National Organic Monitoring Survey (NOMS)

The National Organic Monitoring Survey (NOMS), which was conducted by the USEPA in 1976 and 1977, was intended primarily to provide data for establishing MCLs for organic compounds in drinking water. A substudy of NOMS analyzed samples for 27 trace elements in the 113 supplies sampled (91 surface water, 19 ground water, 3 mixed sources) (USEPA, 1980, as cited in Wade Miller, 1990). Mercury data are available for 86 surface water and 15 ground water supplies. Samples were taken of treated, finished water leaving the treatment plant. Occasionally, samples were taken of distribution system water in close proximity to the treatment plant. The results of the inorganic analyses for NOMS were provided to SAIC by the Technical Support Division of EPA's Office of Drinking Water (USEPA, 1985, as cited in Wade Miller, 1990). No information on the analytical procedures used was available; the minimum quantifiable concentration appeared to be approximately 0.5 µg/L.

Mercury was not found in any of the 15 ground water supplies sampled. For surface water supplies, mercury was observed in two of the 86 supplies sampled (2 percent) at concentrations of 0.5 µg/L and 1.5 µg/L.

National Inorganics and Radionuclides Survey (NIRS)

In 1981 the USEPA's Office of Drinking Water (ODW) initiated the National Inorganics and Radionuclides Survey (NIRS) to characterize the occurrence of various contaminants in community drinking water supplies. The survey focused on the presence of 36 inorganics, including mercury, and four radionuclides in ground water supplies from throughout the United States. Implementation of the survey and sampling were accomplished by the ODW's Technical Support Division between July 1984 and October 1986.

The NIRS sampling program was designed to reflect the national distribution of community ground water supplies by size of population served as inventoried by the Federal Reporting Data System (FRDS). The FRDS data was stratified into the following four population-size categories: very small (serving 25-500), small (serving 501-3,300) medium (serving 3,301-10,000), and large/very large (serving >10,000). A total of 1,000 sites were selected randomly from the FRDS data in proportion to the four size categories. Approximately 2.1% of the supplies in each size category were chosen for sampling. Of the 1,000 targeted sites, 990 were actually sampled in the NIRS.

Sample collection and location within each supply were designed to reflect the quality of water actually received by the consumer. Samples were collected after three minutes of flushing in order to represent the finished water in the distribution system. To the extent possible, the sampling location was chosen at a point of maximum use in the distribution system. The method used to analyze for mercury was not reported. The minimum reporting limit (MRL) was 0.2 µg/L.

Mercury results are available for all of the 990 sites sampled in the NIRS. Approximately 98% of the samples had mercury concentrations less than 0.5 µg/L. Of the 19 supplies (two percent) with higher mercury concentrations, only one exceeded the current MCL of 2 µg/L. This maximum value was 2.1 µg/L for a small supply, serving between 501 and 3,300 people. The overall mean of the samples was approximately 0.2 µg/L, which was the MRL.

2.4.5.1.2 Compliance Monitoring Data

The Federal Reporting Data System (FRDS) provides information on public water supplies in violation of current MCLs as determined through compliance monitoring of all supplies performed by the States under the requirements of the National Interim Primary Drinking Water Regulations. Only violations of current MCLs (i.e., 2 µg/L for mercury) and approved variances and exemptions from the standards are recorded in FRDS. Monitoring is required annually for surface water supplies and every three years for ground water supplies.

The FRDS database (FRDS, 1990, as cited in Wade Miller, 1990) was searched for violations reported during the three year period from 1987 through 1989. The data indicated that there were three public ground water and three public surface water supplies providing drinking water which had mercury levels above the current MCL of 2 µg/L. The ground water supplies were all in the very small and small size categories. A maximum value of 4.3 µg/L was reported for a supply serving 70 people.

The three surface water violations were distributed between the very small, medium, and large/very large size categories. A maximum value of 7 µg/L was reported for a system serving 8,000 people. Additionally, no variances or exemptions to the current mercury MCL of 2 µg/L were reported to have been granted for surface water supplies.

2.4.5.2 Estimated National Occurrence in Public Water Supplies

Section 2.4.5.1 presented the results of several studies that provide information on the occurrence of mercury in public drinking water supplies. This section presents national estimates of mercury occurrence in public drinking water supplies based on those study results.

2.4.5.2.1 Methodology

National estimates of the occurrence of contaminants in drinking water supplies are needed to serve as input to the analysis of regulatory costs and benefits. A draft document has been prepared that describes the methodology used to estimate national occurrence of the inorganic drinking water contaminants addressed under Phase II of the national primary drinking water regulations development process (USEPA, 1986, as cited in Wade Miller, 1990). In general, national survey data are used as the basis for the national estimates. The most representative data sets are selected and combined, stratified appropriately by water source and system size sampled, and applied to a "delta-log normal" distribution model. Using that model, the probability of contaminant occurrence above any given concentration is determined for each source/size category of supplies and applied to the total number of water supplies in those groups. The resulting national occurrence estimates are presented in tables that show the cumulative number of public water supplies, within various water source and size categories, expected to have certain concentrations.

The mercury occurrence estimates are based on the results of the NIRS survey for ground water supplies and the combined results of the 1978 CWSS, the RWS, and the NOMS for surface water supplies. The NIRS data are the most current ground water data available, and the analytical results are considered to be highly reliable because of the extensive quality assurance program being employed. None of the surveys that analyzed surface water supplies could be shown to be any more or less representative of the universe of water supplies than the other surveys, and it was therefore determined to be most appropriate to combine the results from all of the surveys to form the basis of the national occurrence estimates.

2.4.5.2.2 Results

Section 2.4.5.2.1 noted that the national estimates of mercury in finished water are based on the results from NIRS for ground water supplies, and on the combined results from the 1978 CWSS, RWS and NOMS for the surface water supplies.

For ground water, the model estimates that 45 public ground water supplies have mercury levels greater than the proposed MCLG and MCL of 2 µg/L. Six of those supplies are estimated to have mercury levels exceeding 3 µg/L. The majority of the supplies expected to have mercury concentrations above 2 µg/L are in the small and very small size categories. FRDS reports only three systems in violation of the 2 μg/L MCL.

For surface water, the model predicts that approximately 7 percent or 395 surface water supplies contain mercury in excess of 2 μg/L. An estimated 3 percent (189 supplies) are expected to contain greater than 6 μg/L mercury. The systems expected to exceed the proposed MCLG and MCL of 2 μg/L are distributed throughout all size categories. FRDS reports only three systems in violation of the current MCL of 2 μg/L, one of which contains mercury at levels greater than 6 μg/L.

The occurrence estimates formulated from the delta lognormal distribution model predict a larger number of systems contain mercury in excess of 2 μg/L than reported by FRDS for both ground and surface water supplies. It cannot be determined whether this is due to an over-estimate by the model or an under-reporting of actual violations in FRDS. For the surface water estimates the higher number of supplies predicted to exceed 2 μg/L are attributed to the use of the Rural Water Survey results. Six of the 21 samples from the RWS exceeded 2 μg/L and five of the six were above 6 μg/L. None of the surface water samples from the 1978 CWSS or the NOMS contained mercury above 2 μg/L. The RWS data may have significantly skewed the estimated occurrence numbers.

2.4.5.3 Estimated National Exposure from Public Water Supplies

2.4.5.3.1 Methodology

Section 2.4.5.2.1 noted that a separate methodology document has been prepared to describe the approach used to estimate national occurrence of inorganic contaminants in public water supplies. That document also addresses the approach to estimating the population exposed to contaminant levels in public drinking water supplies. In summary, the occurrence probability density functions obtained from the national survey data on supplies contaminated at various levels are applied to the number of people using water supplies in the various size categories.

2.4.5.3.2 Results

Based on the national occurrence estimates derived from the national survey data, 72,000 people are expected to be exposed to mercury from ground water supplied drinking water systems above the proposed MCLG and MCL of 2 μg/L. The model also estimates that 6,000 of those people will be exposed to mercury at levels greater than 3 μg/L. Zero people are expected to be exposed to mercury in drinking water at levels greater than 4 μg/L. The FRDS data indicate that only 424 people are exposed to mercury at levels exceeding the current MCL of 2 μg/L. Additionally, 70 people receive drinking water with a mercury concentration between 4 and 5 μg/L.

Based upon the cumulative national population exposure estimates from the national survey data for mercury in surface water supplies, the model predicts that approximately 10 million people are exposed to mercury levels above 2 μg/L. Information regarding the population exposed to mercury at levels exceeding the current MCL of 2 μg/L as reported in FRDS indicates that 18,766 people are exposed to mercury levels above 2 μg/L.

The FRDS data and the modeled exposure estimates differ by several orders of magnitude. Once again, this may be due to an over estimation by the mathematical model or an underreporting of FRDS violations. It should also be noted that the higher national occurrence and exposure estimates for surface water supplies are due to the fact that they are based on the (apparently) anomalous high results of the RWS.

Overall, the model predicts that, of the estimated 219 million people using public drinking water supplies, about 5 percent or 10.3 million are exposed to mercury at levels above 2 µg/L. The remaining 95 percent of the population (208.7 million people) are either not exposed to mercury or are receiving levels less than 2 µg/L. Of the 10.3 million people exposed, approximately 5 million are expected to receive drinking water with mercury levels in excess of 6 µg/L.

2.4.6 Conclusion

Mercury and many of its compounds are naturally occurring and found at low levels in soil, water, and air. Furthermore, mercury is mined in the United States for widespread use. Most mercury is used in production of mercury cells, while other uses for mercury include manufacture of wiring devices and switches, dental equipment, and electric lighting. Recent statistics regarding production and use of mercury indicate they are steady. Industrial releases of mercury and mercury compounds have been reported to TRI since 1988 from 31 States and 32 States, respectively. Off-site releases constitute a considerable amount of total releases, with releases to land the most significant on-site releases. No national NAWQA data were available for mercury. The Stage 2 analysis, based on the 16-State cross-section, estimated that approximately 0.0672% of combined ground water and surface water systems serving 0.00627% of the population had estimated mean concentrations of mercury greater than the MCL of 0.002 mg/L. Based on this estimate, approximately 44 PWSs nationally serving about 13,400 people are expected to have estimated mean concentrations of mercury greater than 0.002 mg/L.

Mercury is a naturally occurring element. Therefore, the balanced geographic distribution of the 16-State cross-section should adequately cover the range of natural occurrence of mercury from low to high. The 16-State cross-section also contains a substantial proportion of the States with reported TRI releases of mercury and mercury compounds. Based on this use and release evaluation, the 16-State cross-section appears to adequately represent mercury occurrence nationally.

2.4.7 References

Agency for Toxic Substances and Disease Registry (ATSDR). 1999a. *Toxicological Profile for Mercury*. U.S. Department of Health and Human Services, Public Health Service. 617 pp. + Appendices. Available on the Internet at: http://www.atsdr.cdc.gov/toxprofiles/tp46.pdf

Agency for Toxic Substances and Disease Registry (ATSDR). 1999b. *ToxFAQs for Mercury*. U.S. Department of Health and Human Services, Public Health Service. Available on the Internet at: http://atsdr.cdc.gov/tfacts46.html

Battelle. 1977. *Multimedia levels: Mercury.* Washington, DC: Office of Toxic Substances, USEPA. EPA-560/6-77-031.

Brass, H. 1983. U.S. Environmental Protection Agency, Office of Drinking Water, Technical Support Division, Cincinnati, OH. Personal communication to Frank Letkiewicz, SAIC.

Brower, B. 1983. Computer data file of analytical results for public water supplies sampled in the Rural Water Survey. Cornell University, Department of Rural Sociology.

Federal Reporting Data System (FRDS). 1990. Computer file extracts of compliance monitoring data for the Safe Drinking Water Act. 1987-1989.

Glick, E. 1984. U.S. Environmental Protection Agency, Office of Drinking Water, Technical Support Division, Cincinnati, OH. Personal communication to Frank Letkiewicz, SAIC.

National Safety Council (NSC). 2001. *Mercury Chemical Backgrounder*. Itasca, IL: National Safety Council. Available on the Internet at: http://www.crossroads.nsc.org/ChemicalTemplate.cfm?id=117&chempath=chemicals, accessed July 23, 2001.

Perwak, J., M. Goyer, L. Nelken, K. Scow, M. Wald, and D. Wallace. 1980. An exposure and risk assessment mercury. Final draft report prepared by A.D. Little submitted to Office of Water and Waste Management, USEPA, Washington, DC. EPA Contracts 68-01-3857, 68-01-5949.

USGS. 1997. *Mercury.* United States Geological Survey.

USEPA. 1979. Water-related environmental fate of 129 priority pollutants. Volume 1. Office of Water Planning and Standards, USEPA. EPA-440/4-79-029a.

USEPA. 1980. *Trace elements in 113 U.S. drinking waters*. A substudy of the National Organics Monitoring Survey. Cincinnati, OH: Technical Support Division, Office of Drinking Water, USEPA.

USEPA. 1983. Data on inorganics from the Community Water Supply Survey. Provided by E.M. Glick, Drinking Water Quality Assessment Branch, Technical Support Division, Office of Drinking Water, Cincinnati, Ohio.

USEPA. 1985. U.S. Environmental Protection Agency. Computerized listing of inorganics data for the National Organics Monitoring Survey (NOMS). Provided to Science Applications International Corporation by E.B. Dotson, Water Supply Technology Branch, Technical Support Division, Office of Drinking Water, Cincinnati, Ohio. November 12, 1985.

USEPA. 1986. *Overview of methodology used to estimate national occurrence and exposure to inorganic drinking water contaminants (draft)*. Prepared by Science Applications International Corporation for U.S. Environmental Protection Agency, Office of Drinking Water, Science and Technology Branch.

USEPA. 2000. *TRI Explorer: Trends*. Available on the Internet at: http://www.epa.gov/triexplorer/trends.htm, last updated May 5, 2000.

USEPA. 2002. *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT*. EPA Report/815-D-02-005, Office of Water, 55 pp.

USEPA. 2001. *National Primary Drinking Water Regulations - Consumer Factsheet on: Mercury.* Office of Ground Water and Drinking Water, USEPA. Available on the Internet at: http://www.epa.gov/safewater/dwh/c-ioc/mercury.html, last updated March 9, 2001.

Wade Miller Associates, Inc. 1990. *Occurrence and Exposure Assessment for Mercury in Public Drinking Water Supplies*. Prepared for and submitted to EPA on July 26, 1990.

2.5 Thallium

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Tables and Figures

2.5.1 Introduction, Use and Production

Pure thallium (Tl) is a bluish-white metal that is found in trace amounts in the earth's crust. Thallium metal forms alloys with other metals and readily amalgamates with mercury (Wade Miller, 1989). Thallium forms compounds in which it occurs in either the +1 (thallous) or +3 (thallic) valence states. The +1 salts are slightly to moderately soluble in water; however, trivalent thallium is reportedly the predominant ionic species found in seawater and freshwater in equilibrium with atmospheric oxygen (Wade Miller, 1989).

Thallium is found mainly in several rare minerals, deposits of which are so small that they have not been of commercial importance. The main commercial sources of thallium have been as by-products from the production or processing of other materials, notably flue dusts from pyrites (FeS_2), lead, zinc and cadmium (Wade Miller, 1989).

In its pure form, thallium is odorless and tasteless. It can also be found combined with other substances such as bromine, chlorine, fluorine, and iodine. When it's combined, it appears colorless-to-white or yellow (ATSDR, 1995).

Thallium is a metal found in natural deposits in ores containing other elements. The greatest use of thallium is in specialized electronic research equipment (USEPA, 2001). The domestic production of thallium ceased in 1981. Prior to that, thallium had been recovered as a byproduct from the flue dust and residuals that resulted from the smelting of zinc, copper, and lead ores. Based upon the estimated thallium content of zinc ores, U.S. mine production of thallium was 992 pounds in 1986 and 1987, compared to 31,000 pounds in the rest of the world (ATSDR, 1992).

Currently thallium can only be obtained by importation. In 1987, about 4,500 pounds of thallium were imported (USEPA, 2001) and in 1990, approximately 1,540 pounds were imported (HSDB, 2000). About 60-70% of thallium use is concentrated in the semiconductor industry in the production of switches and closures (ATSDR, 1992). Thallium is also used in the pharmaceutical industry for myocardial imaging, in the manufacture of thallaphide cells, atomic beam clocks, photoelectric cells, lamps, thermometers, alloys, scintillation counters (HSDB, 2000), and in highly refractive optical glass (ATSDR, 1992). Thallium was formerly used as a rodenticide and ant killer, but it has not been available for that function in the U.S. since 1975 and its use as such is restricted in many other parts of the world (HSDB, 2000).

Table 2.5-1 shows the six facilities that either import thallium, use thallium and its compounds in manufacturing processes, or produce them as byproducts. The table also gives the uses of the product and the range of maximum amounts on site. All information was derived from the Toxics Release Inventory (TRI) of EPA (ATSDR, 1992).

Table 2.5-1: Facilities that Manufacture or Process Thallium and Compounds[a]

Facility	Location	Maximum amount on site in pounds	Use
Philips Industries, Inc., Dexter Axle	Albion, IN	10,000-99,999	Import; as a manufacturing aid
Tenneco Oil Company	Chalmette, LA	0-99	As a processing aid
Koch Refining Company	Saint Paul, MN	1,000-9,999	As an impurity
River Cement Company	Festus, MO	100,000,000-499,999,999	As a reactant

Facility	Location	Maximum amount on site in pounds	Use
Sohio Oil Company Toledo Refinery	Oregon, OH	100-999	As an impurity
Dana Corporation	Reading, PA	0-99	As an impurity

[a] Derived from TRI 1989

Source: ATSDR, 1992 compilation of 1989 TRI data

2.5.2 Environmental Release

Thallium and thallium compounds are both listed as Toxics Release Inventory (TRI) chemicals. Table 2.5-2 illustrates the environmental releases for thallium from 1989 - 1999. No thallium data were reported in 1992 or 1996. Air emissions and releases to land are the only factors that have consistently contributed to on-site releases. Air emissions decreased (from a high of 1,000 pounds in 1989 to a low of 15 pounds in 1998) until 1999, when they spiked to over 2,000 pounds. Total on- and off-site releases of thallium remained relatively stable for many years until just recently. Off-site releases have been on an upward trend since 1997, and releases to land went from 755 pounds to 4,355 pounds from 1995-1999. No underground injection releases and very few surface water discharges were reported for thallium. These TRI data for thallium were reported from 10 States (USEPA, 2000). Of the 10 States, four are included in the 16 State cross-section (used for analyses of thallium occurrence in drinking water; see Section 2.5.4). (For a map of the 16-State cross-section, see Figure 1.3-1.)

Table 2.5-2: Environmental Releases (in pounds) for Thallium in the United States, 1989-1999

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1999	2,137	--	--	4,355	4,828	11,320
1998	15	--	--	3,400	3,665	7,080
1997	256	--	--	1,000	1,500	2,756
1995	255	--	--	755	195	1,205
1994	255	--	--	755	255	1,265
1993	255	--	--	755	5	1,015
1991	30	1	--	--	953	984
1990	750	5	--	--	916	1,671
1989	1,000	--	--	500	250	1,750

Source: USEPA, 2000

Table 2.5-3 illustrates the environmental releases for thallium compounds between 1988 and 1999. There were no data, however, reported in 1993 or 1995. Releases to land have generally constituted most of the on-site releases, with dramatic increases in 1994 and 1998. No real trend is suggested in the data. Air emissions were relatively constant from 1988-1991, but since then have fluctuated from zero to over 1,000 pounds. Releases to land have fluctuated dramatically; from 1988-1991 they were constant, then they increased to about 3,700 pounds in 1994 and over 400,000 pounds in 1998. Off-site releases of thallium compounds vary from almost zero to under 2,000 pounds. No underground injection releases and very few surface water discharges were reported for thallium compounds. Overall, total on- and off-site releases have ranged from 5 to over 400,000 pounds. The fluctuations are relatively modest except for increases in 1998, mostly as a result of the increased releases to land. The TRI data for thallium compounds were reported from 20 States (USEPA, 2000). Of the 20 States, eight are included in the 16 State cross-section (used for analyses of thallium occurrence in drinking water; see Section 2.5.4). (For a map of the 16-State cross-section, see Figure 1.3-1.)

Table 2.5-3: Environmental Releases (in pounds) for Thallium Compounds in the United States, 1988-1999

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1999	654	750	--	252,800	1,838	256,042
1998	1,060	250	--	409,000	759	411,069
1997	0	--	--	--	180	180
1996	0	--	--	--	5	5
1994	171	--	--	3,695	5	3,871
1992	755	--	--	505	255	1,515
1991	255	--	--	255	5	515
1990	255	--	--	255	5	515
1989	256	--	--	250	504	1,010
1988	253	--	–	250	1,256	1,759

Source: USEPA, 2000

2.5.3 Ambient Occurrence

The most comprehensive and nationally consistent data describing ambient water quality in the United States are being produced through the United States Geological Survey's (USGS) National Water Quality Assessment (NAWQA) program. However, no national NAWQA data are available for thallium.

2.5.3.1 Additional Ambient Occurrence Data

Information is very limited with regard to concentrations of thallium in ambient waters. A summary document entitled "Occurrence and Exposure Assessment of Thallium in Public Drinking Water Supplies" (Wade Miller, 1989), was previously prepared for past USEPA assessments of beryllium. No additional national or regional studies on the occurrence of thallium in ground water were available. However, one additional study was presented regarding levels of thallium in ambient surface waters. The following information is taken directly from that document.

V.J. Ciccone and Associates (USEPA, 1984, as cited in Wade Miller, 1989) provided information on a study by Durum and Haffty (1961, as cited in Wade Miller, 1989) in which analyses of ambient water for the occurrence of minor elements were reported. The study involved analysis of samples collected at 15 surface water sites throughout the United States and Canada. The number of samples collected varied from two to seven per site. Samples were analyzed for thallium using the emission spectroscopy technique. The results of this study revealed that thallium was below the analytical detection limit in all samples collected; however, the detection limit was not provided.

2.5.4 Drinking Water Occurrence Based on the 16-State Cross-Section

The analysis of thallium occurrence presented in the following section is based on State compliance monitoring data from the 16 cross-section States. The 16-State cross-section is the largest and most comprehensive compliance monitoring data set compiled by EPA to date. These data were evaluated relative to two concentration thresholds of interest: 0.002 mg/L; and 0.001 mg/L.

All sixteen cross-section State data sets contained occurrence data for thallium. These data represent more than 47,000 analytical results from approximately 18,000 PWSs during the period from 1985 to 1998 (with most analytical results from 1992 to 1997). The number of sample results and PWSs vary by State, although the State data sets have been reviewed and checked to ensure adequacy of coverage and completeness. The overall modal detection limit for thallium in the 16 cross-section States is equal to 0.001 mg/L. (For details regarding the 16-State cross-section, please refer to Section 1.3.5 of this report.)

2.5.4.1 Stage 1 Analysis Occurrence Findings

Table 2.5-4 illustrates the Stage 1 analysis of thallium occurrence in drinking water for the public water systems in the 16-State cross-section relative to two thresholds of interest: 0.002 mg/L (the current MCL) and 0.001 mg/L (the modal MRL). Approximately 0.679% (122 systems) of all ground water and surface water PWSs had any analytical results of thallium exceeding the MCL. Approximately 1.89% (340 systems) of PWSs had any exceedances of the modal MRL.

A greater proportion of surface water systems, as compared to ground water systems, exceeded each threshold. However, the actual number of ground water systems with threshold exceedances was much greater than the actual number of surface water systems with threshold exceedances. Over 100 (approximately 0.660% of) ground water PWSs had any analytical results exceeding the MCL, compared to 13 (about 0.886% of) surface water PWSs. About 1.81% (299 systems) of ground water PWSs had any analytical results exceeding 0.001 mg/L. This compares to about 2.79% (41 systems) of surface water PWSs with any analytical results greater than the modal MRL.

Table 2.5-4: Stage 1 Thallium Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Ground Water	0.002	0.660%	109
	0.001	1.81%	299
Surface Water	0.002	0.886%	13
	0.001	2.79%	41
Combined Ground & Surface Water	0.002	0.679%	122
	0.001	1.89%	340

Reviewing thallium occurrence in the 16 cross-section States by PWS population served (Table 2.5-5) shows approximately 1.85% (a total of 1,927,200 people) of the population was served by PWSs with any analytical results greater than the MCL. The percentage of population served by PWSs with any exceedance of the modal MRL was 4.32% (4,500,600 people).

The number of people served by ground water systems with any analytical results greater than 0.002 mg/L was equal to 858,700 (about 2.01%). A total of 1,068,500 people (approximately 1.73%) were served by surface water systems with any analytical results greater than 0.002 mg/L. About 4.46% of the population served by ground water PWSs (1,903,500 people) had any exceedances of 0.001 mg/L, compared to approximately 4.21% (2,597,100 people) of the population served by surface water systems.

Table 2.5-5: Stage 1 Thallium Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Ground Water	0.002	2.01%	858,700
	0.001	4.46%	1,903,500
Surface Water	0.002	1.73%	1,068,500
	0.001	4.21%	2,597,100
Combined Ground & Surface Water	0.002	1.85%	1,927,200
	0.001	4.32%	4,500,600

2.5.4.2 Stage 2 Analysis Occurrence Findings

The Stage 2 occurrence findings, based on the cross-section data, are presented in Tables 2.5-6 and 2.5-7. The statistically generated best estimate values, as well as the ranges around the best estimate value, are presented. (For a review of the Stage 2 analytical approach, please refer to Section 1.4 of this report. For complete details regarding the Stage 2 analyses, please refer to *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT* (USEPA, 2002)).

Approximately 0.283% (51 systems) of all ground water and surface water PWSs in the 16-States are estimated to have mean concentrations of thallium above 0.002 mg/L (the current MCL). The percentage of PWSs in the 16 cross-section States with estimated mean concentrations exceeding 0.001 mg/L (the modal detection limit) was about 1.20% (215 PWSs).

A greater proportion of ground water systems, as compared to surface water systems, were estimated to exceed each threshold. Approximately 48 (0.292% of) ground water systems in the 16 cross-section States had estimated mean concentrations of thallium above 0.002 mg/L, compared to approximately 3 (0.180% of) surface water systems. About 1.21% (an estimated 199 systems) of ground water systems in the 16-State cross-section had estimated mean concentrations greater than 0.001 mg/L. This compares with about 1.07% (about 16 systems) of the surface water systems with estimated mean concentrations greater than 0.001 mg/L.

Table 2.5-6: Stage 2 Estimated Thallium Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.002	0.292%	0.206% - 0.382%	48	34 - 63
	0.001	1.21%	1.01% - 1.41%	199	167 - 232
Surface Water	0.002	0.180%	0.000% - 0.409%	3	0 - 6
	0.001	1.07%	0.545% - 1.64%	16	8 - 24
Combined Ground & Surface Water	0.002	0.283%	0.195% - 0.367%	51	35 - 66
	0.001	1.20%	1.01% - 1.39%	215	181 - 250

Reviewing thallium occurrence by PWS population served (Table 2.5-7) shows that approximately 77,500 (0.0743% of) the PWS population in the 16 States were served by systems with mean thallium concentrations above 0.002 mg/L. When evaluated relative to a threshold of 0.001 mg/L, the percent of population exposed increased significantly to about 0.527% (approximately 550,000 people served in the 16 States).

About 63,800 (0.150% of) people served by ground water systems in the 16 States were served by systems with estimated mean concentrations of thallium above 0.002 mg/L. An estimated 0.887% of the population (about 378,100 people) were served by ground water systems whose mean concentration value exceeded 0.001 mg/L.

Approximately 0.0222% of the population served by surface water PWSs (an estimated 13,700 people nationally) had estimated mean concentrations of thallium above 0.002 mg/L. About 0.279% of the population served by surface water PWSs had mean concentrations greater than 0.001 mg/L (almost 172,000 people).

Table 2.5-7: Stage 2 Estimated Thallium Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.002	0.150%	0.0319% - 0.573%	63,800	13,600 - 244,300
	0.001	0.887%	0.383% - 1.41%	378,100	163,300 - 602,200

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Surface Water	0.002	0.0222%	0.000% - 0.0866%	13,700	0 - 53,400
	0.001	0.279%	0.0664% - 1.41%	171,900	40,900 - 869,800
Combined Ground & Surface Water	0.002	0.0743%	0.0156% - 0.246%	77,500	16,300 - 256,900
	0.001	0.527%	0.244% - 1.24%	550,000	254,600 - 1,296,300

2.5.4.3 Estimated National Occurrence

Based on the Stage 2 estimated percent of systems (and population served by systems) exceeding each threshold, an estimated 184 PWSs serving approximately 158,300 people nationally could be exposed to thallium concentrations above 0.002 mg/L. Approximately 778 systems serving about 1.1 million people served nationally were estimated to have thallium concentrations greater than 0.001 mg/L. (See Section 1.4 for a description of how Stage 2 16-State estimates are extrapolated to national values.)

For ground water systems, an estimated 174 PWSs serving about 128,200 people nationally had mean concentrations greater than 0.002 mg/L. Approximately 717 systems serving about 759,7000 people nationally had estimated mean concentration values that exceeded 0.001 mg/L.

Approximately 10 surface water systems serving 28,300 people were estimated to have mean concentrations of thallium above 0.002 mg/L. About 60 surface water systems serving 355,100 people had estimated mean concentrations greater than 0.001 mg/L.

Table 2.5-8: Estimated National Thallium Occurrence - Systems and Population Served

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.002	174	122 - 227	128,200	27,300 - 490,900
	0.001	717	602 - 836	759,700	328,100 - 1,209,800
Surface Water	0.002	10	0 - 23	28,300	0 - 110,300
	0.001	60	30 - 91	355,100	84,500 - 1,796,600
Combined Ground & Surface Water	0.002	184	127 - 239	158,300	33,300 - 524,600
	0.001	778	655 - 905	1,123,400	520,000 - 2,647,700

2.5.5 Additional Drinking Water Occurrence Data

Additional data sources regarding the occurrence of thallium in drinking water are also reviewed. Previously compiled occurrence information, from an OGWDW summary document entitled "Occurrence and Exposure Assessment of Thallium in Public Drinking Water Supplies" (Wade Miller, 1989), is presented in this section. Only one national scale study – the National Inorganics and Radionuclides Survey – provided data on the occurrence of thallium in drinking water sources. That survey, however, is limited to ground water sources. No regional ground water or surface water studies or national surface water studies were found. Note that none of the studies presented in the following section provide the quantitative analytical results or comprehensive coverage that would enable direct comparison to the occurrence findings estimated with the cross-section occurrence data presented in Section 2.5.4. These additional studies, however, do enable a broader assessment of the Stage 2 occurrence estimates presented for this Six-Year Review. All the following information in Section 2.5.5 is taken directly from "Occurrence and Exposure Assessment of Thallium in Public Drinking Water Supplies" (Wade Miller, 1989).

2.5.5.1 Ground Water Sources – National Studies

The National Inorganics and Radionuclides Survey (NIRS) was a two-year national sampling and analytical study designed to gather information on the occurrence of selected inorganic compounds and radionuclides in drinking water. From July 1984 through May 1986 approximately 1,000 samples of finished drinking water from ground water supplies throughout the United States were collected. Of 989 utilities for which thallium data were reported, 28 systems served populations greater than 10,000 (large and very large, combined), 54 served populations of 3,301 to 10,000 (medium), 233 served populations of 501 to 3,300 (small), and 674 served populations of 25 to 500 (very small).

The analytical results of the NIRS were made available in printed form by EPA's Technical Support Division, Office of Drinking Water. Additional information regarding the location and sources of supplies, population served, methods, and detection limits was available in an EPA Status Report, also provided by the Technical Support Division (USEPA, 1985, as cited in Wade Miller, 1989).

Samples were collected in the field by representatives of local utilities. Samplers were provided with complete kits including detailed instructions, and a rigorous quality control procedure was developed to ensure the representativeness of the samples. The samples collected for metals analyses were preserved in the field with nitric acid and shipped to one of several EPA laboratories for testing.

Of the 989 utilities for which thallium data were reported, only one returned a sample that revealed a thallium concentration above the minimum reporting level of 8 µg/L. That positive sample was collected at a very small utility and was reported to contain 10 µg/L thallium.

2.5.5.2 Ground Water and Surface Water Sources – STORET

The EPA computerized water quality data base, known as STORET, was devised to help Federal and State institutions meet the objectives of Public Law 92-500 to maintain and enhance the physical, chemical, and biological quality of the nation's ambient waterways by providing for the collection and dissemination of basic water quality data (Staples et al., 1985, as cited in Wade Miller, 1989). Data are collected by States, EPA regional offices, and other government agencies and maintained in the STORET system. STORET contains approximately 80 million pieces of data, including data for drinking water from ground water and surface water sources.

Before presenting a summary of the drinking water data in STORET, it is important to note that there are significant limitations in using the data base to estimate representative concentrations of a contaminant such as thallium. Data entered into STORET are gathered from an array of studies conducted for various purposes. Analyses are conducted in a number of different laboratories employing different methodologies with a range of detection limits. In many cases, detection limits are not reported, making the reliability of the data highly questionable. Where detection limits have been reported, STORET assigns the detection limit value to those observations reported as not detected. This can lead to errors in interpretation and overestimation of concentrations in cases in which there is a preponderance of nondetectable values. Additionally, a few high values can inflate mean values and result in large standard deviations relative to the means (Staples et al., 1985, as cited in Wade Miller, 1989). Very high values may not be correct, as they may reflect sample contamination or analytical error, and can significantly distort assessment of average concentrations. Staples et. al. (1985, as cited in Wade Miller, 1989) also notes that the use of data collected prior to the 1980s is not recommended, since such data was obtained using less sensitive laboratory techniques and quality assurance procedures were not yet mandated for the data entered into the system.

With these limitations in mind, a summary of STORET's most recently obtained data for drinking water from ground water and surface water sources is presented here (USEPA, 1988, as cited in Wade Miller, 1989). For ground water, there were two positive observations for total thallium from February 1978 to April 1979, with both values reported at 0.8 µg/L. There were 221 samples reported as undetected; the apparent detection limit for these samples was 50 µg/L. Including the undetected samples and detections known to be less than the reported value, there were 227 observations for total thallium in ground water from February 1978 to November 1987. With detection limit value assigned to the undetected samples, STORET reported an overall mean value of 48.7 µg/L and a range of 0.2 to 50 µg/L. The standard deviation for all observations was 7.9 µg/L. Detection limits and other sampling information were not reported.

For surface water, there were 11 positive observations for total thallium from April 1978 to September 1981, with an overall mean value of 3.4 µg/L and a range of 0.2 to 9.0 µg/L. The standard deviation for these observations was 2.9 µg/L. Seven samples were reported as undetected, with a mean value of 30.3 µg/L, apparently reflecting a detection limit value range of 20 to 50 µg/L. Including the undetected samples and the detections known to be less than the reported value, there were 54 observations for total thallium in surface water from February 1978 to July 1987, with an overall mean value of 5.4 µg/L and a range of 0.2 to 50 µg/L. The standard deviation for all observations was 12.9 µg/L. Detection limits and other sampling information were not reported.

2.5.6 Conclusion

Thallium and some of its compounds are naturally occurring and found at low levels as natural deposits. Thallium is no longer produced domestically, and all thallium used in the United States is imported. Most thallium is used in production of specialized electronic research equipment. Some statistics regarding import for consumption of thallium indicate that imports may be declining. Industrial releases of thallium have occurred since 1989 in 10 States, while releases of thallium compounds have occurred since 1988 in 20 States. Air emissions and off-site releases constitute the greatest proportion of the total on- and off-site releases of thallium and thallium compounds. No national NAWQA data were available for thallium. The Stage 2 analysis, based on the 16-State cross-section, estimated that approximately 0.283% of combined ground water and surface water systems serving 0.07439% of the population had estimated mean concentrations of thallium greater than the MCL of 0.002 mg/L. Based on this estimate, approximately 184 PWSs nationally serving about 158,300 people are expected to have estimated mean concentrations of thallium greater than 0.002 mg/L.

Since thallium and its compounds occur naturally occurring, the balanced geographic distribution of the 16-State cross-section should adequately cover the range of natural occurrence of thallium from low to high. The 16-State cross-section also contains a substantial proportion of the States with reported TRI releases of thallium and thallium compounds. Based on this use and release evaluation, the 16-State cross-section appears to adequately represent thallium occurrence nationally.

2.5.7 References

Agency for Toxic Substances and Disease Registry (ATSDR). 1992. *Toxicological Profile for Thallium*. U.S. Department of Health and Human Services, Public Health Service. 90 pp. + Appendices. Available on the Internet at: http://atsdr1.atsdr.cdc.gov/toxprofiles/tp54.pdf

Agency for Toxic Substances and Disease Registry (ATSDR). 1995. *ToxFAQs for Thallium*. U.S. Department of Health and Human Services, Public Health Service. Available on the Internet at: http://atsdr.cdc.gov/tfacts54.html

Center for Disease Control and Prevention (CDC). 1992. *Fluoridation Census 1992*. Atlanta, GA: Centers for Disease Control and Prevention, Public Health Service, U.S. Department of Health and Human Services.

Center for Disease Control and Prevention (CDC). 2002. Written comments (including information from the unpublished *Fluoridation Census 2000*) from CDC staff to OGWDW staff, January 8, 2002.

Durum, W.H., and J. Haffty. 1961. *Occurrence of minor elements in water.* U.S. Geological Survey Circular 445, U.S. Geological Survey, U.S. Department of the Interior, as cited in USEPA. 1984.

Hazardous Substances Data Bank (HSDB). 2000. Search for Thallium. Available on the Internet through TOXNET, sponsored by the National Institute of Health's National Library of Medicine. Available on the Internet at: http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB,

Staples, C.A., A.F. Werner, and T.J. Hoogheem. 1985. Assessment of priority pollutant concentrations in the United States using STORET database. In: *Environmental Toxicology and Chemistry*. v. 4, pp. 131-142. New York, New York: Pergamon Press, Ltd.

USEPA. 1984. *Thallium in water: An assessment of occurrence and exposure. First Draft.* Prepared by: V.J. Ciccone & Associates, Inc., Woodbridge, VA. Prepared for: Science and Technology Branch, Criteria and Standards Division, Office of Drinking Water, USEPA, Washington, DC. September 28, 1984.

USEPA. 1985. *Status report: National Inorganics and Radionuclides Survey.* By Jon P. Longtin. Cincinnati, OH: Technical Support Division, Office of Drinking Water, USEPA. August 30, 1985.

USEPA. 1988. Computer printout of STORET water quality data base retrieval conducted March 23, 1988 by Science Applications International Corporation. Data available through the Office of Water Regulations and Standards, USEPA.

USEPA. 2000. *TRI Explorer: Trends*. Available on the Internet at: http://www.epa.gov/triexplorer/trends.htm, last updated May 5, 2000.

USEPA. 2001. *National Primary Drinking Water Regulations - Consumer Factsheet on: Thallium.* Office of Ground Water and Drinking Water, USEPA. Available on the Internet at: http://www.epa.gov/OGWDW/dwh/c-ioc/thallium.html, last updated March 9, 2001.

USEPA. 2002. *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT*. EPA Report/815-D-02-005, Office of Water, 55 pp.

Wade Miller Associates, Inc. 1989. *Occurrence and Exposure Assessment of Thallium in Public Drinking Water Supplies*. Prepared for and submitted to EPA on February 24, 1989.

3.0 SYNTHETIC ORGANIC CONTAMINANTS

3.1 Alachlor

Table of Contents

Tables and Figures

3.1.1 Introduction, Use and Production

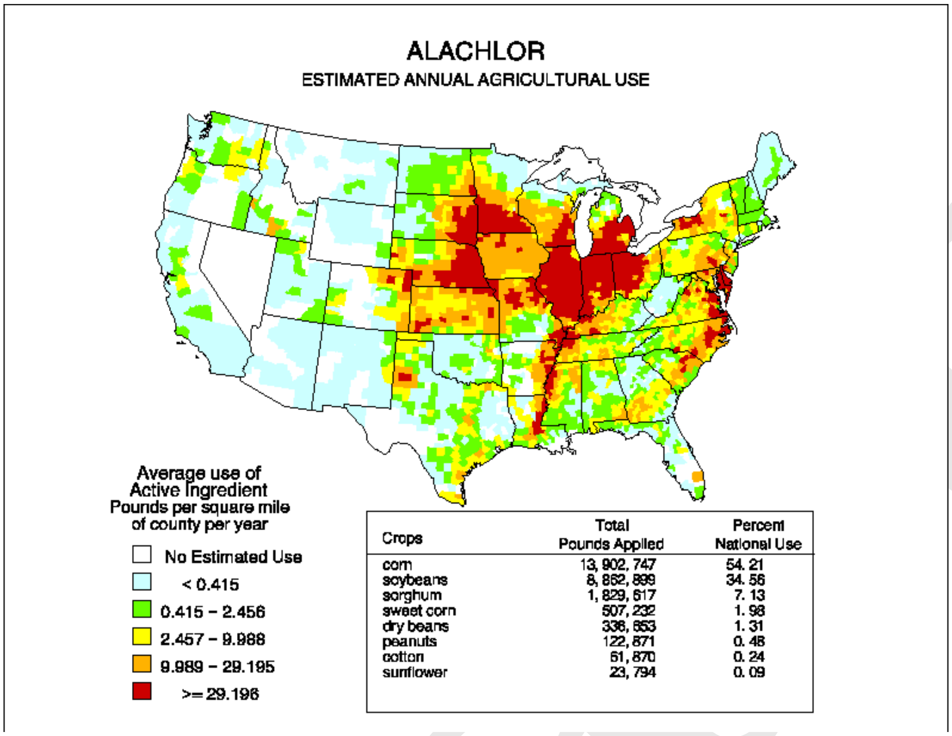
Alachlor [2-chloro-2', 6'-diethyl-N-(methoxymethyl) acetanilide] is a pre-emergent amide herbicide. It is an odorless, white crystalline solid. Alachlor is found in a variety of commercial herbicides including Lasso, Lariat, and Crop Star. It also mixes well with other herbicides such as Bullet, Freedom, and Rasta and in mixed formulations with atrazine, glyphosate, trifluralin and imazaquin (EXTOXNET, 2001).

The greatest use of alachlor is as a herbicide for control of annual grasses and broadleaf weeds in crops, primarily on corn, sorghum and soybeans. Alachlor is the second most widely used herbicide in the U.S., with particularly heavy use on corn and soybeans in Illinois, Indiana, Iowa, Minnesota, Nebraska, Ohio, and Wisconsin (USEPA, 2001). It is a selective systemic herbicide, absorbed by germinating shoots and by roots. The chemical works by interfering with a plant's ability to produce protein and by interfering with root elongation (EXTOXNET, 2001).

Recent national estimates of agricultural use for alachlor are available. The United States Geological Survey (USGS, 1998a) estimates approximately 25.65 million pounds of alachlor active ingredient were used in 1992. These estimates were derived using State-level data sets on pesticide use rates available from the National Center for Food and Agricultural Policy (NCFAP) combined with county-level data on harvested crop acreage from the Census of Agriculture (Thelin and Gianessi, 2000). Corn accounts for the majority of usage (13.9 million pounds alachlor ai), while moderate use can be found on several other crops as well (e.g., soybeans, sorghum, beans). According to EPA estimates, from 1993-1995 annual alachlor use ranged between 29.3 and 44.6 million pounds, with 20.5 to 28.0 million acres treated (number of acres times number of times treated) (USEPA, 1998). Although no production data is available, Monsanto in St. Louis, MO is the basic manufacturer of alachlor (EXTOXNET, 2001).

Figure 3.1-1 shows the USGS (1998a) derived geographic distribution of estimated average annual alachlor use in the United States for 1992. A breakdown of use by crop is also included. The greatest amount of alachlor is used in corn production, with the largest concentration of alachlor use seen in the Midwest, where corn and soybeans are plentiful. While non-agricultural uses are not reflected here and any sharp spatial differences in use within a county are not well represented (USGS, 1998c), existing data suggest that non-agricultural use of alachlor is minimal to non-existent (USEPA, 1998). A comparison of this use map with the map of the 16 cross-section States (Figure 1.3-1) shows that States across the range of high of low alachlor use are well represented in the cross-section.

Figure 3.1-1: Estimated Annual Agricultural Use for Alachlor (1992)



Crops	Total Pounds Applied	Percent National Use
corn	13,902,747	54.21
soybeans	8,862,899	34.56
sorghum	1,829,617	7.13
sweet corn	507,232	1.98
dry beans	336,653	1.31
peanuts	122,871	0.48
cotton	61,870	0.24
sunflower	23,794	0.09

Source: USGS 1998a

3.1.2 Environmental Release

Alachlor is listed as a Toxics Release Inventory (TRI) chemical. Table 3.1-1 illustrates the environmental releases for alachlor from 1995 to 1999. (There are only alachlor data for these years.) Air emissions constitute most of the on-site releases, with a decrease since 1997. Total on- and off-site releases first increased from 1995 to 1998 and then dropped off dramatically in 1999, as both air emissions and off-site releases (including metals or metal compounds transferred off-site) decreased in 1999. Surface water discharges have remained relatively stable over the five-year period. No underground injection or releases to land (such as spills or leaks within the boundaries of the reporting facility) were reported for alachlor. These TRI data for alachlor were reported from five States: Illinois, Iowa, Nebraska, Ohio, and Texas, with only Iowa reporting every year (USEPA, 2000). Illinois, Nebraska, and Texas are included in the 16-State cross-section (used for analyses of alachlor occurrence in drinking water; see Section 3.1.4). (For a map of the 16-State cross-section, see Figure 1.3-1.)

Table 3.1-1: Environmental Releases (in pounds) for Alachlor in the United States, 1995-1999

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1999	755	390	--	--	1,270	2,415
1998	1,510	220	--	--	9,100	10,830
1997	2,700	290	--	--	3,600	6,590
1996	2,340	330	--	--	4,100	6,770
1995	756	280	--	--	2,940	3,976

Source: USEPA, 2000

3.1.3 Ambient Occurrence

Alachlor is an analyte for both surface and ground water NAWQA studies, with a method detection limit (MDL) of 0.002 µg/L. Additional information on analytical methods used in the NAWQA study units, including method detection limits, are described by Gilliom and others (1998).

Alachlor concentrations at all of the ground and surface water sites exceed the detection limit, with the exception of urban ground water sites. High percentages of surface water samples exceed detection frequencies of 0.01 and 0.05 µg/L. Within surface water sites, urban sites have consistently lower percentage exceeding the detection frequencies then agricultural or integrator sites. Within ground water sites, agricultural sites have a slightly higher percentage exceeding the detection frequencies than urban or integrator sites. The maximum concentration exceeds the detection limit in all ground and surface water sites. The 95th percentile values exceed the detection limit for all surface water sites, while none of the 95th percentile values exceed the detection limit for any ground water sites. None of the median values exceed the detection limit in ground or surface water sites.

Table 3.1-2: Alachlor Detections and Concentrations in Surface Water and Ground Water

	Detection frequency (% of samples)			**Concentration percentiles (all samples; µg/L)**			
	all samples	> 0.01 µg/L	> 0.05 µg/L	10th	median	95th	max
surface water							
agricultural	36.36%	27.37%	11.49%	< MDL	< MDL	0.22	5.4
urban	13.46%	8.87%	3.67%	< MDL	< MDL	0.019	3.8
integrator	39.02%	26.02%	10.16%	< MDL	< MDL	0.17	2.1
all sites	30.58%	22.62%	9.91%	< MDL	< MDL	0.19	25E

	Detection frequency (% of samples)			**Concentration percentiles (all samples; µg/L)**			
ground water							
agricultural	3.14%	1.49%	0.54%	< MDL	< MDL	< MDL	0.55
urban	0.33%	ND	ND	< MDL	< MDL	< MDL	0.007
major aquifers	1.61%	0.86%	0.54%	< MDL	< MDL	< MDL	0.14
all sites	3.04%	1.95%	1.03%	< MDL	< MDL	< MDL	10E

Note: Individual maximum values with an "E-code" have much greater uncertainty because the values were beyond the calibration range.
ND=No detect
Source: USGS, 1998b

Alachlor was also an analyte in the 1999 Pilot Monitoring Program (Blomquist, et al., 2001). Alachlor was detected in almost 30% of the 323 raw water samples and in about 22.4% of the 228 finished water samples. The 95th percentile value was equal to 0.002 µg/L and 0.027 µg/L for raw and finished water samples, respectively. The maximum concentration of alachlor in raw water was 0.655 µg/L. In finished water, the maximum concentration of alachlor was 0.148 µg/L.

3.1.3.2 Additional Ambient Occurrence Data

A summary document entitled "Occurrence and Human Exposure to Pesticides in Drinking Water, Food, and Air in the United States of America" (USEPA, 1989), was previously prepared for past USEPA assessments of alachlor. Eleven studies reviewed in that document provided data on concentrations of alachlor in water other than drinking water. Three studies assessed levels of alachlor in ground water, and eight studies provided information on levels of alachlor in surface water. The following information is taken directly from "Occurrence and Human Exposure to Pesticides in Drinking Water, Food, and Air in the United States of America" (USEPA, 1989).

3.1.3.2.1 Ground Water Sources

Spalding, et al., (1980, as cited in USEPA, 1989) presented data from a study conducted in atrazine high-use areas of Nebraska. Water samples from 14 wells, out of a total of more than 1,000 wells that were studied in the area, were selected as representative of water in the area. Water samples from 2 of the 14 wells contained an average alachlor concentration of approximately 0.04 µg/L (range = 0.018 to 0.071 µg/L). No detection limit was reported.

In addition, ground water wells from Nebraska, as well as from Iowa, Maryland, and Pennsylvania, have been found to have concentrations of alachlor typically in the range of 0.1 to 10.0 µg/L (Cohen, et al., 1986, as cited in USEPA, 1989). No other information on these wells was available.

Ground water wells and spring water in the Big Spring Basin, Clayton County, Iowa, were sampled during 1981-1982 for the occurrence of alachlor (Datta, no date, as cited in USEPA, 1989). Ninety-five samples from 21 locations were analyzed for alachlor, and 4 positive samples were found. An overall mean of 0.082 µg/L (range = 0.05 to 0.15 µg/L) was calculated.

A survey of alachlor in rural private wells was performed (Monsanto, 1986, as cited in USEPA, 1989). The survey analyzed for alachlor in 246 wells in 9 States. The wells sampled were selected from private wells in areas where alachlor was extensively used. Of the 246 wells sampled, 10 wells had detectable levels of alachlor. The highest level reported was 5.8 µg/L. The remaining nine wells had levels below 1 µg/L. The detection limit was 0.1 µg/L.

3.1.3.2.2 Surface Water Sources

Baker et al. (1981, as cited in USEPA, 1989) presented data from a study that examined concentrations of alachlor in stream water in Ohio. A total of 292 samples were collected from 12 different streams during the spring and summer of 1981 and analyzed for alachlor. The analysis identified 235 (80%) positive samples. The maximum concentration observed was 104.6 µg/L. No detection limit for the analysis was given.

Baker (1983, as cited in USEPA, 1989) reported on levels of alachlor in water samples collected from two Ohio rivers. Between May 28, 1983, and July 27, 1983, a total of 46 samples were collected (23 samples from each river). The average alachlor concentrations for samples collected and analyzed from each of the rivers were 1.24 µg/L and 3.11 µg/L, respectively. The number of positive values and the detection limit for alachlor were not reported.

Another study examining surface waters in Ohio was reviewed for alachlor occurrence data. Datta (no date, as cited in USEPA, 1989) reported analyses of a creek in southwest Ohio during 1981, and again in 1982. Mean concentrations of alachlor for the two years were 13.9 µg/L and 7.6 µg/L, respectively. No other information was reported. The same source (Datta, no date, as cited in USEPA, 1989) also reported that for 5 northwest Ohio rivers, 233 samples were found to have mean peak concentrations of 23.2 µg/L (maximum concentration = 69.6 µg/L). The number of positives and the detection limit were not reported.

River samples from the Little Sioux River in northwest Iowa and Big Spring Basin, Iowa, were analyzed for alachlor by the Iowa Department of Water, Air, and Waste Management and as part of the Review of Hydrogeology, Water Quality, and Land Management in the Big Spring Basin, respectively (Kelley and Wnuk, 1986; Datta, no date, all as cited in USEPA, 1989). During the overall study period from 1981 to 1985, 18 samples from 5 locations were taken, and 10 proved positive for alachlor. These positive samples represent a mean of 2.59 µg/1 (range = 0.06-20.0 µg/L). No detection limit was given. A reservoir on the Des Moines River was sampled for alachlor during 1977-1978 by Leung et al. (1982, as cited in USEPA, 1989). Three sites were sampled (upstream, within, and downstream of the reservoir). A mean concentration of 0.089 µg/L (range = 0 to 0.82 µg/L) was reported for positive samples. The number of positives, number of samples, and detection limit were not reported.

Twenty-five samples from River Raisin, Michigan, were taken at U.S. Geological Survey stations during 1982 (Datta, no date, as cited in USEPA, 1989). A maximum concentration of 8.16 µg/L was reported for alachlor. No other information was reported.

Dudley and Karr (1980, as cited in USEPA, 1989) analyzed levels of atrazine and alachlor in 45 samples of water, sediment, and fish. The samples were collected in mid-July from a stream draining an agricultural watershed (Black Creek) in Allen County, Indiana. No samples of water showed levels of alachlor in excess of the detection limit of 100 µg/1. The exact number of water samples was not reported.

Schepers et al. (1980, as cited in USEPA, 1989) assessed concentrations of alachlor in 30 samples of water collected from a watershed in Nebraska. Concentrations of alachlor in the 30 samples ranged between "non-detectable" and 1.41 µg/L. However, the period of collection, detection limit, and number of positive samples for alachlor were not reported.

Lake Erie water samples were collected during a study by Konasevich et al. (1978, as cited in USEPA, 1989). Three samples were positive for alachlor at a mean concentration of 3.05 µg/L (range = 0.07 to 9.0 µg/L). The number of samples and detection limit were not reported.

3.1.4 Drinking Water Occurrence Based on the 16-State Cross-Section

The analysis of alachlor occurrence presented in the following section is based on State compliance monitoring data from the 16 cross-section States. The 16-State cross-section is the largest and most comprehensive compliance monitoring data set compiled by EPA to date. These data were evaluated relative to two concentration thresholds of interest: 0.002 mg/L; and 0.0002 mg/L.

All sixteen cross-section State data sets, with the exception of New Jersey, contained occurrence data for alachlor. These data represent more than 58,000 analytical results from approximately 14,000 PWSs during the period from 1984 to 1998 (with most analytical results from 1992 to 1997). The number of sample results and PWSs vary by State, although the State data sets have been reviewed and checked to ensure adequacy of coverage and completeness. The overall modal detection limit for alachlor in the 16 cross-section States is equal to 0.0002 mg/L. (For details regarding the 16-State cross-section, please refer to Section 1.3.5 of this report.)

3.1.4.1 Stage 1 Analysis Occurrence Findings

Table 3.1-3 illustrates the Stage 1 analysis of alachlor occurrence in drinking water for the public water systems in the 16-State cross-section relative to two thresholds: 0.002 mg/L (the current MCL), and 0.0002 mg/L (the modal MRL). Approximately 0.0419% of (a total of 6 systems) all ground water and surface water PWSs had any analytical results of alachlor exceeding the MCL. Approximately 0.488% (70 systems) of PWSs had any exceedances of the modal MRL.

A greater proportion of surface water systems, as compared to ground water systems, exceeded each threshold. Only 1 (approximately 0.00774% of) ground water PWSs had any analytical results exceeding the MCL, compared to 5 (about 0.354% of) surface water systems. About 0.132% (17 systems) of ground water PWSs had any analytical results exceeding 0.0002 mg/L. This compares to about 3.75% (53 systems) of surface water systems with any analytical results greater than the modal MRL.

Table 3.1-3: Stage 1 Alachlor Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Ground Water	0.002	0.00774%	1
	0.0002	0.132%	17
Surface Water	0.002	0.354%	5
	0.0002	3.75%	53

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Combined Ground & Surface Water	0.002	0.0419%	6
	0.0002	0.488%	70

Reviewing alachlor occurrence in the 16 cross-section States by PWS population served (Table 3.1-4) shows approximately 0.259% of the population (a total of 247,300 people) was served by PWSs with any analytical results greater than the MCL. The percentage of population served by PWSs with any exceedance of the modal MRL was 1.19% (over 1.1 million people).

The number of people served by ground water systems with any analytical results greater than 0.002 mg/L was equal to 700 (about 0.00171%). A total of 246,700 (approximately 0.445% of) people were served by surface water systems with any analytical results greater than 0.002 mg/L. About 0.249% of the population served by ground water PWSs (100,200 people) had any exceedances of 0.0002 mg/L, compared to approximately 1.87% of the population served by surface water systems (1,036,700 people).

Table 3.1-4: Stage 1 Alachlor Occurrence Based on 16-State Cross-Section - Population Served

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Ground Water	0.002	0.00171%	700
	0.0002	0.249%	100,200
Surface Water	0.002	0.445%	246,700
	0.0002	1.87%	1,036,700
Combined Ground & Surface Water	0.002	0.259%	247,300
	0.0002	1.19%	1,136,900

3.1.4.2 Stage 2 Analysis Occurrence Findings

The Stage 2 occurrence findings, based on the cross-section data, are presented in Tables 3.1-5 and 3.1-6. The statistically generated best estimate values, as well as the ranges around the best estimate value, are presented. (For a review of the Stage 2 analytical approach, please refer to Section 1.4 of this report. For complete details regarding the Stage 2 analyses, please refer to *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations* (USEPA, 2002)).

No ground water or surface water PWSs had an estimated mean concentration of alachlor exceeding 0.002 mg/L (the current MCL). Approximately 8 (0.0559% of) ground water and surface water PWSs in the 16-States were estimated to have mean concentrations of alachlor above 0.0002 mg/L (the modal detection limit).

A greater proportion of surface water systems, as compared to ground water systems, were estimated to exceed 0.0002 mg/L. Approximately 3 (0.0266% of) ground water systems in the 16 States had estimated mean concentrations of alachlor above 0.0002 mg/L, compared to approximately 5 (0.323% of) surface water systems. As stated above, no ground water or surface water PWSs had an estimated mean concentration of alachlor exceeding 0.002 mg/L.

Table 3.1-5: Stage 2 Estimated Alachlor Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.002	0.000%	0.000% - 0.000%	0	0 - 0
	0.0002	0.0266%	0.0077% - 0.0542%	3	1 - 7
Surface Water	0.002	0.000%	0.000% - 0.000%	0	0 - 0
	0.0002	0.323%	0.0708% - 0.566%	5	1 - 8
Combined Ground & Surface Water	0.002	0.000%	0.000% - 0.000%	0	0 - 0
	0.0002	0.0559%	0.0279% - 0.0907%	8	4 - 13

Reviewing alachlor occurrence by PWS population served (Table 3.1-6) shows that approximately 68,500 (0.0716% of) the PWS population in the 16 States were served by systems with mean alachlor concentrations above 0.0002 mg/L. When evaluated relative to a threshold of 0.002 mg/L, the percent of population exposed was equal to 0%.

For ground water systems, about 15,500 people nationally (0.0385% of the population served by ground water systems in the 16 cross-section States) were exposed to alachlor levels above 0.0002 mg/L. Approximately 0.0956% of the population served by surface water PWSs (about 53,000 people in the 16-State cross-section) had estimated mean concentrations of alachlor above 0.0002 mg/L.

Table 3.1-6: Stage 2 Estimated Alachlor Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.002	0.000%	0.000% - 0.000%	0	0 - 0
	0.0002	0.0385%	0.00383% - 0.112%	15,500	1,500 - 45,200

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Surface Water	0.002	0.000%	0.000% - 0.000%	0	0 - 0
	0.0002	0.0956%	0.00250% - 0.408%	53,000	1,400 - 226,200
Combined Ground & Surface Water	0.002	0.000%	0.000% - 0.000%	0	0 - 0
	0.0002	0.0716%	0.0104% - 0.2576%	68,500	9,900 - 246,500

3.1.4.3 Estimated National Occurrence

Based on the Stage 2 estimated percent of systems (and population served by systems) exceeding each threshold, no PWSs (therefore, no population served by systems) had estimated mean concentrations of alachlor above 0.002 mg/L. Approximately 36 systems serving about 152,500 people served nationally were estimated to have alachlor concentrations greater than 0.0002 mg/L. An estimated 16 ground water systems serving about 33,000 people nationally had mean concentration values that exceeded 0.0002 mg/L. Approximately 18 surface water systems serving 121,700 people had estimated mean concentrations greater than 0.0002 mg/L. (See Section 1.4 for a description of how Stage 2 16-State estimates are extrapolated to national values.)

Table 3.1-7: Estimated National Alachlor Occurrence - Systems and Population Served

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.002	0	0 - 0	0	0 - 0
	0.0002	16	5 - 32	33,000	3,300 - 96,200
Surface Water	0.002	0	0 - 0	0	0 - 0
	0.0002	18	4 - 32	121,700	3,200 - 519,500
Combined Ground & Surface Water	0.002	0	0 - 0	0	0 - 0
	0.0002	36	18 - 59	152,500	22,100 - 548,700

3.1.5 Additional Drinking Water Occurrence Data

Several additional data sources regarding the occurrence of alachlor in drinking water are also reviewed. Previously compiled alachlor occurrence information is presented in following section. Information from the EPA's Office of Pesticide Program's (OPP's) "Reregistration Eligibility Decision (RED): Alachlor"

(USEPA, 1988) is presented in Section 3.1.5.1, and information from an OGWDW summary document entitled “Occurrence and Human Exposure to Pesticides in Drinking Water, Food, and Air in the United States of America” (USEPA, 1989) is presented in Sections 3.1.5.2 - 3.1.5.5. The following variety of studies and information is presented regarding levels of alachlor in drinking water, with the scope of the reviewed studies ranging from national to regional. Note that none of the studies presented in the following section provide the quantitative analytical results or comprehensive coverage that would enable direct comparison to the occurrence findings estimated with the cross-section occurrence data presented in Section 3.1.4. These additional studies, however, do enable a broader assessment of the Stage 2 occurrence estimates presented for this Six-Year Review. The information in Section 3.1.5.1 is taken directly from “Reregistration Eligibility Decision (RED): Alachlor” (USEPA, 1988). All the information in Sections 3.1.5.2 - 3.1.5.5 is taken directly from “Occurrence and Human Exposure to Pesticides in Drinking Water, Food, and Air in the United States of America” (USEPA, 1989).

3.1.5.1 Summary of Alachlor Monitoring Information from OPP’s Alachlor Reregistration

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) states that “the Administrator shall determine whether pesticides containing such active ingredient are eligible for reregistration,” before either reregistering products or taking “other appropriate regulatory action.” Thus, reregistration involves a thorough review of the scientific data base underlying a pesticide's registration. The purpose of the Agency's review is to reassess the potential hazards arising from the currently registered uses of the pesticide; to determine the need for additional data on health and environmental effects; and to determine whether the pesticide meets the “no unreasonable adverse effects” criterion of FIFRA.

In 1988, OPP published a “Reregistration Eligibility Decision” (RED) for alachlor (USEPA, 1988). Several sources of information on monitoring/detections of alachlor in ground water and surface water were reviewed in the RED, and are summarized below. However, because most of these studies were conducted in predominantly high atrazine use areas, the occurrence findings cannot be directly compared to the Stage 2 national occurrence estimates for alachlor.

The most extensive review of alachlor occurrence data included in the RED was collected through the Acetochlor Registration Partnership (ARP) Monitoring Program. This study included monitoring for alachlor as part of Monsanto's conditional registration monitoring program for Acetochlor. Since 1995, wells and surface waters in the major corn growing regions of the U.S. have been monitored.

The ARP Ground Water Monitoring Program involved the creation of a unique network of 175 ground water monitoring wells. These wells are of great relevance to U.S. agriculture because they represent the range of soil and agriculture in seven key Midwest states (Illinois, Indiana, Iowa, Kansas, Minnesota, Nebraska, and Wisconsin) and are positioned directly next to treated corn fields. As a requirement for the registration of acetochlor, the two acetochlor registrants are conducting a ground water monitoring program in seven major use states. Analytes include alachlor, acetochlor, and atrazine, dimethenamid, and metolachlor. Ground water samples are collected monthly from 175 wells located in corn producing areas. The limits of detection and quantification for all analytes are 0.03 µg/L and 0.05 µg/L, respectively.

Results for alachlor are summarized in Table 3.1-8. Fourteen of the wells had alachlor detects greater than limit of quantification (LOQ - 0.05 µg/L). Twenty-seven wells had alachlor detections above the limit of detection (LOD) of 0.03 µg/L. Approximately 36% of the alachlor detections exceeded the MCL (2.0 µg/L) and 54% exceeded a one-in-million cancer risk level of 0.4 µg/L. Approximately 75% of the detections exceeded 0.11 µg/L.

Table 3.1-8. Summary Alachlor Monitoring in Ground Water Conducted by the ARP

Statistic	Detection/Concentration (µg/L)
Number of Samples with Detects ≥0.05 µg/L (% of samples)	30 (1.7%)
Number of Wells (% of 173)	14 (8.1%)
Number of Samples[1]	1,720
Mean	3.38
Minimum	0.05
Median	0.73
Maximum	15.89

The Acetochlor Registration Partnership also provides the most extensive data on alachlor concentrations in finish surface drinking water available to OPP. Samples were collected at 179 different sites (drinking water utilities) in the following 12 states: DE, IL, IN, IA, KS, MD, MN, MO, NE, OH, PA, and WI. Samples were collected approximately once every two weeks from April through early September. Two to three additional samples were collected at most sites, one to two in the fall and one in the winter. Unfiltered samples were analyzed for total alachlor.

Additional detail is provided in a review and analysis of the data by R. David Jones (EFED memo dated May 24, 1996 to B. Montague) and in an electronic spreadsheet (summary statistics) by S. Abel. These analyses provide yearly summary statistics for peak, 96-hour time weighted mean concentrations (TWMC), annual TWMC for 1995 (R. David Jones), and peak and annual TWMC for 1996 (S. Abel). Additionally, running peak and annual TWMC are provided for both years data. Based on the re-analysis of data from 1995 through 1996, Table 3.1-9 provides maximum and 90th percentile (upper 10th percentile) concentrations (peak and annual TWMC).

Table 3.1-9. Summary of 1995 and 1996 Alachlor Monitoring in Surface Water Conducted by the ARP

Statistic	Calculation for a given site	Summary Across Sites	
		Maximum Value for any Site (µg/l)	Value Equaled/Exceeded on 10% of Sites (µg/l)
Peak Concentrations	Highest Value Observed 1995-1996, for any Site	4	0.63
Annual Time Weighted Mean	Weighted Mean for 1995-1996, for any Site (weight by time)	0.36	0.1

In addition to the ARP data, several other studies of alachlor monitoring data were summarized in the Alachlor RED. Table 3.1-10 presents a summary of additional ground water occurrence findings and Table 3.1-11 summarizes the major surface water studies contained in that report.

Table 3.1-10. Summary of Wells with Detections of Alachlor from Various Studies Presented in the Alachlor RED

Study[1]	**Well type**	**Number of Wells (%)**			
		Sampled	**Alachlor Detected**	**Concentration < MCL**	**Concentration ≥ MCL**
USGS (1991 - 1994)	drinking	303	10 (3.3%)	9 (3.0%)	1 (0.3%)
ARP-GWMP	monitoring	173	27 (15.6%)	25 (14.5%)	2 (1.2%)
PGWDB	mixed, most drinking	25,933	467 (1.8%)	368 (1.4%)	99 (0.4%)
NPS	drinking	1300	1 (< 0.1%)	0 (0%)	1 (< 0.1%)
NAWWS	drinking	1430	28 (2.0%)	26 (1.8%)	2 (0.1%)

[1] USGS = U.S. Geological Survey Midcontinent Study, ARP-GWMP = Acetochlor Registration Partnership Ground water Monitoring Program; PGWDB = Pesticides in Ground Water Database; NPS = National Pesticide Survey; NAWWS = National Alachlor Water Well Survey.

Table 3.1-11. Summary of Major Surface Water Sources with Detections of Alachlor from Various Studies Presented in the Alachlor RED

Study	**Number of Sites**	**Maximum Peak (µg/l)**	**Maximum TWMC**[1] **(µg/l)**
ARP (1995-1996)	175-179	4.0	0.36
USGS - Midwestern Stream Recon. (1989)	48	51.3	11.6
USGS - Mississippi River Basin Study (1991-1992)	8	3.6	0.43
State of Illinois (1986-1988)	30	18	0.81
Monsanto Finished Surface Water Study (1986)	30	9.5	1.1
Monsanto Finished Surface Water Study 1985	30	12	1.5
USGS Cedar River basin Study (1984)	6	23	1.7
Ohio Tributaries to Lake Erie (1982-1985)	8	76	3.3[2]
Lake Erie Basin Case Study (1983-1987)	7	91.47	1.74

1. TWMC: Time weighted mean concentrations, annual unless otherwise noted.
2. Time weighted mean concentration calculated over a 4 month period of the study; April 15 to August 15

3.1.5.2 Ground Water Sources – National Study

The National Screening Program for Organics in Drinking Water (NSP) (Boland, 1981, as cited in USEPA, 1989) was conducted by SRI from June 1977 to March 1981. Samples of finished drinking water were collected from 12 ground water systems of varying size throughout the United States and analyzed for alachlor. None of the drinking water samples from the 12 ground water systems contained levels of alachlor in excess of the quantification limit of 0.1 µg/L.

3.1.5.3 Ground Water Sources – Regional Studies

Drinking water wells from eight counties in Maryland were examined by the State of Maryland's Office of Environmental Programs, Department of Health and Mental Hygiene, in the fall of 1983 (State of Maryland, 1983, as cited in USEPA, 1989). Thirteen samples were collected from 11 locations and analyzed for alachlor. Two samples were positive at concentrations of 0.1 and 0.8 µg/L. The detection limit was 0.1 µg/L.

The Suffolk County Department of Health Services analyzed drinking water wells in Long Island, New York, during 1984 (Holden, 1986, as cited in USEPA, 1989). Alachlor was not detected in any of 24 samples collected (detection limit not reported).

Drinking water wells throughout the State of Wisconsin were analyzed by Union Carbide during 1983-1984 as part of a Wisconsin Department of Natural Resources program (Holden, 1986, as cited in USEPA, 1989). Possible contamination may have occurred from both point and nonpoint sources. Of the 377 samples analyzed, 47 were found positive for alachlor, with a maximum concentration of 88 µg/L. The mean concentration, range of values, and detection limit were not reported.

Two studies of drinking water wells in Iowa were available for information on the occurrence of alachlor: one conducted by Iowa State University and the other by the Iowa Department of Water, Air, and Waste Management (Baker and Austin, 1983: Kelley and Wnuk, 1986, all as cited in USEPA, 1989). Combined, the studies included six Iowa counties sampled between 1981 and 1985. Fifty-nine samples were analyzed from 25 sites, with all but one positive sample coming from Humboldt County. The overall range was 0 to 2.7 µg/L (the detection limit was 0.01 µg/L). The one positive sample from outside Humboldt County was 0.18 µg/L. The mean for Humboldt County samples, all taken at one site, was 0.08 µg/L (the detection limit was 0.01 µg/L). The total number of positives and other detection limits were not reported.

3.1.5.4 Surface Water Sources – National Study

The National Screening Program for Organics in Drinking Water (NSP) (Boland, 1981, as cited in USEPA, 1989) also contained information on alachlor contamination in drinking water from surface water sources. Finished drinking water samples, collected from 104 surface water systems of varying size throughout the United States, were analyzed for alachlor. Drinking water samples from four very large systems (serving greater than 100,000 individuals) were found to contain levels of alachlor in excess of the quantification limit of 0.1 µg/L, ranging between 0.1 and 0.9 µg/L, with an average value of 0.38 µg/L.

3.1.5.5 Surface Water Sources – Regional Studies

Alachlor was monitored in known high-use areas of Illinois, Indiana, Iowa, Michigan, Missouri, North Carolina, and Ohio (Monsanto, 1986, as cited in USEPA, 1989). Sampling occurred at 24 community water treatment plants in these seven States, which primarily or exclusively utilize surface water supplies. Populations of the 24 communities ranged from 356 to 388,000 and, overall, the study is representative of over 1.3 million people using public drinking water. Both raw and finished water samples were collected daily from each location for 1 year, and were turned into weekly composites. Sampling took place between April 1985 and April 1986. The lower limit of method validation (LLMV) was 0.02 µg/L.

Alachlor was not detected in any weekly sample of finished water from 10 of the 24 plants. Of the other 14 plants, the annualized mean concentration (AMC, i.e., a time-weighted average concentration) at 12 plants was less than 0.50 µg/L. The other two plants had AMCs of 0.69 µg/L and 1.4 µg/L. Rarely was alachlor found above 2.0 µg/L in a weekly composite: only 2.6 percent of the weekly composites exceeded 2.0 µg/L during the sampling year (Monsanto, 1986, as cited in USEPA, 1989). The weekly composite maximum concentrations ranged from <0.20 to 10.7 µg/L for raw water samples and from <0.20 to 10.9 µg/L for finished water samples. The AMCs ranged from 0 to 1.5 µg/L for raw water samples, and from 0 to 1.4 µg/L for finished water samples. [Note: For the AMC range, the lower value assumes that all non-detected = 0 µg/L and the higher value assumes that all non-detected = 0.20 µg/L.] Individual sample results were not presented in the report.

Baker (1983, as cited in USEPA, 1989) provided the results of analysis of finished drinking water samples collected from a water supply in Ohio from 1981-1982. The supply obtained water from a river draining an agricultural area. Between June 1981 and July 1982, 15 finished drinking water samples were collected from this plant. Although no detection limits were given, 14 of the samples had positive concentrations of alachlor that ranged between 0.03 and 14.3 µg/L, with an average of 4.5 µg/L.

In the study by Baker (1983, as cited in USEPA, 1989), 49 samples were collected from 3 water supplies in Ohio and analyzed for alachlor. The supplies obtained their raw water from two rivers that drain agricultural areas. Average concentrations for samples collected at each of the supplies between May 28 and July 27, 1983 were 1.08 (18 samples), 0.22 (15 samples), and 1.87 µg/L (16 samples). Peak concentrations observed in 1983 were 2.73, 0.47, and 5.91 µg/L, respectively. Datta (no date, as cited in USEPA, 1989) reported an overall mean concentration of 1.07 µg/L for these supplies. The detection limit and number of positive samples were not reported.

Finished drinking water samples from New Orleans, Louisiana were analyzed by Keith et al. (1976, as cited in USEPA, 1989). The range of positive samples for alachlor was 0.17 to 2.9 µg/L. The number of samples analyzed, number of positive samples, mean, and detection limit were not reported.

3.1.6 Conclusion

Alachlor is a manufactured chemical that is the second most commonly used herbicide in the United States. It is most often used for control of annual grasses and broadleaf weeds in crops, primarily on corn, sorghum and soybeans. Recent statistics regarding use of alachlor indicate production and use are considerable. Industrial releases of alachlor have been reported to TRI since 1995 from five States. Alachlor was also an analyte for the NAWQA occurrence studies. In the NAWQA study, alachlor was detected in ground and surface water; however, none of the median values exceeded the detection limit. The Stage 2 analysis, based on the 16-State cross-section, estimated that zero percent of combined ground water and surface water systems serving zero percent of the population exceeded the MCL of 0.002 mg/L. Based on this estimate, zero PWSs nationally are estimated to have levels greater than the MCL.

The 16-State cross-section was designed to be nationally representative based upon VOC, SOC, and IOC pollution potentials as suggested by considerations of manufacturing, agriculture, and geographic diversity factors. Nationally, TRI releases have been reported for alachlor from 5 States, including 3 of 16 cross-section States. According to information from USGS, all of the 16 cross-section States use alachlor, although for most States in light to moderate amounts. Alachlor is used most heavily in the Midwest, where there are six cross-section States. The cross-section should adequately represent the occurrence of alachlor on a national scale based upon the use, production, and release patterns of the 16-State cross-section in relation to the patterns observed for all 50 States.

3.1.7 References

Baker, D.B., K.A. Krieger, and J.V. Setzler. 1981. *The Concentrations and Transport of Pesticides in Northwestern Ohio Rivers.* Prepared by Water Quality Laboratory, Heidelberg College, Tiffin, Ohio, for Lake Erie Wastewater Management Study, U.S. Army Corps of Engineers, Buffalo, New York.

Baker, D.B. 1983. *Herbicide Contamination in Municipal Water Supplies of Northwestern Ohio. Draft Final Report.* Water Quality Laboratory, Heidelberg College, Tiffin, OH.

Baker, J.L., and T.A. Austin. 1983. *Impact of Agricultural Drainage Wells on Groundwater Quality. Completion Report 1981-1983.* Departments of Agricultural Engineering and Civil Engineering, Iowa State University. EPA Grant No. G007228010.

Blomquist, J.D., J.M. Denis, J.L. Cowles, J.A. Hetrick, R.D. Jones, and N.B. Birchfield. 2001. *Pesticides in Selected Water-Supply Reservoirs and Finished Drinking Water, 1999-2000: Summary of Results from a Pilot Monitoring Survey*. U.S. Geological Survey Open-File Report 01-456. 65 pp.

Boland, P.A. 1981. *National Screening Program for Organics in Drinking Water. Part II. Data.* Prepared by SRI International, Menlo Park, California, for Office of Drinking Water, U.S. Environmental Protection Agency, Washington, DC. EPA Contract No. 68-01-4666.

Cohen, S.Z., C. Eiden, and M.N. Lorder. 1986. *Evaluation of Pesticides in Groundwater.* W.Y. Garner, R.C. Honeycutt, H.N. Nigg (eds.). American Chemical Society, Washington, DC. ACS Symposium Series 315.

Datta, P.R. No date. Memorandum: Review of six documents regarding monitoring of pesticides in Northwestern Ohio rivers. Sent to: D.J. Severn, Chief - Exposure Assessment Branch, HED. Washington, DC: Office of Pesticides and Toxic Substances, USEPA.

Dudley, D.R., and J.R. Karr. 1980. Pesticides and PCB residues in the Black Creek watershed, Allen County, Indiana, 1977-1978. *Pestic. Monit. J.* v.13, no. 4, pp.155-157.

EXTOXNET. 2001. *Pesticide Information Profile: Alachlor*. Ithaca, NY: Extension Toxicology Network, Pesticide Management Education Program. Available on the Internet at http://pmep.cce.cornell.edu/profiles/extoxnet/24d-captan/alachlor-ext.html, last updated March 1, 2001.

Gilliom, R.J., D.K. Mueller, and L.H. Nowell. 1998. *Methods for comparing water-quality conditions among National Water-Quality Assessment Study Units, 1992-95*. U.S. Geological Survey Open-File Report 97-589. Available on the Internet at: http://ca.water.usgs.gov/pnsp/rep/ofr97589, last updated October 9, 1998.

Holden, P.W. 1986. *Pesticides and Groundwater Quality. Issues and Problems in Four States.* Prepared for the Board of Agriculture, National Research Council. Washington, DC: National Academy Press.

Keith, L.H., H.W. Garrison, F.R. Allen, *et al.* 1976. Identification of organic compounds in drinking water from 13 U.S. cities. In: *Identification and Analysis of Organic Pollutants in Water.* Ann Arbor, MI: Ann Arbor Sciences Publishers, Inc. pp. 329-373.

Kelley, R., and M. Wnuk. 1986. *Little Synthetic Organic Compound Municipal Well Sampling Survey.* Des Moines, IA: Iowa Department of Water, Air, and Waste,.

Konasevich, D., W. Traversy, and H. Zar. 1978. *Status Report on Organic and Heavy Metal Contaminants in the Lakes Erie, Michigan, Huron and Superior Basins.* Great Lakes Water Quality Board. p. 37.

Leung, SY.Th., R.V. Bulkley, and J.J. Richard. 1982. Pesticide accumulation in a new impoundment in Iowa. *Water Res. Bull.* v. 18, no. 3, pp. 485-493.

Monsanto Agricultural Company. 1986. Information to support the registration of Lasso herbicides. EAP Reg. Nos. 524-285, 524-296, 524-314, 524-329, 524-341, 524-344. Alachlor in raw and finished drinking water derived from surface sources from 24 community water systems located in regions of extensive Lasso use. Compiled by S.R. Muench, Monsanto Agricultural Company, St. Louis, MO.

Schepers, J.S., E.J. Vavricka, and G.E. Schuman. 1980. Agricultural runoff during a drought period. *J. WPCF* v. 52, no. 4.

Spalding, R.F., G.A. Junk, and J.J. Richard. 1980. *Pestic. Monit. J.* v. 14, no. 2, pp. 70-73.

State of Maryland. 1983. Summary Report: Results of a Maryland ground water herbicide survey. Fall 1983. Office of Environmental Programs. Department of Health and Mental Hygiene.

Thelin, Gail P., and Leonard P. Gianessi. 2000. *Method for Estimating Pesticide Use for County Areas of the Conterminous United States*. U.S. Geological Survey Open-File Report 00-250. 62 pp. Available on the Internet at: http://water.wr.usgs.gov/pnsp/rep/ofr00250/ofr00250.pdf.

USEPA. 1989. *Draft Final Report on the Occurrence and Human Exposure to Pesticides in Drinking Water, Food, and Air in the United States of America*. Office of Drinking Water, USEPA. September, 1989.

USEPA. 1998. *Reregistration Eligibility Decision (RED): Alachlor.* EPA Report 738-R-98-020. Washington, DC: Office of Prevention, Pesticides, and Toxic Substances, USEPA. Available on the Internet at: http://www.epa.gov/oppsrrd1/REDs/0063red.pdf.

USEPA. 1998. *R.E.D. Facts: Alachlor*. EPA Report 738-F-98-018. Washington, DC: Office of Prevention, Pesticides, and Toxic Substances, USEPA. 12 pp. Available on the Internet at: http://www.epa.gov/oppsrrd1/REDs/factsheets/0063fact.pdf

USEPA. 2000. *TRI Explorer: Trends*. Available on the Internet at: http://www.epa.gov/triexplorer/trends.htm, last updated May 5, 2000.

USEPA. 2001. *National Primary Drinking Water Regulations - Consumer Factsheet on: Alachlor.* Office of Ground Water and Drinking Water, USEPA. Available on the Internet at http://www.epa.gov/safewater/dwh/c-soc/alachlor.html, last updated April 12, 2001.

USEPA. 2002. *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT*. EPA Report/815-D-02-005, Office of Water, 55 pp.

USGS. 1998a. *Annual Use Maps*. Available on the Internet at: http://water.wr.usgs.gov/pnsp/use92/, last updated March 20, 1998.

USGS. 1998b. *Pesticides in Surface and Ground Water of the United States: Summary of Results of the National Water Quality Assessment Program (NAWQA). PROVISIONAL DATA -- SUBJECT TO REVISION*. Available on the Internet at: http://water.wr.usgs.gov/pnsp/allsum/, last updated October 9, 1998.

USGS. 1998c. *Sources & limitations of data used to produce maps of annual pesticide use*. Reston, VA: United States Geological Survey. Available on the Internet at: http://water.wr.usgs.gov/pnsp/use92/mapex.html (last updated March 20, 1998).

3.2 Bis(2-ethylhexyl)phthalate (DEHP)

Table of Contents

Tables and Figures

3.2.1 Introduction, Use and Production

Bis(2-ethylhexyl)phthalate (also known as di(2-ethylhexyl)phthalate, or DEHP) is the most commonly used chemical of a group of related synthetic organic chemicals called phthalates or phthalic acid esters. DEHP is a colorless liquid with almost no odor. It does not evaporate easily, and little will be present in the air even near sources of production. It dissolves more easily in materials such as gasoline, than it does in water. Trade names for DEHP are Platinol DOP, Octoil, Silicol 150, Bisoflex 81, and Eviplast 80 (ATSDR, 2000).

DEHP is a manufactured chemical that makes plastic more flexible. It is one of several plasticizers in polyvinyl chloride (PVC) resins used to fabricate flexible vinyl products (NSC, 2001). At least 95% of DEHP produced is used as a plasticizer for polyvinylchloride (PVC) and other polymers including rubber, cellulose and styrene. PVC is used in many consumer products such as wall coverings, tablecloths, floor tiles, furniture upholstery, shower curtains, garden hoses, swimming pool liners, rainwear, baby pants, dolls, toys, shoes, automobile upholstery and tops. A number of packaging materials and tubing used in the production of foods and beverages are PVC contaminated with phthalic acid esters, primarily DEHP (USEPA, 2001). These materials include packaging film and sheet, sheathing for wire and cable, medical tubing, and blood storage bags.

Although DEHP does have uses as a non-plasticizer, they are very minor and relatively unimportant. It can be used as a solvent in erasable ink, as an acaricide in orchards, as a component of dielectric fluids in electrical capacitors, to detect leaks in respirators, and as an inert ingredient in pesticide products, in cosmetics, in vacuum pump oil. DEHP can also be used in testing air filtration systems. In some cases, its use has been discontinued because of concerns about health effects. Many toy manufacturers have stopped using DEHP, and it is also no longer used for teethers and rattlers or in plastic food wrap products (ATSDR, 2000).

DEHP is produced as part of a group of chemicals that are collectively known as phthalate esters, and, as such, no production value for any single one of them is recorded. DEHP is included in a subgroup called dioctyl phthalates, which also includes di-ethylhexyl phthalate, diisooctyl phthalate, and di-n-octyl phthalate. Collective production amounts of dioctyl phthalates are as follows: 1990, 309 million pounds; 1994, 258 million pounds; 1995, 280 million pounds; 1996, 280 million pounds; 1997, 287 million pounds, and 1998, 285 million pounds. Production of DEHP in coming years is expected to grow at a slower rate than the economy because of limited growth in the PVC market. Demand for DEHP will also continue to decrease due to health concerns (ATSDR, 2000).

Table 3.2-1 shows the number of facilities in each State that manufacture and process DEHP, the intended uses of the product, and the range of maximum amounts derived from the Toxics Release Inventory (TRI) of EPA (ATSDR, 2000).

Table 3.2-1: DEHP Manufacturers and Processors by State

State[a]	Number of facilities	Range of maximum amounts on site in pounds[b]	Activities and uses[c]
AL	4	1,000-99,999	8,11,13
AR	6	100-999,999	8,9,12,13
CA	15	1,000-999,999	2,3,8,9,12
CO	1	1,000-99,999	8,9
CT	4	1,000-99,999	8,9,10,12
DE	1	1,000-9,999	8
FL	3	1,000-99,999	8,9

State[a]	Number of facilities	Range of maximum amounts on site in pounds[b]	Activities and uses[c]
GA	8	1,000-99,999	8,9,10
IA	1	10,000-99,999	9
IL	19	100-999,999	2,3,7,8,9,11
IN	8	1,000-99,999	7,8,9
KS	4	100-99,999	8,9,13
KY	3	100-99,999	8
LA	2	1,000-99,999	7,8
MA	12	100-999,999	1,6,8,9,10,11,13
MD	6	100-9,999,999	1,4,8,13
MI	11	100-99,999,999	8,9,12,13
MN	9	1,000-99,999	7,8,9
MO	12	1,000-999,999	7,8,9,13
MS	7	1,000-999,999	8,9
NC	17	100-999,999	1,2,3,5,8,9,11
NE	3	10,000-99,999	8,9
NH	4	1,000-99,999	8,9,13
NJ	11	1,000-999,999	2,3,8,9,11
NV	2	1,000-999,999	8
NY	11	1,000-9,999,999	1,3,5,7,8,9,13
OH	31	1,000-999,999	2,3,7,8,9,12
OK	3	1,000-999,999	7,9
PA	16	1,000-9,999,999	1,4,8,9,12,13
PR	8	10,000-999,999	8,9
RI	3	10,000-999,999	8,9
SC	7	100-999,999	8,9,12,13
SD	1	1,000-9,999	9
TN	13	1,000-9,999,999	1,3,4,5,6,7,8,9,10,11,12
TX	12	1,000-999,999	2,3,8,9,10,13
UT	1	1,000-9,999	2,5,8,12
VA	4	10,000-999,999	8,9
VT	1	10,000-99,999	8
WA	2	100-9,999	8
WI	9	1,000-999,999	8,9
WV	2	1,000-9,999	8

[a] Post office State abbreviations used
[b] Range represents maximum amounts on site reported by facilities in each State
[c] Activities/Uses:

1. Produce
2. Import
3. On-site use/processing
4. Sale/distribution
5. Byproduct
6. Impurity
7. Reactant
8. Formulation component
9. Article component
10. Repackaging
11. Chemical processing aid
12. Manufacturing aid
13. Ancillary/other uses

Source: ATSDR, 2000 compilation of TRI97 2000 data

3.2.2 Environmental Release

DEHP is listed as a Toxics Release Inventory (TRI) chemical. Table 3.2-2 illustrates the environmental releases for DEHP from 1988 to 1999. (There are only DEHP data for these years.) Air emissions constitute most of the on-site releases, with a relatively steady decrease over the years. Other on-site releases, such as surface water releases and releases to land (such as spills or leaks within the boundaries of the reporting facility) do not display any discernable trend from 1988 to 1999. Underground injections decreased from 1988 to1993, and have remained at zero ever since. Off-site releases (including metals or metal compounds transferred off-site) have generally fallen over the years (with the exception of a brief spike in 1995) from almost 4 million pounds to under 1 million pounds. The decrease in off-site releases, as well as the decrease in air emissions, have contributed to decreases the total on- and off-site releases of DEHP in recent years. These TRI data for DEHP were reported from 44 States, with 33 States reporting every year (USEPA, 2000). Of the 44 States, 14 are included in the 16-State cross-section (used for analyses of DEHP occurrence in drinking water; see Section 3.2.4). (For a map of the 16-State cross-section, see Figure 1.3-1.)

Table 3.2-2: Environmental Releases (in pounds) for DEHP in the United States, 1988-1999

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1999	226,926	2,629	0	4,685	917,024	1,151,264
1998	215,583	669	0	24,184	1,121,544	1,361,980
1997	240,523	595	0	71,009	1,087,976	1,400,103
1996	447,429	363	0	59,612	1,946,238	2,453,642
1995	504,167	921	0	19,705	3,041,389	3,566,182
1994	462,795	967	0	5,308	1,988,809	2,457,879
1993	571,014	1,248	0	7,192	2,894,667	3,474,121
1992	911,486	954	35	5,357	2,816,258	3,734,090
1991	1,161,162	3,849	370	87,625	2,955,417	4,208,423
1990	1,413,760	2,424	265	19,551	3,236,012	4,672,012
1989	1,173,021	2,987	600	25,937	3,723,521	4,926,066
1988	1,217,329	2,781	3,091	20,748	3,630,612	4,874,561

Source: USEPA, 2000b

3.2.3 Ambient Occurrence

To understand the presence of a chemical in the environment, an examination of ambient occurrence is useful. In a drinking water context, ambient water is untreated source water residing in surface waters and aquifers. There are few available data on the occurrence of DEHP in ambient waters of the United States. The most comprehensive and nationally consistent data describing ambient water quality in the United States are being produced through the United States Geological Survey's (USGS) National Water Quality Assessment (NAWQA) program. However, national NAWQA data, as well as NPDES and NURP data, are currently unavailable for DEHP.

3.2.3.1 Additional Ambient Occurrence Data

A summary document entitled Occurrence and Exposure of Phthalate Esters in Public Drinking Water Supplies" (Wade Miller, 1989), was previously prepared for past USEPA assessments of DEHP. A number of studies reviewed in that document provided data on concentrations of DEHP in water other than drinking water. These studies, conducted on both regional and national levels, are summarized in the following section. The following information is taken directly from "Occurrence and Exposure of Phthalate Esters in Public Drinking Water Supplies" (Wade Miller, 1989).

3.2.3.1.1 Ground Water Sources

DEHP was detected in ground waters at infiltration sites of secondary effluents at Ft. Devens, MA; Boulder, CO; Lubbock, TX; and Phoenix, AZ. The maximum reported concentration for DEHP was 1.40 µg/L (USEPA, 1987, as cited in Wade Miller, 1989).

Several phthalate esters have been detected in ground waters from landfill sites nationwide. DEHP was detected at a maximum concentration of 100.0 µg/L at a landfill site in New Castle County, DE (USEPA, 1987, as cited in Wade Miller, 1989).

The USEPA's computerized water quality data base known as STORET was devised to assist Federal and State institutions meet objectives of Public Law 92-500 to maintain and enhance the physical, chemical, and biological quality of the nation's ambient waterways by providing for the collection and dissemination of basic water quality data (Staples et al., 1985, as cited in Wade Miller, 1989). Data are collected by States, EPA regional offices, and other government agencies and are maintained in the STORET system.

Before presenting a summary of the ambient water data in STORET, it is important to note that there are significant limitations in using the data base to estimate representative concentrations of a contaminant such as hexachlorobenzene. Data entered into STORET are gathered from an array of studies conducted for various purposes. Analyses are conducted in a number of different laboratories employing different methodologies with a range of detection limits. In many cases, detection limits are not reported, making the reliability of the data highly questionable. Where detection limits have been reported, STORET assigns the detection limit value to those observations reported as not detected. This can lead to errors in interpretation and overestimation of concentrations in cases in which there is a preponderance of nondetectable values. Additionally, a few high values can inflate mean values and result in large standard deviations relative to the means (Staples et al., 1985, as cited in Wade Miller, 1989). Very high values may not be correct, as they may reflect sample contamination or analytical error and can significantly distort assessment of average concentrations. Staples et al. (1985, as cited in Wade Miller, 1989) also notes that the use of data collected prior to the 1980s is not recommended, since such data was obtained using less sensitive laboratory techniques and quality assurance procedures were not yet mandated for the data entered into the system.

The STORET water quality data base provides information on the occurrence of contaminants at ambient water stations in U.S. waterways. A summary of this information was obtained for DEHP in ambient waters. Ambient sites include streams, lakes, ponds, wells, reservoirs, canals, estuaries, and oceans. While the preponderance of data were collected from surface water sources, the number of samples collected from ground water wells, relative to the total number of samples collected from all ambient sites combined, is unspecified (Staples et al., 1985, as cited in Wade Miller, 1989). Staples et al. (1985, as cited in Wade Miller, 1989) have summarized data from the 1980's only; that is, data from 1980 through 1983. This was done based on the number of data points and the likelihood that better quality assurance practices have been employed in more recent years. In the absence of sophisticated statistical analyses to eliminate improbable data, median values have been reported. The median value is sensitive to extreme values, and reflects a measure of central tendency more accurately than the mean value in the presence of these extreme values (Staples et al., 1985, as cited in Wade Miller, 1989).

The median concentration of DEHP was 10.0 µg/L, with 24 percent of 901 observations reported as detectable. Detection limits and other sampling information were not given for any of the contaminants.

3.2.3.1.2 Surface Water Sources

Phthalate esters have been detected in surface waters throughout the United States. DEHP was detected in Delaware River water two miles downstream from a Philadelphia wastewater treatment plant at a concentration of 1.0 µg/L (USEPA, 1987, as cited in Wade Miller, 1989). DEHP was detected in water from Galveston Bay, TX at a mean concentration of 0.6 µg/L, and in Mississippi River water at a (tentatively) maximum concentration of 600.0 µg/L (USEPA, 1987, as cited in Wade Miller, 1989).

DEHP has also been detected in U.S. industrial water basins at concentrations ranging from 1.0 to 85.0 µg/L (USPHS, 1987, as cited in Wade Miller, 1989).

3.2.4 Drinking Water Occurrence Based on the 16-State Cross-Section

The analysis of DEHP occurrence presented in the following section is based on State compliance monitoring data from the 16 cross-section States. The 16-State cross-section is the largest and most comprehensive compliance monitoring data set compiled by EPA to date. These data were evaluated relative to several concentration thresholds of interest: 0.006 mg/L; 0.003 mg/L; and 0.0006 mg/L.

Thirteen of the sixteen cross-section State data sets contained occurrence data for DEHP. (No data were reported from New Jersey, New Mexico, or Oregon.) These data represent more than 41,000 analytical results from approximately 9,400 PWSs during the period from 1984 to 1998 (with most analytical results from 1992 to 1997). The number of sample results and PWSs vary by State, although the State data sets have been reviewed and checked to ensure adequacy of coverage and completeness. The overall modal detection limit for DEHP in the 16 cross-section States is equal to 0.0006 mg/L. (For details regarding the 16-State cross-section, please refer to Section 1.3.5 of this report.)

3.2.4.1 Stage 1 Analysis Occurrence Findings

Table 3.2-3 illustrates the Stage 1 analysis of DEHP occurrence in drinking water for the public water systems in the 16-State cross-section relative to three thresholds: 0.006 mg/L (the current MCL), 0.003 mg/L, and 0.0006 mg/L (the modal MRL). A total of 207 (approximately 2.20% of) ground water and surface water PWSs had analytical results exceeding the MCL (0.006 mg/L); 3.81% of systems (359 systems) had results exceeding 0.003 mg/L. When evaluated relative to a threshold of 0.0006 mg/L, the percentage of systems tripled to 11.7% (1,106 systems).

Approximately 2.07% of ground water systems (178 systems) had any analytical results greater than the MCL (0.006 mg/L). About 3.55% of ground water systems (305 systems) had results above 0.003 mg/L. The percentage of ground water systems with at least one result greater than 0.0006 mg/L was equal to 10.7% (921 systems).

A total of 29 (3.51% of) surface water systems had results greater than 0.006 mg/L. Fifty-four (6.53% of) surface water systems had at least one analytical result greater than 0.003 mg/L. Approximately 22.4% of surface water systems (185 systems) had results exceeding 0.0006 mg/L.

Table 3.2-3: Stage 1 DEHP Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Ground Water	0.006	2.07%	178
	0.003	3.55%	305
	0.0006	10.7%	921
Surface Water	0.006	3.51%	29
	0.003	6.53%	54

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
	0.0006	22.4%	185
Combined Ground & Surface Water	0.006	2.20%	207
	0.003	3.81%	359
	0.0006	11.7%	1,106

Table 3.2-4 illustrates DEHP occurrence in the 16 cross-section States by PWS population served. Approximately 3.20% of the 16-State population (over 2.5 million people) was served by PWSs with at least one analytical result of DEHP greater than the MCL. Approximately 5.5 million people (7.06%) were served by systems with an exceedance of 0.003 mg/L. Over 19 million people (24.6%) were served by systems with at least one analytical result greater than 0.0006 mg/L.

The percentage of population served by ground water systems with analytical results greater than 0.006 mg/L was equal to 3.46% (about 1.1 million people). When evaluated relative to 0.003 mg/L and 0.0006 mg/L, the percent of population exposed was equal to 8.51% (approximately 2.7 million people) and 19.5% (over 6 million people), respectively.

The percentage of population served by surface water systems with exceedances of 0.006 mg/L was equal to 3.01% (almost 1.4 million people). Approximately 6.05% of the population served by surface water systems (almost 2.8 million people) were exposed to DEHP concentrations greater than 0.003 mg/L. When evaluated relative to 0.0006 mg/L, the percent of population exposed was equal to 28.2% (over 13 million people).

Table 3.2-4: Stage 1 DEHP Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Ground Water	0.006	3.46%	1,112,500
	0.003	8.51%	2,735,100
	0.0006	19.5%	6,265,300
Surface Water	0.006	3.01%	1,388,900
	0.003	6.05%	2,792,100
	0.0006	28.2%	13,028,100
Combined Ground & Surface Water	0.006	3.20%	2,501,300
	0.003	7.06%	5,527,200
	0.0006	24.6%	19,293,400

3.2.4.2 Stage 2 Analysis Occurrence Findings

The Stage 2 occurrence findings, based on the cross-section data, are presented in Tables 3.2-5 and 3.2-6. The statistically generated best estimate values, as well as the ranges around the best estimate value, are presented. (For a review of the Stage 2 analytical approach, please refer to Section 1.4 of this report. For complete details regarding the Stage 2 analyses, please refer to *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations* (USEPA, 2002)).

About 0.256% (approximately 24) of ground water and surface water PWSs had estimated mean concentrations of DEHP greater than the MCL (0.006 mg/L). Approximately 89 systems (0.948%) in the 16 States had mean concentrations of DEHP exceeding 0.003 mg/L. When evaluated relative to 0.0006 mg/L, the percentage of systems exceeding the threshold increased by a factor of ten to 10.2% (an estimated 957 systems).

Approximately 23 ground water systems in the 16 States (0.263%) have an estimated mean concentration of DEHP greater than 0.006 mg/L. An estimated 0.944% of ground water systems (about 81 systems) had mean concentration values greater than 0.003 mg/L. A total of 846 PWSs (9.85%) had estimated mean concentration values of DEHP greater than 0.0006 mg/L.
Only 2 (about 0.184% of) surface water systems in the 16 States had estimated mean concentrations greater than the MCL. Eight (0.988% of) surface water systems had estimated mean concentration values greater than 0.003 mg/L. Approximately 13.3% (about 110 systems) of surface water systems in the 16 States had estimated mean concentration values of DEHP greater than 0.0006 mg/L.

Table 3.2-5: Stage 2 Estimated DEHP Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.006	0.263%	0.151% - 0.396%	23	13 - 34
	0.003	0.944%	0.698% - 1.23%	81	60 - 106
	0.0006	9.85%	8.93% - 10.8%	846	767 - 928
Surface Water	0.006	0.184%	0.000% - 0.484%	2	0 - 4
	0.003	0.988%	0.363% - 1.69%	8	3 - 14
	0.0006	13.3%	10.8% - 15.7%	110	89 - 130
Combined Ground & Surface Water	0.006	0.256%	0.149% - 0.393%	24	14 - 37
	0.003	0.948%	0.690% - 1.24%	89	65 - 117
	0.0006	10.2%	9.22% - 11.1%	957	868 - 1,043

Reviewing DEHP occurrence by PWS population served (Table 3.2-6) shows that approximately 0.119% of population served by all PWSs in the 16 cross-section States (an estimate of approximately 93,400 people) was served by systems with estimated mean concentrations of DEHP above 0.006 mg/L. The percentage of population served by PWSs in the 16 States with levels of DEHP above 0.003 mg/L and 0.0006 mg/L were 0.652% (an estimated 510,100 people) and 9.82% (almost 7.7 million people), respectively.

When the percent of population served by ground water systems was evaluated relative to a threshold of 0.006 mg/L, 0.003 mg/L, and 0.0006 mg/L, the percentage of population exposed in the 16 cross-section States was equal to 0.189% (an estimated 60,600 people), 0.676% (an estimated 217,400 people) and 7.22% (an estimated 2.3 million people), respectively.

The percentage of population served by surface water systems with levels above 0.006 mg/L was equal to 0.0712% (an estimated 32,900 people), and the percentage of population served with levels above 0.003 mg/L was 0.634% (an estimated 292,700 people nationally). The percentage of the population served by surface water systems with levels above 0.0006 mg/L was 11.6% (almost 5.4 million people).

Table 3.2-6: Stage 2 Estimated DEHP Occurrence Based on 16-State Cross-Section - Population

Source Water Type	**Threshold (mg/L)**	**Percent of Population Served by Systems Estimated to Exceed Threshold**		**Total Population Served by Systems in the 16 States Estimated to Exceed Threshold**	
		Best Estimate	**Range**	**Best Estimate**	**Range**
Ground Water	0.006	0.189%	0.0215% - 0.463%	60,600	6,900 - 148,700
	0.003	0.676%	0.326% - 1.19%	217,400	104,600 - 382,400
	0.0006	7.22%	5.45% - 9.92%	2,320,700	1,751,000 - 3,187,300
Surface Water	0.006	0.0712%	0.000% - 0.426%	32,900	0 - 196,600
	0.003	0.634%	0.0312% - 3.00%	292,700	14,400 - 1,386,600
	0.0006	11.6%	5.81% - 18.2%	5,363,700	2,679,600 - 8,410,200
Combined Ground & Surface Water	0.006	0.119%	0.0186% - 0.363%	93,400	14,600 - 284,500
	0.003	0.652%	0.220% - 2.02%	510,100	172,200 - 1,580,700
	0.0006	9.82%	6.20% - 13.9%	7,686,000	4,852,600 - 10,851,400

3.2.4.3 Estimated National Occurrence

Based on the Stage 2 estimated percent of systems (and population served by systems) exceeding each threshold, an estimated 166 PWSs serving approximately 254,100 people nationally could be exposed to DEHP concentrations above 0.006 mg/L. About 616 systems serving almost 1.4 million people nationally had estimated mean concentrations greater than 0.003 mg/L. Approximately 6,607 systems serving almost 21 million people served nationally were estimated to have DEHP concentrations greater than 0.0006 mg/L. (See Section 1.4 for a description of how Stage 2 16-State estimates are extrapolated to national values.)

For ground water systems, an estimated 156 PWSs serving about 161,500 people nationally had mean concentrations greater than 0.006 mg/L. Approximately 561 systems serving about 579,600 people nationally had estimated mean concentration values that exceeded 0.003 mg/L. About 5,856 ground water systems serving almost 6.2 million people nationally had estimated mean concentrations greater than 0.0006 mg/L.

Approximately 10 surface water systems serving 90,600 people nationally were estimated to have mean concentrations of DEHP above 0.006 mg/L. An estimated 55 surface water systems serving 807,500 people had estimated mean concentrations greater than 0.003 mg/L. An estimated 745 surface water systems serving almost 15 million people had mean concentrations greater than 0.0006 mg/L.

Table 3.2-7: Estimated National DEHP Occurrence - Systems and Population Served

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.006	156	90 - 235	161,500	18,400 - 396,400
	0.003	561	415 - 733	579,600	278,900 - 1,019,600
	0.0006	5,856	5,307 - 6,420	6,187,900	4,668,800 - 8,498,800
Surface Water	0.006	10	0 - 27	90,600	0 - 542,400
	0.003	55	20 - 95	807,500	39,700 - 3,824,900
	0.0006	745	601 - 879	14,795,300	7,391,300 - 23,198,900
Combined Ground & Surface Water	0.006	166	97 - 256	254,100	39,700 - 774,100
	0.003	616	449 - 808	1,387,700	468,600 - 4,300,600
	0.0006	6,607	5,993 - 7,199	20,911,000	13,202,200 - 29,522,900

3.2.5 Additional Drinking Water Occurrence Data

Several additional data sources regarding the occurrence of DEHP in drinking water are also reviewed. Previously compiled occurrence information, from an OGWDW summary document entitled "Occurrence and Exposure of Phthalate Esters in Public Drinking Water Supplies" (Wade Miller, 1989), is presented in following section. This variety of regional studies and information are presented regarding levels of DEHP in drinking water. (No national studies were included.) Note that none of the studies presented in the following section provide the quantitative analytical results or comprehensive coverage that would enable direct comparison to the occurrence findings estimated with the cross-section occurrence data presented in Section 3.2.4. These additional studies, however, do enable a broader assessment of the Stage 2 occurrence estimates presented for this Six-Year Review. All the following information in Section 3.2.5 is taken directly from "Occurrence and Exposure of Phthalate Esters in Public Drinking Water Supplies" (Wade Miller, 1989).

3.2.5.1 Groundwater Studies

Thirty-nine public water wells in New York State were sampled and analyzed for the presence of phthalate esters. DEHP was detected at a maximum concentration of 170.0 µg/L. The frequency of occurrence for DEHP was 92 percent (USEPA, 1987, as cited in Wade Miller, 1989).

DEHP was detected in drinking water obtained from groundwater sources in Miami, FL at a concentration of 30.0 µg/L. The number of positive detections was not reported (USEPA, 1987, as cited in Wade Miller, 1989). DEHP was detected in five small water systems (wells with fewer than 200 connections) in Santa Cruz County, CA at concentrations ranging from 8.7 to 102.0 µg/L (California Department of Health Services, Unpublished, as cited in Wade Miller, 1989).

3.2.5.2 Surface Water Studies

Water from three water treatment plants in New Orleans, LA was sampled and analyzed for the presence of phthalate esters. DEHP was detected at concentrations ranging from 0.1 to 0.46 µg/L. The number of positive detections was not reported (USEPA, 1987, as cited in Wade Miller, 1989). Water from a water treatment plant in Philadelphia, PA was also sampled and analyzed for the presence of phthalate esters. DEHP was detected at a concentration of 0.6 µg/L. The number of positive detections was not reported (USEPA, 1987, as cited in Wade Miller, 1989).

Drinking water from Seattle, WA; Ottumwa, IA; Philadelphia, PA: and Cincinnati, OH was sampled and analyzed for the presence of phthalate esters. DEHP was not detected in the drinking water of any of the four cities surveyed. The number of positive detections was not reported for any of the contaminants in any of the cities (USEPA, 1987, as cited in Wade Miller, 1989).

3.2.5.5 Unspecified Water Sources

Tap water concentrations of phthalate esters in Cincinnati, OH: Hartford, CT; Atlanta, GA; and St. Louis, MO were reported in USEPA (1987). DEHP was detected in Cincinnati at a concentration of 16.5 µg/L. The water sources were unspecified.

3.2.6 Conclusion

DEHP is a manufactured chemical that is part of a group of chemicals known as phthalate esters. Over 95% of DEHP is used as a plasticizer for PVC. Recent statistics regarding production and release of DEHP indicate production and use are steady, but have the possibility of decline. Industrial releases of DEHP have been reported to TRI since 1988 from 44 States. DEHP was not analyzed in any available ambient studies. The Stage 2 analysis, based on the 16-State cross-section, estimated that approximately 0.256% of combined ground water and surface water systems serving 0.119% of the population exceeded the MCL of 0.006 mg/L. Based on this estimate, approximately 166 PWSs serving approximately 254,100 people nationally are estimated to have levels greater than the MCL.

The 16-State cross-section was designed to be nationally representative based upon VOC, SOC, and IOC pollution potentials as suggested by considerations of manufacturing, agriculture, and geographic diversity factors. Nationally, DEHP is manufactured and/or processed in 40 States and has TRI releases in 44 States. DEHP is manufactured and/or processed in 13 out of the 16 cross-section States and has TRI releases in 14 of the 16 cross-section States. The cross-section should adequately represent the occurrence of DEHP on a national scale based upon the use, production, and release patterns of the 16-State cross-section in relation to the patterns observed for all 50 States.

3.2.7 References

Agency for Toxic Substances and Disease Registry (ATSDR). 2000. *Toxicological Profile for Di(2-ethylhexyl)phthalate*. U.S. Department of Health and Human Services, Public Health Service. 252 pp. + Appendices. Available on the Internet at http://www.atsdr.cdc.gov/toxprofiles/tp9.pdf.

California Department of Health Services. Unpublished. *Final Report on a Monitoring Program for Organic Chemical Contamination of Small Public Water Systems in California. Summary Version.* Sacramento, CA.

National Safety Council (NSC). 2001. *Di(2-ethylhexyl) Phthalate Chemical Backgrounder*. Itasca, IL: National Safety Council. Available on the Internet at: http://www.crossroads.nsc.org/ChemicalTemplate.cfm?id=103&chempath=chemicals, accessed July 23, 2001.

Staples, C.A., A.F. Werner, and T.J. Hoogheem. 1985. Assessment of Priority Pollutant Concentrations in the United States Using STORET Data Base. *Environmental Toxicology and Chemistry.* v. 4, pp. 131-142.

USEPA. 1987. *Health and Environmental Effects Profile for Phthalic Acid Alkyl, Aryl, and Alkyl/Aryl Esters. Final Draft.* Cincinnati, OH: Environmental Criteria and Assessment Office, Office of Health and Environmental Assessment. ECAO-CIN-P188.

USEPA. 2000. *TRI Explorer: Trends*. Available on the Internet at: http://www.epa.gov/triexplorer/trends.htm, last updated May 5, 2000.

USEPA. 2001. *National Primary Drinking Water Regulations - Consumer Factsheet on: Di(2-ethylhexyl) Phthalate.* Office of Ground Water and Drinking Water, USEPA. Available on the Internet at http://www.epa.gov/safewater/dwh/c-SOC/DEHP.html, last updated April 12, 2001.

USEPA. 2002. *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT*. EPA Report/815-D-02-005, Office of Water, 55 pp.

USPHS. 1987. *Draft Toxicological Profile for Di(2-Ethylhexyl) Phthalate.* Atlanta, GA: Agency for Toxic Substances and Disease Registry.

Wade Miller Associates, Inc. 1989. *Occurrence and Exposure Assessment of Phthalate Esters in Public Drinking Water Supplies - DRAFT*. Draft report submitted to EPA for review July 10, 1989.

3.3 Carbofuran

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Tables and Figures

3.3.1 Introduction, Use and Production

Carbofuran (2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate) is a white crystalline solid with a slightly phenolic odor. Carbofuran is available in liquid and granular formulations. Thermal decomposition of carbofuran may include toxic oxides of nitrogen. Fires, and the runoff from fire control, may produce irritating or poisonous gases. Some of its trade names are Furadan, Bay 70143, Curaterr, D 1221, ENT 27164, Yaltox, Furacarb (EXTOXNET, 1998).

Carbofuran is a broad spectrum insecticide used primarily to exterminate insects, mites, nematodes and rootworm on contact or after ingestion. Earlier uses were primarily on corn crops. The greatest use of carbofuran is against foliar pests on alfalfa and rice, with turf and grapes making up most of the remainder. It is sprayed directly onto soil and plants just after emergence to control beetles, nematodes and rootworm. These insecticides work by blocking the normal functioning of cholinesterase, an essential nervous system enzyme (EXTOXNET, 1998).

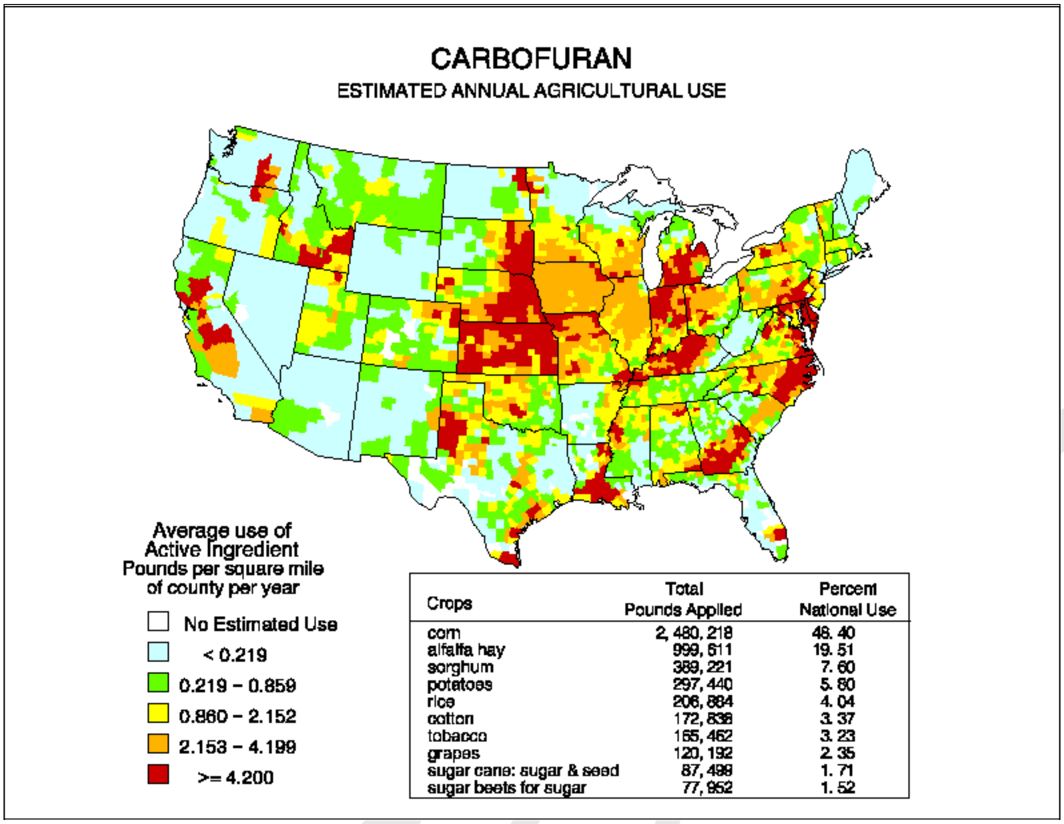
Glaze (1982, as cited in USEPA, 1989) estimated that in 1980 approximately 11 million pounds of carbofuran active ingredient were available for domestic use and approximately 8 million pounds were exported. Gianessi (1986, as cited in USEPA, 1989) estimated that of the approximately 30 million pounds of carbofuran used nationwide from 1978 to 1982, 20 million pounds were applied to field corn and 4 million pounds were applied to sorghum. The remaining production was used on a larger number of crops, including alfalfa, tobacco, peanuts, rice, sugarcane, potatoes, soybeans, sweet corn, cotton, grapes and small grains (USEPA, 1989).

The National Center for Food and Agricultural Policy (NCFAP) estimates total annual agricultural use at about 5.1 million pounds per year (based on the 1992 agricultural census with updates from 1993 and 1995). The NCFAP estimates, combined with Census of Agriculture data on crop distributions can be used to estimate the geographic distribution of carbofuran use (USGS, 1997).

Carbofuran is used on about 30 crops -- the largest markets (in terms of pounds of active ingredient) are for use on corn, alfalfa, rice, sorghum, potatoes, and cotton; followed by grapes, sugarbeets, soybeans, wheat, tobacco, sunflowers, sweet corn, sugarcane, and peanuts (USGS, 1997).

Figure 3.3-1 shows the United States Geological Survey (USGS, 1998a) derived geographic distribution of estimated average annual carbofuran use in the United States for 1992. A breakdown of use by crop is also included. The USGS (1998a) estimates almost 5 million pounds of carbofuran active ingredient were used in 1992. The largest concentrations of carbofuran use are seen in the Midwest. A comparison of this use map with the map of the 16 cross-section States (Figure 1.3-1) shows that States across the range of high of low carbofuran use are well represented in the cross-section.

Figure 3.3-1: Carbofuran Estimated Annual Agricultural Use



Crops	Total Pounds Applied	Percent National Use
corn	2, 480, 218	48. 40
alfalfa hay	999, 611	19. 51
sorghum	389, 221	7. 60
potatoes	297, 440	5. 80
rice	206, 884	4. 04
cotton	172, 836	3. 37
tobacco	165, 462	3. 23
grapes	120, 192	2. 35
sugar cane: sugar & seed	87, 498	1. 71
sugar beets for sugar	77, 952	1. 52

Source: USGS, 1998a

3.3.2 Environmental Release

Carbofuran is listed as a Toxics Release Inventory (TRI) chemical. Table 3.3-1 illustrates the environmental releases for carbofuran from 1995 to 1999. Air emissions constitute most of the on-site releases. Carbofuran air emissions generally decreased over the years, with the exception of a sharp increase in 1999. Surface water discharges also dramatically increased in 1999. However, before 1999, surface water discharges were negligible. Underground injection and releases to land are less significant on-site releases, with underground injections always equal to zero and the only releases to land occurring in 1995. Off-site releases of carbofuran are minimal. The TRI data for carbofuran were reported from 10 States, with four reporting every year (USEPA, 2000). Four of the 10 States with TRI data are included in the 16-State cross-section (used for analyses of carbofuran occurrence in drinking water; see Section 3.3.4). (For a map of the 16-State cross-section, see Figure 1.3-1.)

Table 3.3-1: Environmental Releases (in pounds) for Carbofuran in the United States, 1995-1999

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1999	13,999	112	--	--	--	14,111
1998	2,921	1	--	--	--	2,922
1997	3,903	1	--	--	42	3,946
1996	3,854	1	--	--	--	3,855
1995	4,187	2	--	250	250	4,689

Source: USEPA, 2000

3.3.3 Ambient Occurrence

Carbofuran is an analyte for both surface and ground water NAWQA studies, with a method detection limit (MDL) of 0.003 µg/L. Additional information on analytical methods used in the NAWQA study units, including method detection limits, are described by Gilliom and others (1998).

Carbofuran concentrations exceed the detection limit in all of the ground and surface sites. Detection frequencies are consistently greater for surface water than for ground water, possibly because surface waters are more sensitive to anthropogenic releases. High percentages of surface water samples exceed detection frequencies of 0.01 and 0.05 µg/L. Within surface water sites, urban sites have consistently lower percentage exceeding the detection frequencies then agricultural or integrator sites. Within ground water sites, agricultural sites have slightly higher percentage exceeding the detection frequencies then urban or major aquifer sites. The maximum concentration exceeds the detection limit in all ground and surface water sites. The 95th percentile values exceed the detection limit for all surface water sites except urban sites, while none of the 95th percentile values exceed the detection limit for any ground water sites. None of the median values exceed the detection limit in ground or surface water sites.

Table 3.3-2: Carbofuran Detections and Concentrations in Surface Water and Ground Water

	Detection frequency (% of samples)			**Concentration percentiles (all samples; µg/L)**			
	all samples	> 0.01 µg/L	> 0.05 µg/L	10th	median	95th	max
surface water							
agricultural	11.99%	10.79%	5.49%	< MDL	< MDL	0.059	7E
urban	2.75%	2.75%	0.31%	< MDL	< MDL	< MDL	0.062E
integrator	9.35%	7.72%	2.85%	< MDL	< MDL	0.025	0.18E
all sites	7.96%	6.93%	3.08%	< MDL	< MDL	0.022	9.7E

	Detection frequency (% of samples)			Concentration percentiles (all samples; µg/L)			
ground water							
agricultural	0.76%	0.65%	0.43%	< MDL	< MDL	< MDL	1.3E
urban	0.66%	0.66%	0.33%	< MDL	< MDL	< MDL	0.058E
major aquifers	0.54%	0.54%	0.21%	< MDL	< MDL	< MDL	0.4E
all sites	0.50%	0.46%	0.26%	< MDL	< MDL	< MDL	1.3E

Note: Carbofuran has more variable analytical performance than other analytes and usually lower recoveries. Individual maximum values with an "E-code" have much greater uncertainty because the values were beyond the calibration range.
Source: USGS, 1998b

Carbofuran was also an analyte in the 1999 Pilot Monitoring Program (Blomquist et. al, 2001). Carbofuran was detected in less than 1% of the 323 raw water samples and approximately 1.3% of the 228 finished water samples. The 95th percentile value was reported as less than the MRL for both raw and finished water samples. The maximum concentration of carbofuran in raw water was 0.050 µg/L. In finished water, the maximum concentration of carbofuran was 0.030 µg/L.

3.3.3.2 Additional Ambient Data

Several additional data sources regarding the occurrence of carbofuran in non-drinking water are also reviewed. Previously compiled carbofuran occurrence information is presented in following section. NAWQA summary data from EFED's Risk Assessment for the carbofuran Reregistration Eligibility Decision (RED) (USEPA, 2001) is presented in Section 3.3.3.2.1, while information from an OGWDW summary document entitled "Occurrence and Human Exposure to Pesticides in Drinking Water, Food, and Air in the United States of America" (USEPA, 1989) is presented in Sections 3.3.3.2.2 - 3.3.3.2.4. The following variety of studies and information is presented regarding levels of carbofuran in drinking water, with the scope of the reviewed studies ranging from national to regional. The information in Section 3.3.3.2.1 is taken directly from EFED's RED Science Chapter for carbofuran (USEPA, 2001). All the information in Sections 3.3.3.2.2 - 3.3.3.2.4 is taken directly from "Occurrence and Human Exposure to Pesticides in Drinking Water, Food, and Air in the United States of America" (USEPA, 1989).

3.3.3.2.1 Summary of Carbofuran Monitoring Information from EFED's RED Science Chapter

As part of the Reregistration Eligibility Decision (RED) for carbofuran[5], the Environmental Fate and Effects Division (EFED) of the Office of Pesticide Programs (OPP) put together a water resources assessment to describe the occurrence of carbofuran in water resources of the United States. Table 3.3-3 summarizes results from all NAWQA sites where streams were sampled for carbofuran. These include sites sampled many times over several years, as well as sites sampled only once or twice. The results summarized in Table 3.3-3 are from all stream samples, including samples collected on a fixed sampling frequency, high flow samples, low flow samples, diurnal and storm hydrograph samples, and samples collected as part of special synoptic studies. Because all sites and samples are included, the summary statistics shown in Table 3.3-3 are likely to be biased. The detection frequencies and concentration

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[5] For a more detailed description of the Reregistration Eligibility Decision (RED) process, please refer to Section 3.1.5.1.

percentiles shown will be biased high for commonly occurring conditions because more samples were collected at sites where concentrations were high, or samples were collected more frequently during periods of elevated concentrations. On the other hand, the values shown may be biased low because sampling was not conducted during high-use periods. The maximum concentrations shown in Table 3.3-3 are the highest concentrations observed in all NAWQA stream samples. Table 3.3-3 should not be presumed to be a statistically representative summary of the NAWQA pesticide results. Samples were collected between 4/20/92 and 12/16/96. The Level of Detection (LOD) for carbofuran was 0.003 µg/L.

Table 3.3-3. Results (µg/L) from the USGS NAWQA Surface Water Monitoring Program

Land Use	Sites	Samples	Detects	Range [1]	Mean	95th Percentile	Median
Agricultural	506	2,996	297	9.70 - ND[2]	0.023	0.040	ND
Non-Agricultural	550	2,203	117	7.00 - ND	0.012	0.008	ND

1. Range, mean, median and 95th percentile are determined from all samples. Samples below the LOD were given a value one-half the LOD.
2. Below the LOD.

Table 3.3-4 summarizes data for every NAWQA ground water sample that was analyzed for carbofuran, including newly drilled monitoring wells, production wells (such as domestic and public-supply wells), springs, and tile drains. Although Table 3.3-4 provides a complete summary of all NAWQA results, it should not be presumed to be a statistically representative summary of the NAWQA pesticide results. The data in the table contain a variety of spatial and temporal biases for which corrections must be applied before any reliable statistical summaries can be compiled. For example, many of the sites were sampled more than once. Failure to account for this would lead to an over-representation of these sites in any statistical summary of chemistry data in which they were included. Samples were collected between 8/19/92 and 11/15/96. The LOD for carbofuran was 0.003 µg/L.

Table 3.3-4. Results from the USGS NAWQA Ground Water Monitoring Program (for all wells sampled)

Wells	Samples	Detects	Range[1](µg/L)	Mean	95th Percentile	Median
2,550	3,024	15	1.30 - ND[2]	ND	ND	ND

1. Range, mean, median and 95th percentile are determined from all samples. Samples below the LOD were given a value one-half the LOD.
2. Below the LOD.

The USGS generated statistical summaries of the ground water data for three different settings: shallow ground water in primarily agricultural areas, shallow ground water in primarily urban areas, and major aquifers. The agricultural and urban land-use categories were represented by wells chosen or designed to sample shallow, recently recharged (less than ten years old) ground water to determine the effects of specific land uses on water quality. Sites comprising the “major aquifer” (an aquifer that is currently being used as a source of drinking water) category had no such restrictions on land use or water age, and thus, represent a broader mixture of land uses and ground water depths. The USGS followed the following procedures to generate the relatively unbiased and comparable statistical summaries: tile drains and springs were excluded to reduce the variability in site type; any well co-located with another existing well was excluded; networks with fewer than 10 wells were excluded because they contained an insufficient number of wells to be spatially representative of an area; wells that were included in more than one type of network (e.g. a land-use study and an aquifer survey) were allowed to exist in both; one sample from each well was selected.

Table 3.3-5. Results from the USGS NAWQA Monitoring Program for Ground Water

Setting/Land Use		Wells	Samples	Detects	Range[1] (μg/L)	Mean	95th Percentile	Median
Shallow Ground Water	Urban	301	301	2	0.058 - ND[2]	NR[3]	ND	ND
	Agricultural	925	925	7	1.30 - ND	NR	ND	ND
Major Aquifer		933	933	5	0.40 - ND	NR	ND	ND

1. Range, mean, median and 95th percentile are determined from all samples. Samples below the LOD were given a value one-half the LOD.
2. Below the LOD.
3. Not Reported.

3.3.3.2.2 Groundwater Sources

Unpublished data summarized from EPA registration files and reported in Cohen et al. (1984, as cited in USEPA, 1989) indicated that concentrations of carbofuran were present in samples of ground water collected from private wells in areas with sandy soils and water table aquifers in Wisconsin and New York. Concentrations ranged from 1 to 50 μg/L carbofuran. The number of samples, number of positive samples, and detection limit were not reported.

Three studies were obtained examining ground water wells in California. These studies were conducted by the California Department of Food and Agriculture in 1981, and again in 1982, and an evaluation in 1984 during the California State Board's Toxics Special Project (Ramlit Associates, Inc., 1983; Holden, 1986; Cohen and Bowes, 1984, respectively, all as cited in USEPA, 1989). Overall, approximately 30 counties were sampled for the occurrence of carbofuran. Over 200 samples were collected from as many sites, with only 2 proving positive. One concentration was 0.5 μg/L; the other was not reported. The detection limit for the sample concentration given above was not reported.

3.3.3.2.3 Surface Water Sources

The Army Corps of Engineers sampled U.S. Geological Survey water stations along rivers of the Honey Creek watershed in northwest Ohio during 1981 (Datta, no date, as cited in USEPA, 1989). Carbofuran was sampled for at 12 locations and a maximum concentration of 45 μg/L was found. The number of samples, number of positives, and detection limit were not reported.

Dudley and Karr (1980, as cited in USEPA, 1989) presented data on levels of carbofuran in water, fish, and sediment samples collected from a stream draining the Black Creek agricultural watershed in Allen County, Indiana, during 1977 to 1978. Although the detection limit and the number of water samples collected and tested were not reported, none of the samples contained carbofuran in excess of the detection limit.

Woodham et. al (1975, as cited in USEPA, 1989) presented monitoring data from a study to determine whether significant pesticide accumulation had occurred in two counties in North Carolina. Samples of pond water collected both inside and outside the study area contained no carbofuran in excess of the detection limit of 0.05 µg/L.

3.3.3.2.4 Unidentified Sources

Water samples of unidentified sources were collected nationally from various studies and entered in the U.S. EPA's STORET database (as reported in USEPA, 1984, as cited in USEPA, 1989) during 1979 to 1982. Of the 21 stations sampled for carbofuran, 11 had undetectable levels. However, 58 samples were reported as positive. The total number of samples, detection limit(s), and range of positive values were not reported.

3.3.4 Drinking Water Occurrence Based on the 16-State Cross Section

The analysis of carbofuran occurrence presented in the following section is based on State compliance monitoring data from the 16 cross-section States. The 16-State cross-section is the largest and most comprehensive compliance monitoring data set compiled by EPA to date. These data were evaluated relative to several concentration thresholds of interest: 0.04 mg/L; 0.007 mg/L; and 0.004 mg/L.

All sixteen cross-section State data sets, with the exception of New Jersey, contained occurrence data for carbofuran. These data represent almost 52,000 analytical results from approximately 14,000 PWSs during the period from 1983 to 1998 (with most analytical results from 1992 to 1997). The number of sample results and PWSs vary by State, although the State data sets have been reviewed and checked to ensure adequacy of coverage and completeness. The overall modal detection limit for carbofuran in the 16 cross-section States is equal to 0.0009 mg/L. (For details regarding the 16-State cross-section, please refer to Section 1.3.5 of this report.)

3.3.4.1 Stage 1 Analysis Occurrence Findings

Table 3.3-3 illustrates the very low occurrence of carbofuran in public drinking water in drinking water for the public water systems in the 16-State cross-section. Zero systems had any analytical results exceeding the MCL (0.04 mg/L); 0.00718% of systems (1 system) had results exceeding 0.007 mg/L; and 0.0215% of systems (3 systems) had results exceeding 0.004 mg/L.

Only 1 (0.00798% of) ground water system had any analytical results greater than 0.007 mg/L. No surface water systems had results exceeding 0.007 mg/L. About 0.0160% of ground water systems (2 systems) had results above 0.004 mg/L. The percentage of surface water systems with at least one result greater than 0.004 mg/L was equal to 0.0717% (1 system).

Table 3.3-3: Stage 1 Carbofuran Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Ground Water	0.04	0.000%	0
	0.007	0.00798%	1
	0.004	0.0160%	2

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Surface Water	0.04	0.000%	0
	0.007	0.000%	0
	0.004	0.0717%	1
Combined Ground & Surface Water	0.04	0.000%	0
	0.007	0.00718%	1
	0.004	0.0215%	3

Reviewing carbofuran occurrence in the 16 cross-section States by PWS population served (Table 3.3-4) shows that approximately 0.000239% of the population (200 people) was served by PWSs with at least one analytical result of carbofuran greater than 0.007 mg/L. A total of 2,100 (0.00218% of) people were served by systems with an exceedance of 0.004 mg/L. As indicated above, no systems (therefore, no population served by systems) had any analytical results greater than the MCL (0.04 mg/L).

The percentage of population served by ground water systems with analytical results greater than 0.007 mg/L was equal to 0.000576% (200 people). When evaluated relative to 0.004 mg/L, the percent of population by ground water systems exposed was equal to 0.00105% (400 people). No surface water systems had exceedances of 0.007 mg/L. The percentage of population served by surface water systems with exceedances of 0.004 mg/L was equal to 0.00308% (1,700 people).

Table 3.3-4: Stage 1 Carbofuran Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Ground Water	0.04	0.000%	0
	0.007	0.000576%	200
	0.004	0.00105%	400
Surface Water	0.04	0.000%	0
	0.007	0.000%	0
	0.004	0.00308%	1,700
Combined Ground & Surface Water	0.04	0.000%	0
	0.007	0.000239%	200
	0.004	0.00218%	2,100

3.3.4.2 Stage 2 Analysis Occurrence Findings

The Stage 2 occurrence findings, based on the cross-section data, are presented in Tables 3.3-5 and 3.3-6. The statistically generated best estimate values, as well as the ranges around the best estimate value, are presented. (For a review of the Stage 2 analytical approach, please refer to Section 1.4 of this report. For complete details regarding the Stage 2 analyses, please refer to *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations* (USEPA, 2002)).

No ground water or surface water PWSs in the 16 States had an estimated mean concentration of carbofuran exceeding 0.04 mg/L or 0.007 mg/L. The percentage of total ground and surface water systems in the 16 States with estimated mean concentration values of carbofuran greater than 0.004 mg/L was equal to 0.000115% (an estimate of less than one system in the 16-State cross-section). The percentage of ground water systems with estimated mean concentration values greater than 0.004 mg/L was equal to 0.000112%. The percentage of surface water systems with estimated mean concentration values greater than 0.004 mg/L was equal to 0.000144%.

Table 3.3-5: Stage 2 Estimated Carbofuran Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.04	0.000%	0.000% - 0.000%	0	0 - 0
	0.007	0.000%	0.000% - 0.000%	0	0 - 0
	0.004	0.000112%	0.000% - 0.000%	0	0 - 0
Surface Water	0.04	0.000%	0.000% - 0.000%	0	0 - 0
	0.007	0.000%	0.000% - 0.000%	0	0 - 0
	0.004	0.000144%	0.000% - 0.000%	0	0 - 0
Combined Ground & Surface Water	0.04	0.000%	0.000% - 0.000%	0	0 - 0
	0.007	0.000%	0.000% - 0.000%	0	0 - 0
	0.004	0.000115%	0.000% - 0.000%	0	0 - 0

Reviewing carbofuran occurrence by PWS population served (Table 3.3-6) shows that approximately 0.00000461% of population served by all PWSs (less than 1 system in the 16 States) were potentially exposed to carbofuran levels above 0.004 mg/L. The percentage of population served by ground water systems potentially exposed to carbofuran levels above 0.004 mg/L was equal to 0.00000806%. The percentage of population served by surface water systems with estimated mean concentration values greater than 0.004 mg/L was equal to 0.00000217%. When evaluated relative to a threshold of 0.04 mg/L, and 0.007 mg/L, the percent of population exposed was equal to 0% for all system types.

Table 3.3-6: Stage 2 Estimated Carbofuran Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.04	0.00000%	0.000% - 0.000%	0	0 - 0
	0.007	0.00000%	0.000% - 0.000%	0	0 - 0
	0.004	0.00000806%	0.000% - 0.000%	0	0 - 0
Surface Water	0.04	0.00000%	0.000% - 0.000%	0	0 - 0
	0.007	0.00000%	0.000% - 0.000%	0	0 - 0
	0.004	0.00000217%	0.000% - 0.000%	0	0 - 0
Combined Ground & Surface Water	0.04	0.00000%	0.000% - 0.000%	0	0 - 0
	0.007	0.00000%	0.000% - 0.000%	0	0 - 0
	0.004	0.00000461%	0.000% - 0.000%	0	0 - 0

3.3.4.3 Estimated National Occurrence

As illustrated in Table 3.3-7, the Stage 2 analysis estimates zero systems serving none of the national population have estimated mean concentration values of carbofuran greater than 0.04 mg/L, 0.007 mg/L, or 0.004 mg/L. (See Section 1.4 for a description of how Stage 2 16-State estimates are extrapolated to national values.)

Table 3.3-7: Estimated National Carbofuran Occurrence - Systems and Population Served

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.04	0	0 - 0	0	0 - 0
	0.007	0	0 - 0	0	0 - 0
	0.004	0	0 - 0	0	0 - 0
Surface Water	0.04	0	0 - 0	0	0 - 0
	0.007	0	0 - 0	0	0 - 0
	0.004	0	0 - 0	0	0 - 0

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Combined Ground & Surface Water	0.04	0	0 - 0	0	0 - 0
	0.007	0	0 - 0	0	0 - 0
	0.004	0	0 - 0	0	0 - 0

3.3.5 Additional Drinking Water Occurrence Data

Several additional data sources regarding the occurrence of carbofuran in drinking water are also reviewed. Previously compiled occurrence carbofuran information, from an OGWDW summary document entitled "Occurrence and Human Exposure to Pesticides in Drinking Water, Food and Air in the United States of America" (USEPA, 1989), is presented in the following section. This variety of studies and information are presented regarding levels of carbofuran in drinking water, with the scope of the reviewed studies ranging from national to regional. Note that none of the studies presented in the following section provide the quantitative analytical results or comprehensive coverage that would enable direct comparison to the occurrence findings estimated with the cross-section occurrence data presented in Section 3.3.4. These additional studies, however, do enable a broader assessment of the Stage 2 occurrence estimates presented for this Six-Year Review. The information presented in the following section is taken directly from "Occurrence and Human Exposure to Pesticides in Drinking Water, Food and Air in the United States of America" (USEPA, 1989).

3.3.5.1 Ground Water Sources – Regional Studies

In 1984, the Suffolk County Department of Health Services (Holden, 1986, as cited in USEPA, 1989) examined drinking water wells in Long Island, New York, for various pesticides. The survey sampled both public and private wells in close proximity to fields where carbofuran, aldicarb, and other pesticides were used. Of the 5,083 wells sampled, 1,535 contained detectable levels of carbofuran and 250 to 300 wells contained levels greater than 15 µg/L. The maximum level reported was 65 µg/L.

As part of a program of the Wisconsin Department of Natural Resources (Holden, 1986, as cited in USEPA, 1989), drinking water wells were also analyzed for carbofuran during 1983-1984. This study examined wells suspected of contamination by both point and nonpoint sources. Of 78 samples analyzed, 2 were positive, with a high concentration of 7 µg/L. No other information was reported.

Ground water wells were sampled near Richmond, Rhode Island, as part of a cooperative project between the U.S. Geological Survey and the Rhode Island Water Resources Board to identify potential drinking water sources for future water supply use (Offutt, 1984, as cited in USEPA, 1989). Eleven samples were collected during 1984 from five locations and analyzed for carbofuran. Seven were positive, with a mean concentration of 3.7 µg/L (range = 2 to 7 µg/L). The detection limit was 1.0 µg/L.

3.3.6 Conclusion

Carbofuran is a broad spectrum carbamate pesticide used primarily to exterminate insects, mites, nematodes and rootworm on contact or after ingestion. It is used against soil and foliar pests of field, fruit, vegetable and forest crops. The USGS (1998a) estimates almost 5 million pounds of carbofuran active ingredient were used in 1992. The largest concentrations of carbofuran use are seen in the Midwest. Industrial releases of carbofuran have been reported to TRI since 1995 from 10 States, with four reporting every year. Carbofuran was also an analyte for the NAWQA occurrence studies. In the NAWQA study, carbofuran was detected in ground and surface water; however, none of the median values exceeded the detection limit. The Stage 2 analysis, based on the 16-State cross-section, estimated that zero percent of combined ground water and surface water systems serving zero percent of the population exceeded the MCL of 0.04 mg/L. Based on this estimate, zero PWSs nationally are estimated to have levels greater than the MCL.

The 16-State cross-section was designed to be nationally representative based upon VOC, SOC, and IOC pollution potentials as suggested by considerations of manufacturing, agriculture, and geographic diversity factors. According to information from USGS, all of the 16 cross-section States use carbofuran, although most States in light to moderate amounts. Carbofuran is used most heavily in the Midwest and California, covered by seven cross-section States. Nationally, TRI releases have been reported for carbofuran from 10 States, including 4 of 16 cross-section States. The cross-section should adequately represent the occurrence of carbofuran on a national scale based upon the use, production, and release patterns of the 16-State cross-section in relation to the patterns observed for all 50 States.

3.3.7 References

Blomquist, J.D., J.M. Denis, J.L. Cowles, J.A. Hetrick, R.D. Jones, and N.B. Birchfield. 2001. *Pesticides in Selected Water-Supply Reservoirs and Finished Drinking Water, 1999-2000: Summary of Results from a Pilot Monitoring Survey*. U.S. Geological Survey Open-File Report 01-456. 65 pp.

Cohen, S.Z., S.M. Creeger, R.F. Carsel, and C.G. Enfield. 1984. *Pesticide Contamination of Groundwater from Agricultural Uses.* American Chemical Society Symposium Series Treatment and Disposal of Pesticide Wastes.

Cohen, D.B, and G.W. Bowes. 1984. *Water Quality and Pesticides: A California Risk Assessment Program (Volume 1).* Sacramento, CA: State Water Resources Control Board, Toxic Substances Control Program.

Datta, P.R. No date. Memorandum: Review of six documents regarding monitoring of pesticides in Northwestern Ohio rivers. Sent to: D.J. Severn, Chief - Exposure Assessment Branch, HED. Washington, DC: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

Dudley, D.R, and J.R. Karr. 1980. Pesticides and PCB residues in the Black Creek watershed, Allen County, Indiana, 1977-1978. *Pestic. Monit. J.* v. 13, no. 4, pp. 155-157.

EXTOXNET. 1998. *Pesticide Information Profile: Carbofuran*. Ithaca, NY: Extension Toxicology Network, Pesticide Management Education Program. Available on the Internet at http://pmep.cce.cornell.edu/profiles/extoxnet/metiram-propoxur/carbofuran-ext.html, last updated March 1, 2001.

Gianessi, L.P. 1986. *A National Pesticide Usage Database.* Prepared by Resources for the Future for U.S. Environmental Protection Agency, Office of Standards and Regulations, Washington, DC. Cooperative Agreement CR 811858-01-0.

Gilliom, R.J., D.K. Mueller, and L.H. Nowell. 1998. *Methods for comparing water-quality conditions among National Water-Quality Assessment Study Units, 1992-95*. U.S. Geological Survey Open-File Report 97-589. Available on the Internet at: http://ca.water.usgs.gov/pnsp/rep/ofr97589, last updated October 9, 1998.

Glaze, M.H. 1982. *Preliminary Quantitative Usage of Carbofuran.* Washington, DC: Office of Pesticide Programs, U.S. Environmental Protection Agency.

Holden, P.W. 1986. *Pesticides and Groundwater Quality. Issues and Problems in Four States*. Prepared for the Board of Agriculture, National Research Council. Washington, DC: National Academy Press.

JRB Associates. 1984. *Occurrence of Carbofuran in Drinking Water, Food, and Air.* Prepared for and submitted to EPA on February 9, 1984.

Offutt, C.K. 1984. Memorandum: Aldicarb in Rhode Island Groundwater. From: Carolyn K. Offutt, Chief - Environmental Processes and Guidelines Section, Exposure Assessment Branch, HED. Sent to: Paul Lapsley, Chief - Special Review Branch, Registration Division. Washington, DC: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

Ramlit Associates, Inc. 1983. *Groundwater Contamination by Pesticides: A California Assessment.* Submitted to: State Water Resources Control Board, Sacramento, California. Submitted by: Ramlit Associates, Inc., Berkeley, California. Publication No. 83-4SP.

USEPA. 1984. *Health and Environmental Effects Profile for Carbofuran.* Prepared for Office of Solid Waste and Emergency Response, Washington, DC, by Experimental Criteria and Assessment Office, Cincinnati, OH.

USEPA. 1989. *Draft Final Report on the Occurrence and Human Exposure to Pesticides in Drinking Water, Food, and Air in the United States of America*. Office of Drinking Water, USEPA. September, 1989.

USEPA. 2000. *TRI Explorer: Trends*. Available on the Internet at: http://www.epa.gov/triexplorer/trends.htm, last updated May 5, 2000.

USEPA. 2001. *EFED Risk Assessment for the Reregistration Eligibility Decision on Carbofuran, 2/15/2001.* Environmental Fate and Effects Division, Office of Pesticide Programs, USEPA. February, 2001.

USEPA. 2002. *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT*. EPA Report/815-D-02-005, Office of Water, 55 pp.

USGS. 1997. *Carbofuran Occurrence and Distribution in Surface and Ground Waters 1991-1997 - DRAFT*. Pesticides National Synthesis Project, USGS. November 25, 1997.

USGS. 1998a. *Annual Use Maps*. Available on the Internet at: http://water.wr.usgs.gov/pnsp/use92/, last updated 3/20/1998.

USGS. 1998b. *Pesticides in Surface and Ground Water of the United States: Summary of Results of the National Water Quality Assessment Program (NAWQA). PROVISIONAL DATA -- SUBJECT TO REVISION*. Available on the Internet at: http://water.wr.usgs.gov/pnsp/allsum/, last updated October 9, 1998.

Woodham, D.W., M.C. Ganyard, C.A. Bond, and R.G. Reeves. 1975. Monitoring of agricultural pesticides in a cooperative pest management project in North Carolina, 1971, first year of study. In: Savage, E.P. (ed.). Environmental chemicals. Human and animal health. Proceedings of 4th Annual Conference, Colorado State University, Fort Collins, CO.

3.4 Chlordane

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Tables and Figures

3.4.1 Introduction, Use and Production

Chlordane (1,2,4,5,6,7,8,8-octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene) does not occur naturally in the environment. It is a thick nonpolar liquid with a mild, irritating odor whose color ranges from colorless to amber. “Technical chlordane” (the contaminant described throughout this report) is actually not a single chemical. It is a mixture of pure chlordane and about 10 major related chemicals and numerous other components. Some of the major components are trans-chlordane, cis-chlordane, beta-chlordene, heptachlor, and trans-nonachlor. Chlordane does not dissolve in water. Therefore, before it can be used as a spray, it must be placed in water with emulsifiers (soap-like substances), resulting in a milky-looking mixture. In the environment, chlordane tends to bind to soil and to degrade slowly. Some of its trade names are Octachlor and Velsicol 1068 (ATSDR, 1994).

Chlordane is a manufactured chemical that was used as a pesticide in the United States from 1948 to 1988 (ATSDR, 1994). It was used on corn, citrus, deciduous fruits and nuts, and vegetables. It was also used on garden and ornamentals; lawns, turf, ditchbanks and roadsides. Chlordane was used to control a variety of insect pests including parasitic roundworms and other nematodes, termites, cutworms, chiggers, and leafhoppers (USEPA, 2001). In the mid 1970s the use pattern for chlordane was as follows: 35% used by pest control operators, mostly on termites; 28% on agricultural crops, including corn and citrus; 30% for home lawn and garden use; and 7% on turf and ornamentals (ATSDR, 1994).

On March 6, 1978, use of chlordane was suspended except for termite control and some application on non-food plants. In 1983, its use on non-food plants was also banned (ATSDR, 1994). Its use and production were ultimately banned on April 14, 1988 because of concern over cancer risk, evidence of human exposure and accumulation in body fat, persistence in the environment, and danger to wildlife (NSC, 2001). Currently, its only permitted commercial use is for fire ant control in power transformers (USEPA, 2001).

Prior to 1983 the estimated annual usage of chlordane was over 3.6 million pounds (USEPA, 2001). Velsicol Chemical Company in Memphis, TN, is currently the only U.S. manufacturer of chlordane, and it was the only domestic manufacturer when use of chlordane ceased in 1988 (ATSDR, 1994).

Table 3.4-1 shows the facilities that manufacture and process chlordane, the intended uses of the product, and the range of maximum amounts derived from the Toxics Release Inventory (TRI) of EPA (ATSDR, 1994).

Table 3.4-1: Facilities that Manufacture or Process Chlordane[a]

Facility	Location[b]	Range of maximum amounts on site in pounds	Activities and uses
Stennis Space Center	Stennis Space Cen,	0-99	In ancillary or other uses
Velsicol Chemical Corp.	Memphis, TN	100,000-999,999	Produce; for sale/distribution

[a] Derived from TRI90 (1992)
[b] Post Office State abbreviations

Source: ATSDR, 1994 compilation of TRI90 1992 data

3.4.2 Environmental Release

Chlordane is listed as a Toxics Release Inventory (TRI) chemical. Table 3.4-2 illustrates the environmental releases for chlordane from 1988 to 1996. (There are only chlordane data for these years.) Air emissions constitute most of the on-site releases, and emissions fluctuated from 1988 to 1993, before decreasing from 1994 to 1996. Surface water increases have gradually increased, from 1 pound in 1991 to 95 pounds in 1996. The fluctuation in air emissions has been the major contributor to changes in chlordane total on- and off-site releases in recent years. No releases to land (such as spills or leaks within the boundaries of the reporting facility), or off-site releases (including metals or metal compounds transferred off-site) were reported for chlordane. These TRI data for chlordane were reported from 10 States (USEPA, 2000). Five of the 16 cross-section Sates (used for analyses of chlordane occurrence in drinking water; see Section 3.4.4) reported data for chlordane. (For a map of the 16-State cross-section, see Figure 1.3-1.)

Table 3.4-2: Environmental Releases (in pounds) for Chlordane in the United States, 1988-1996

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1996	660	95	--	--	--	755
1995	823	22	--	--	--	845
1994	1,300	13	--	--	--	1,313
1993	51	15	--	--	--	66
1992	1,713	1	--	--	--	1,714
1991	1,427	1	--	--	--	1,428
1990	4,422	1	--	--	--	4,423
1989	3,753	4	--	--	--	3,757
1988	2,698	4	4,262	--	--	6,964

Source: USEPA, 2000b

3.4.3 Ambient Occurrence

To understand the presence of a chemical in the environment, an examination of ambient occurrence is useful. In a drinking water context, ambient water is untreated source water residing in surface waters and aquifers. There are few available data on the occurrence of chlordane in ambient waters of the United States. The most comprehensive and nationally consistent data describing ambient water quality in the United States are being produced through the United States Geological Survey's (USGS) National Water Quality Assessment (NAWQA) program. However, national NAWQA data are currently unavailable for chlordane.

3.4.3.1 Additional Ambient Occurrence Data

A summary document entitled "Occurrence and Human Exposure to Pesticides in Drinking Water, Food and Air in the United States of America" (USEPA, 1989), was previously prepared for past USEPA assessments of various pesticides. In that review, two national studies and seven regional studies analyzed concentrations of chlordane in water other than drinking water. The following information is taken directly from "Occurrence and Human Exposure to Pesticides in Drinking Water, Food and Air in the United States of America" (USEPA, 1989).

3.4.3.1.1 Ground Water Sources – Regional Study

Tucker and Burke (1978, as cited in USEPA, 1989) reported the results of a Statewide groundwater monitoring project conducted in New Jersey. For this study, samples of water were collected from 163 wells in nine counties. The analysis showed that samples of water from five wells contained levels of chlordane in excess of the minimum reportable concentrations of 0.01 µg/L. The range of positive values was 0.01 to 0.02 µg/L chlordane.

One California study of ground water wells found four samples, from as many counties, positive for chlordane with a maximum value of 22 µg/L. No other data were presented for this study. One of three well samples collected in the Barstow, California, area was found to have a chlordane concentration of 0.4 µg/L by the Victorville Regional Water Quality Board in 1980 (Ramlit Associates, Inc., 1983, as cited in USEPA, 1989).

3.4.3.1.2 Surface Water Sources – National Study

The National Pesticide Monitoring Network (Gilliom et al., 1985, as cited in USEPA, 1989) examined surface water samples from rivers nationwide during 1975-1980, and found no positive samples of chlordane out of 2,943 samples analyzed from 177 locations. The detection limit was 0.15 µg/L.

The National Surface Water Monitoring Program (Carey and Kutz, 1983, as cited in USEPA, 1989) presented data on levels of chlordane in surface water samples collected throughout the United States between 1976 and 1980. Although no detection limit for chlordane was reported, 1.1 percent of the samples analyzed had detectable concentrations of chlordane, with a maximum reported value of 0.23 µg/L. The number of samples taken was not reported. It is not known whether the samples were filtered or unfiltered.

3.4.3.1.3 Surface Water Sources – Regional Studies

Truhlar and Reed (1976, as cited in USEPA, 1989) reported the results of analysis of water samples taken from four streams in Pennsylvania. The streams drained four types of land use areas: forests, general farms, orchards, and residential areas. None of the 19 samples collected and analyzed from April 1970 to February 1971 contained chlordane in excess of the detection limit. The detection limit was not reported.

Benvenue et al. (1972b, as cited in USEPA, 1989) conducted extensive sampling of two canals on Oahu, Hawaii, to determine the extent of organochlorine pesticide contamination. A total of nine samples was collected from two canals and analyzed for residues of chlordane. The analyses showed an average concentration of chlordane of 0.007 µg/L and a range of positive values of 0.003 to 0.018 µg/L. The number of positive samples and the detection limit were not reported.

Barks (1978, as cited in USEPA, 1989) presented the results of a USGS water quality study conducted from April 1973 to July 1974 in the Ozark National Scenic Riverways, Missouri. During the study, 20 surface water samples were collected from 3 sites on the Current River and 1 site on Jacks Fork and analyzed for pesticide content. None of the unfiltered samples contained concentrations of chlordane in excess of the detection limit (no detection limit was reported).

Englande et al. (1978, as cited in USEPA, 1989) presented the results of extensive chemical analyses of six Advanced Wastewater Treatment (AWT) plant effluents. The plants were located in California, the District of Columbia, and Texas. A mean concentration of less than 0.039 µg/L chlordane was identified in one plant effluent; the other systems had no detectable levels of chlordane. The number of positive samples and the detection limit were not reported.

3.4.4 Drinking Water Occurrence Based on the 16-State Cross-Section

The analysis of chlordane occurrence presented in the following section is based on State compliance monitoring data from the 16 cross-section States. The 16-State cross-section is the largest and most comprehensive compliance monitoring data set compiled by EPA to date. These data were evaluated relative to several concentration thresholds of interest: 0.002 mg/L; 0.001 mg/L; and 0.0002 mg/L.

All sixteen cross-section State data sets, with the exception of Michigan, contained occurrence data for chlordane. These data represent more than 59,000 analytical results from approximately 13,000 PWSs during the period from 1984 to 1998 (with most analytical results from 1992 to 1997). The number of sample results and PWSs vary by State, although the State data sets have been reviewed and checked to ensure adequacy of coverage and completeness. The overall modal detection limit for chlordane in the 16 cross-section States is equal to 0.0002 mg/L. (For details regarding the 16-State cross-section, please refer to Section 1.3.5 of this report.)

3.4.4.1 Stage 1 Analysis Occurrence Findings

Table 3.4-3 illustrates the Stage 1 analysis of chlordane occurrence in drinking water for the public water systems in the 16-State cross-section relative to three thresholds: 0.002 mg/L (the current MCL), 0.001, and 0.0002 mg/L (the modal MRL). A total of 2 (approximately 0.0152% of) ground water and surface water PWSs had analytical results exceeding the MCL (0.002 mg/L); 0.303% of systems (4 systems) had results exceeding 0.001 mg/L; and 0.106% of systems (14 systems) had results exceeding 0.0002 mg/L.

Approximately 0.0167% of ground water systems had any analytical results greater than 0.002 mg/L. About 0.0337% of ground water systems had results above the MCL (0.002 mg/L). The percentage of ground water systems with at least one result greater than 0.0002 mg/L was equal to 0.118%. No surface water systems had any analytical results greater than 0.002 mg/L, 0.001 mg/L, or 0.0002 mg/L.

Table 3.4-3: Stage 1 Chlordane Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Ground Water	0.002	0.0167%	2
	0.001	0.0337%	4
	0.0002	0.118%	14
Surface Water	0.002	0.000%	0
	0.001	0.000%	0
	0.0002	0.000%	0

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Combined Ground & Surface Water	0.002	0.0152%	2
	0.001	0.0303%	4
	0.0002	0.106%	14

Reviewing chlordane occurrence in the 16 cross-section States by PWS population served (Table 3.4-4) shows that approximately 0.000477% of the population (about 500 people) was served by ground water PWSs with at least one analytical result of chlordane greater than the MCL (0.002 mg/L). A total of 600 (0.000631% of) people in the 16-States were served by ground water systems with an exceedance of 0.001 mg/L. Approximately 0.0275% of the total 16-State population (26,800 people) was served by ground water systems with at least one analytical result greater than 0.0002 mg/L. No surface water systems exceeded any of the threshold levels.

Table 3.4-4: Stage 1 Chlordane Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Ground Water	0.002	0.00114%	500
	0.001	0.00151%	600
	0.0002	0.0658%	26,800
Surface Water	0.002	0.000%	0
	0.001	0.000%	0
	0.0002	0.000%	0
Combined Ground & Surface Water	0.002	0.000477%	500
	0.001	0.000631%	600
	0.0002	0.0275%	26,800

3.4.4.2 Stage 2 Analysis Occurrence Findings

The Stage 2 occurrence findings, based on the cross-section data, are presented in Tables 3.4-5 and 3.4-6. The statistically generated best estimate values, as well as the ranges around the best estimate value, are presented. (For a review of the Stage 2 analytical approach, please refer to Section 1.4 of this report. For complete details regarding the Stage 2 analyses, please refer to *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations* (USEPA, 2002)).

No ground or surface water systems had estimated mean concentrations of chlordane greater than the MCL (0.002 mg/L). Approximately 0.0000910% of systems (less than 1 system in the 16 States) had estimated mean concentration values greater than 0.001 mg/L. Approximately 0.0363% of systems (about 5 systems) had estimated mean concentrations greater than 0.0002 mg/L.

The percentage of ground water PWSs with an estimated mean concentration of chlordane exceeding 0.001 mg/L was equal to 0.000101% (less than 1 ground water system in the 16 States). Approximately 0.0403% of ground water systems (5 systems) had an estimated mean concentration of chlordane greater than 0.0002 mg/L. A very small proportion (0.000301%) of surface water systems had estimated mean concentration values greater than 0.0002 mg/L.

Table 3.4-5: Stage 2 Estimated Chlordane Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.002	0.000%	0.000% - 0.000%	0	0 - 0
	0.001	0.000101%	0.000% - 0.000%	0	0 - 0
	0.0002	0.0403%	0.0253% - 0.0591%	5	3 - 7
Surface Water	0.002	0.000%	0.000% - 0.000%	0	0 - 0
	0.001	0.000%	0.000% - 0.000%	0	0 - 0
	0.0002	0.000301%	0.000% - 0.000%	0	0 - 0
Combined Ground & Surface Water	0.002	0.000%	0.000% - 0.000%	0	0 - 0
	0.001	0.0000910%	0.000% - 0.000%	0	0 - 0
	0.0002	0.0363%	0.0228% - 0.0531%	5	3 - 7

Table 3.4-6 illustrates chlordane occurrence by PWS population served. Approximately 0.00000146% of population served by all PWSs in the 16 States were potentially exposed to chlordane levels above 0.001 mg/L. The percent of population exposed to levels of 0.0002 mg/L was 0.00147% (approximately 1,400 people in the 16 States). As stated above, no systems had estimated mean concentrations of chlordane greater than the MCL (0.002 mg/L).

The percentage of population served by ground water systems in the 16 cross-section States with estimated mean concentration values greater than 0.001 mg/L was equal to 0.00000350%. When evaluated relative to a threshold of 0.0002 mg/L, the percent of population exposed was equal to 0.00346% (1,400 people). The percentage of population served by surface water systems with estimated mean concentrations of chlordane greater than 0.0002 mg/L was equal to 0.0000479%.

Table 3.4-6: Stage 2 Estimated Chlordane Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.002	0.000%	0.000% - 0.000%	0	0 - 0
	0.001	0.00000350%	0.000% - 0.000%	0	0 - 0
	0.0002	0.00346%	0.000945% - 0.0166%	1,400	400 - 6,700
Surface Water	0.002	0.000%	0.000% - 0.000%	0	0 - 0
	0.001	0.000%	0.000% - 0.000%	0	0 - 0
	0.0002	0.0000479%	0.000% - 0.000%	0	0 - 0
Combined Ground & Surface Water	0.002	0.000%	0.000% - 0.000%	0	0 - 0
	0.001	0.00000146%	0.000% - 0.000%	0	0 - 0
	0.0002	0.00147%	0.000394% - 0.00701%	1,400	400 - 6,800

3.4.4.3 Estimated National Occurrence

Based on the Stage 2 estimated percent of systems (and population served by systems) exceeding each threshold, an estimated 24 PWSs nationally serving approximately 3,100 people could be exposed to chlordane concentrations above 0.0002 mg/L. No systems and population served by systems nationally were estimated to have mean concentrations greater than 0.002 mg/L or 0.001 mg/L. (See Section 1.4 for a description of how Stage 2 16-State estimates are extrapolated to national values.)

For ground water systems, an estimated 24 PWSs serving about 3,000 people nationally were expected to have mean concentrations greater than 0.0002 mg/L. Approximately 1 surface water systems serving less than 100 people was estimated to have mean concentrations of chlordane above 0.0002 mg/L.

Table 3.4-7: Estimated National Chlordane Occurrence - Systems and Population Served

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.002	0	0 - 0	0	0 - 0
	0.001	0	0 - 0	0	0 - 0
	0.0002	24	15 - 35	3,000	800 - 14,200
Surface Water	0.002	0	0 - 0	0	0 - 0
	0.001	0	0 - 0	0	0 - 0

Source Water Type	**Threshold (mg/L)**	**Total Number of Systems Nationally Estimated to Exceed Threshold**		**Total Population Served by Systems Nationally Estimated to Exceed Threshold**	
		Best Estimate	**Range**	**Best Estimate**	**Range**
	0.0002	1	0 - 0	< 100	0 - 0
Combined Ground & Surface Water	0.002	0	0 - 0	0	0 - 0
	0.001	0	0 - 0	0	0 - 0
	0.0002	24	15 - 35	3,100	800 - 14,900

3.4.5 Additional Drinking Water Occurrence Data

Several additional data sources regarding the occurrence of chlordane in drinking water are also reviewed. Previously compiled occurrence chlordane information, from an OGWDW summary document entitled "Occurrence and Human Exposure to Pesticides in Drinking Water, Food and Air in the United States of America" (USEPA, 1989), is presented in following section. This variety of regional studies and information are presented regarding levels of chlordane in drinking water. (No national studies were included in the review.) Note that none of the studies presented in the following section provide the quantitative analytical results or comprehensive coverage that would enable direct comparison to the occurrence findings estimated with the cross-section occurrence data presented in Section 3.4.4. These additional studies, however, do enable a broader assessment of the Stage 2 occurrence estimates presented for this Six-Year Review. All the following information in Section 3.4.5 is taken directly from "Occurrence and Human Exposure to Pesticides in Drinking Water, Food and Air in the United States of America" (USEPA, 1989).

3.4.5.1 Ground Water Sources

Irwin and Healy (1978, as cited in USEPA, 1989) summarized data collected in 1976 during a water quality reconnaissance of public water supplies in Florida. None of the 100 ground water supplies sampled, representative of the 5 aquifers in Florida, contained measurable levels of chlordane (no detection limit was reported).

Less than 8 percent of samples from 96 locations utilizing the Floridian aquifer were found positive for chlordane in a 1984 study by the Florida Department of Environmental Resources and the U.S. Geological Survey (Holden, 1986, as cited in USEPA, 1989). These supplies serve over 3 million people. No other information from the study was reported.

No positive samples were found for chlordane in the following two studies; one involved the 1984-1985 sampling of 42 sites from 12 towns in Connecticut and the other involved the analysis of 67 samples from Long Island, New York, in 1984 (Waggoner, 1985; Holden, 1986, all as cited in USEPA, 1989). The Connecticut drinking water wells serve a population of over 570,000, and the detection limit for that study was 3.3 µg/L. No other information about either study was reported.

Two positive samples (one for alpha-chlordane and one for gamma-chlordane) out of 107 samples analyzed were found for ground water wells in Idaho (Idaho Department of Health and Welfare, 1984, as cited in USEPA, 1989). Monitoring for pesticides in drinking water wells is not routinely done; the sampling performed was in response to a particular contamination incident, not for any comprehensive monitoring program. A relatively low mean of 0.0002 µg/L was reported for these two samples, with one sample having a chlordane concentration of 0.038 µg/L (no detection limit was reported). It appears that "negative" samples, possibly assigned a detection limit value, were included in the calculation of the mean.

Benvenue et al. (1972b, as cited in USEPA, 1989) conducted a study to determine the extent of organochlorine pesticide contamination of drinking water in Hawaii. A total of 45 finished drinking water samples were collected from February 1971 to May 1971. Concentrations of chlordane were detected in four of the samples, with a range of positive values between 0.0005 and 0.005 µg/L, and an average concentration of 0.001 µg/L (no detection limit was reported).

3.4.5.2 Surface Water Sources

Irwin and Healy (1978, as cited in USEPA, 1989), summarizing data collected during a water quality reconnaissance of public water supplies in Florida, reported that none of the 16 surface water supplies sampled contained chlordane in excess of the detection limit. No detection limit was reported.

In the New Orleans Water Supply Study conducted by USEPA Region VI (USEPA, 1975a, as cited in USEPA, 1989), samples of drinking water were analyzed for levels of halogenated organics. Although the number of positive samples was not reported, the concentrations of chlordane in three samples analyzed ranged from "non-detected" to less than 0.1 µg/L. No detection limit for the analyses was reported.

To assemble a database which would reflect the status of Great Lakes drinking water quality, the Canadian Public Health Association gathered data from October 1984 through August 1985 (Canadian Public Health Association, 1986, as cited in USEPA, 1989). The data collected covered the period from the mid 1970s to early 1985. The study was funded by the Health Protection Branch of Health and Welfare Canada and the Ontario Ministry of the Environment. A research team, appointed by the Association, reviewed data on the quality of water at 31 representative Canadian and United States communities and 24 offshore sites to evaluate the human health implications.

For each of the 31 communities, data consisted of: 1) background information on the community; 2) treatment plant schematics and associated treatment process information; and 3) water quality data. Water sample types included raw water (treatment plant intake), distribution water (treated water), and tap water. Water quality data collected included general parameters (e.g., alkalinity, turbidity), microbiological and radiological parameters, inorganic parameters, and organic parameters (including volatiles, base/neutrals, pesticides and PCBs, and phenols and acids). For each parameter, the water type, time period, concentration (mean and range), number of samples, and detection limit are presented.

For most of the volatile organics, including chlordane, the available data indicated that there were very low levels of these contaminants in the raw, treated, or tap water. Most of the values found were "not detected" or near the detection limit (Canadian Public Health Association, 1986, as cited in USEPA, 1989).

3.4.5.3 Unspecified Sources

A Region V Survey (USEPA, 1975b, as cited in USEPA, 1989), conducted during the first three months of 1975, assessed levels of organic chemicals in samples of raw and finished drinking water collected from 83 utilities in Indiana, Illinois, Michigan, Minnesota, Ohio, and Wisconsin. Samples were analyzed for various pollutants including gamma-chlordane. One sample of finished drinking water contained gamma-chlordane at a level of 0.004 µg/L. No limits of detection for pesticides were reported.

In a study to identify the sources of pollutants entering a sewage treatment plant, Levins et al. (1979, as cited in USEPA, 1989) collected samples from two drinking water sources. Although no detection limit was reported, the analyses detected no chlordane in any of the samples.

Schafer et al. (1969, as cited in USEPA, 1989) reported concentrations of chlordane up to 8 µg/L for finished drinking water, although no location(s) were given. No other information on this study was reported.

3.4.6 Conclusion

Chlordane is a synthetic chemical that was used in the 1980s as a pesticide in agriculture and other areas. Today, chlordane's only use is as fire ant control in power transformers. As of 1992, chlordane was produced solely by Velsicol Chemical Corp., and its production has greatly decreased since its cancellation. Industrial releases of chlordane were been reported to TRI from 1988 to 1996 from 10 States. Chlordane ambient occurrence was not analyzed in any available ambient studies. The Stage 2 analysis, based on the 16-State cross-section, estimated that zero percent of combined ground water and surface water systems serving zero percent of the population exceeded the MCL of 0.002 mg/L. Based on this estimate, zero PWSs nationally are estimated to have levels greater than the MCL.

The 16-State cross-section was designed to be nationally representative based upon VOC, SOC, and IOC pollution potentials as suggested by considerations of manufacturing, agriculture, and geographic diversity factors. Nationally, TRI releases have been reported for chlordane from 10 States, including 5 of 16 cross-section States. Chlordane use has been virtually eliminated throughout the U.S. The only producer of chlordane is located in Tennessee, which is not one of the 16 cross-section States. However, the cross-section should adequately represent the occurrence of chlordane on a national scale based upon the use, production, and release patterns of the 16-State cross-section in relation to the patterns observed for all 50 States.

3.4.7 References

Agency for Toxic Substances and Disease Registry (ATSDR). 1994. *Toxicological Profile for Chlordane*. U.S. Department of Health and Human Services, Public Health Service. 234 pp. + Appendices. Available on the Internet at http://atsdr1.atsdr.cdc.gov/toxprofiles/tp31.pdf

Barks, J.H. 1978. *Water Quality in the Ozark National Scenic Riverways, Missouri.* Washington, DC: U.S. Geological Survey, U.S. Department of Interior. Geological Survey Water-Supply Paper 2048.

Benvenue, A., J.N. Ogata, and J.W. Hylin. 1972b. Organochlorine pesticides in rainwater, Oahu, Hawaii, 1971-1972. *Bull. Environ. Contam. Toxicol.* v. 8, no. 4, pp. 238-241.

Canadian Public Health Association. 1986. *Comprehensive Survey of the Status of Great Lakes Drinking Water.* Prepared in cooperation with Health and Welfare Canada and the Ministry of the Environment. Ottawa, Canada: Canadian Public Health Association. August 1986.

Carey, A.E., and F.W. Kutz. 1983. Trends in Ambient Concentrations of Agrochemicals in Humans and the Environment of the United States. Presented at the International Conference on Environmental Hazards of Agrochemicals in Developing Countries, Alexandria, Egypt, November 8-12, 1983.

Englande, A.J., J.K. Smith, and J.N. English. 1978. Potable water quality of advanced wastewater treatment plant effluents. *Prog. Wat. Tech.* v. 10, no. ½, pp. 17-39.

Gilliom, R.J., R.B. Alexander, and R.A. Smith. 1985. *Pesticides in the Nation's Rivers, 1975-1980, and Implications for Future Monitoring.* U.S. Geological Survey Water-Supply Paper 2271. U.S. Government Printing Office, U.S. Department of Interior.

Holden, P.W. 1986. *Pesticides and Groundwater Quality. Issues and Problems in Four States.* Prepared for the Board of Agriculture, National Research Council. Washington, DC: National Academy Press.

Idaho Department of Health and Welfare. 1984. Letter to Charles Berry, Office of Drinking Water, U.S. Environmental Protection Agency, summarizing data on groundwater contamination incidents. Sent by: Charles D. Brokopp, State Epidemiologist, Division of Health, Idaho Department of Health and Welfare.

Irwin, G.A., and H.G. Healy. 1978. *Chemical and Physical Quality of Selected Public Water Supplies in Florida, August-September 1976.* Tallahassee, FL: Water Resources Division, U.S. Geological Survey. USGS/WRI 78-21.

Levins, P., J. Adams, P. Brenner, S. Coons, K. Thrun, and J. Varone. 1979. *Sources of Toxic Pollutants Found in Influents to Sewage Treatment Plants. IV.* R.M. Clayton Drainage Basin, Atlanta report. Prepared by Arthur D. Little, Inc., for Office of Water Planning and Standards, U.S. Environmental Protection Agency, Washington, DC. EPA Contract No. 68-01-3857.

National Safety Council (NSC). 2001. *Chlordane Chemical Backgrounder*. Itasca, IL: National Safety Council. Available on the Internet at: http://www.crossroads.nsc.org/ChemicalTemplate.cfm?id=90&chempath=chemicals, accessed July 18, 2001.

Ramlit Associates, Inc. 1983. *Groundwater Contamination by Pesticides: A California Assessment.* Submitted to: State Water Resources Control Board, Sacramento, CA. Submitted by: Ramlit Associates, Inc., Berkeley, CA. Publication No. 83-4SP.

Schafer, M.L., *et al.* 1969. Pesticides in drinking water. *Environ. Sci. Technol.* v. 3, p. 1261.

Truhlar, J.F., and L.A. Reed. 1976. Occurrence of pesticide residues in four streams draining different land-use areas in Pennsylvania, 1969-1971. *Pestic. Monit. J.* v. 10, no.3, pp. 101-110.

Tucker, R.K., and T.A. Burke. 1978. *A Second Preliminary Report on the Findings of the State Groundwater Monitoring Project.* New Jersey: Department of Environmental Protection.

USEPA. 1975a. *Analytical Report: New Orleans Water Supply Study.* Region VI, EPA. EPA-906/9-75-003.

USEPA. 1975b. *Preliminary Assessment of Suspected Carcinogens in Drinking Water*. Washington, DC: Office of Toxic Substances, USEPA.

USEPA. 1989. *Draft Final Report on the Occurrence and Human Exposure to Pesticides in Drinking Water, Food, and Air in the United States of America*. Office of Drinking Water, USEPA. September, 1989.

USEPA. 2000. *TRI Explorer: Trends*. Available on the Internet at: http://www.epa.gov/triexplorer/trends.htm, last updated May 5, 2000.

USEPA. 2001. *National Primary Drinking Water Regulations - Consumer Factsheet on: Chlordane.* Office of Ground Water and Drinking Water, USEPA. Available on the Internet at http://www.epa.gov/safewater/dwh/c-SOC/chlordan.html, last updated April 12, 2001.

USEPA. 2002. *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT.* EPA Report/815-D-02-005, Office of Water, 55 pp.

Waggoner, P.E. 1985. Memorandum from the Connecticut Agricultural Experiment Station on Pesticides in Connecticut Groundwater. P. Gough, (ed.). New Haven, CT: News of Science.

3.5 1,2-Dibromo-3-Chloropropane (DBCP)

Table of Contents

Tables and Figures

3.5.1 Introduction, Use and Production

1,2-Dibromo-3-chloropropane, also known as DBCP, is a manufactured chemical not found naturally in the environment. It is a colorless liquid with a sharp smell that can be tasted in water at very low concentrations. Most DBCP that enters surface water evaporates into the air within several days or a week. Some of what is spilled on or applied to soil moves through the soil into the groundwater, where it may remain for a long time. Trade names for pesticides containing DBCP are Nemagon, Nemafume, Fumazone, Fumagon, and Nemazon (ATSDR, 1992).

1,2-Dibromo-3-chloropropane is a manufactured chemical and is not found naturally in the environment (ATSDR, 1992). It is used as an intermediate in the synthesis of organic chemicals, such as the brominated flame retardant tris[(2,3-dibromopropyl)phosphate] (Verschueren, 1983, as cited in ATSDR, 1992). Until 1977, DBCP was extensively used as a soil fumigant and nematocide on over 40 different crops in the United States (Anonymous, 1988, as cited in ATSDR, 1992). The chemical was used to protect field crops, vegetables, fruits and nuts, nursery and greenhouse crops, and turf from pests (NTP, 1985, as cited in ATSDR, 1992).

From 1977 to 1979, EPA suspended registration of products containing DBCP except for use on pineapples in Hawaii (Anonymous 1988; USEPA 1977, 1979; all as cited in ATSDR, 1992). In 1985, EPA issued an intent to cancel all registrations for DBCP-containing pesticide products, including use on pineapples. Subsequently, the use of existing stocks of DBCP on pineapples was prohibited (USEPA 1985a, 1985b, all as cited in ATSDR, 1992).

Prior to the cancellation of pesticide uses, DBCP was used extensively; 9.8 million pounds of DBCP were applied in 1974. In California, 831,000 pounds of the chemical were applied, mainly on grapes and tomatoes, during 1977 (NTP, 1985, as cited in ATSDR, 1992). The volume of DBCP applied to pineapple fields in Hawaii between 1979 and 1985 was probably high, since during much of that time, the chemical was the preferred fumigant for use on pineapple fields (Albrecht, 1987, as cited in ATSDR, 1992).

DBCP was first produced commercially in the United States in 1955. In 1969, U.S. production was 8.58 million pounds (IARC, 1979, as cited in ATSDR, 1992). Estimates of annual production during 1974 to 1975 ranged from 18 to 20 million pounds (IARC, 1979; NTP, 1985, all as cited in ATSDR, 1992). DBCP is no longer commercially manufactured in the United States (Hawley, 1981; Sax and Lewis, 1987, all as cited in ATSDR, 1992). R.W. Greeff & Co., Inc., in Old Greenwich, Connecticut, is listed as a current supplier of DBCP for domestic research purposes (OPD, 1989, as cited in ATSDR, 1992). It is not known whether this supplier produces DBCP in the United States or imports the chemical.

Two companies were listed as producers of DBCP in 1977 (USEPA, 1989a, as cited in ATSDR, 1992). The production volume of Columbia Organic Chemicals Co., in Columbia, South Carolina, was listed as less than 1,000 pounds. No production volume was listed for the other producer, Velsicol Chemical Corp., in El Dorado, Arkansas. As DBCP is no longer used as a fumigant and nematocide in the United States, it is likely that its current production volume in the United States, if any, is very low.

3.5.2 Environmental Release

1,2-Dibromo-3-chloropropane is listed as a Toxics Release Inventory (TRI) chemical. Table 3.5-1 illustrates the environmental releases for DBCP from 1991 and 1992. (There are only DBCP data for these years.) Air emissions are the only recorded releases of DBCP, and, given that the data is only for two years, a trend is not self-evident. No surface water discharges, underground injection, releases to land (such as spills or leaks within the boundaries of the reporting facility), or off-site releases (including metals or metal compounds transferred off-site) were reported for DBCP. These TRI data for DBCP were reported in Ohio and Rhode Island, neither of which are included in the 16-State cross-section (used for analyses of DBCP occurrence in drinking water; see Section 3.5.4). (For a map of the 16-State cross-section, see Figure 1.3-1.)

Table 3.5-1: Environmental Releases (in pounds) for 1,2-Dibromo-3-Chloropropane in the United States, 1991-1992

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1992	294	--	--	--	--	294
1991	580	--	--	--	--	580

Source: USEPA, 2000

3.5.3 Ambient Occurrence

To understand the presence of a chemical in the environment, an examination of ambient occurrence is useful. In a drinking water context, ambient water is untreated source water residing in surface waters and aquifers. There are few available data on the occurrence of DBCP in ambient waters of the United States. The most comprehensive and nationally consistent data describing ambient water quality in the United States are being produced through the United States Geological Survey's (USGS) National Water Quality Assessment (NAWQA) program. However, national NAWQA data are currently unavailable for DBCP. Additional studies of ambient data are summarized below.

3.5.3.1 Additional Ambient Occurrence Data

A summary document entitled ""Occurrence and Human Exposure to Pesticides in Drinking Water, Food, and Air in the United States of America" (USEPA, 1989b)), was previously prepared for past USEPA assessments of pesticides. Regional studies reviewed in that document were the only information found that addressed levels of DBCP in water other than drinking water or water not specified as drinking water. The following information is taken directly from "Occurrence and Human Exposure to Pesticides in Drinking Water, Food, and Air in the United States of America" (USEPA, 1989b).

Several regional studies (Peoples et al., 1980; Nelson et al., 1981; Pinto, 1980; Cohen, 1981; Carter and Riley, 1981; and Mink, 1981, all as cited in Cohen et al, 1984 and all as cited in USEPA, 1989b) and the EPA pesticide registration files (as reported in Cohen et al., 1984 and as cited in USEPA, 1989b) provided monitoring data on levels of DBCP in ground water. Positive concentrations of DBCP ranging from 0.02 µg/L to 20 µg/L were detected in samples of ground water in Hawaii, California, Arizona, South Carolina, and Maryland. Areas with the highest concentrations were the San Joaquin Valley in California and the region southwest of Phoenix, Arizona. The number of samples analyzed, the number of positive samples detected, and the detection limit were not reported.

Holden (1986, as cited in USEPA, 1989b) reported that, in a massive survey of more than 8,000 public and private wells in the San Joaquin Valley of California, detectable levels of DBCP were found in approximately 25% of the wells tested. The highest level of DBCP found in the survey was 1,240 µg/L.

Samples of ground water collected from seven previously unsampled sites in Hawaii showed detectable levels of DBCP in the range of 0.05 µg/L to 0.5 µg/L (USEPA, 1984, as cited in USEPA, 1989b). Some of the sites have been used as drinking water supplies. The number of samples tested, the number of positive samples, and the detection limit were not reported.

3.5.4 Drinking Water Occurrence Based on the 16-State Cross-Section

The analysis of DBCP occurrence presented in the following section is based on State compliance monitoring data from the 16 cross-section States. The 16-State cross-section is the largest and most comprehensive compliance monitoring data set compiled by EPA to date. These data were evaluated relative to several concentration thresholds of interest: 0.0002 mg/L; 0.0001 mg/L; and 0.00002 mg/L.

All sixteen cross-section State data sets, with the exception of Texas, contained occurrence data for 1,2-dibromo-3-chloropropane. These data represent more than 98,000 analytical results from approximately 14,000 PWSs during the period from 1984 to 1998 (with most analytical results from 1992 to 1997). The number of sample results and PWSs vary by State, although the State data sets have been reviewed and checked to ensure adequacy of coverage and completeness. The overall modal detection limit for DBCP in the 16 cross-section States is equal to 0.00002 mg/L. (For details regarding the 16-State cross-section, please refer to Section 1.3.5 of this report.)

3.5.4.1 Stage 1 Analysis Occurrence Findings

Table 3.5-2 illustrates the Stage 1 analysis of DBCP occurrence in drinking water for the public water systems in the 16-State cross-section relative to three thresholds: 0.0002 mg/L (the current MCL), 0.0001, and 0.00002 mg/L (the modal MRL). A total of 128 (approximately 0.912% of) ground water and surface water PWSs had analytical results exceeding the MCL (0.0002 mg/L); 1.08% of systems (152 systems) had results exceeding 0.0001 mg/L. When evaluated relative to a threshold of 0.00002 mg/L, the percentage of systems increased to 1.50% (211 systems).

Approximately 0.861% of ground water systems (112 systems) had any analytical results greater than the MCL (0.0002 mg/L). About 1.02% of ground water systems (132 systems) had results above 0.0001 mg/L. The percentage of ground water systems with at least one result greater than 0.00002 mg/L was equal to 1.30% (169 systems).

A total of 16 (1.55% of) surface water systems had results greater than 0.0002 mg/L. Twenty (1.93% of) surface water systems had at least one analytical result greater than 0.0001 mg/L. Approximately 4.06% of surface water systems (42 systems) had results exceeding 0.00002 mg/L.

Table 3.5-2: Stage 1 DBCP Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Ground Water	0.0002	0.861%	112
	0.0001	1.02%	132
	0.00002	1.30%	169

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Surface Water	0.0002	1.55%	16
	0.0001	1.93%	20
	0.00002	4.06%	42
Combined Ground & Surface Water	0.0002	0.912%	128
	0.0001	1.08%	152
	0.00002	1.50%	211

Reviewing DBCP occurrence in the 16 cross-section States by PWS population served (Table 3.5-3) shows that approximately 11.4% of the population served by PWSs in the 16 States (almost 10 million people) was served by PWSs with at least one analytical result of DBCP greater than the MCL. Approximately 10.3 million (11.8% of) people were served by systems with an exceedance of 0.0001 mg/L. Over 11 million (13.0% of) people were served by systems with at least one analytical result greater than 0.00002 mg/L.

The percentage of population served by ground water systems with at least one analytical result greater than 0.0002 mg/L was equal to 3.41% (about 1.3 million people). When evaluated relative to 0.0001 mg/L and 0.00002 mg/L, the percent of population exposed was equal to 3.78% (almost 1.5 million people) and 5.36% (over 2 million people), respectively.

The percentages of population served by surface water systems with exceedances of all thresholds are much greater than the ground water percentages of exceedance. About 17.7% of the population (over 8.6 million people) was served by surface water systems with at least one analytical result greater than the MCL. Approximately 18.1% of the population served by surface water systems (over 8.8 million people) were exposed to DBCP concentrations greater than 0.0001 mg/L. When evaluated relative to 0.00002 mg/L, the percent of population exposed was equal to 19.1% (almost 9.4 million people).

Table 3.5-3: Stage 1 DBCP Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Ground Water	0.0002	3.41%	1,322,000
	0.0001	3.78%	1,466,500
	0.00002	5.36%	2,080,200
Surface Water	0.0002	17.7%	8,638,200
	0.0001	18.1%	8,843,800
	0.00002	19.1%	9,352,000

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Combined Ground & Surface Water	0.0002	11.4%	9,960,300
	0.0001	11.8%	10,310,200
	0.00002	13.0%	11,432,200

3.5.4.2 Stage 2 Analysis Occurrence Findings

The Stage 2 occurrence findings, based on the cross-section data, are presented in Tables 3.5-4 and 3.5-5. The statistically generated best estimate values, as well as the ranges around the best estimate value, are presented. (For a review of the Stage 2 analytical approach, please refer to Section 1.4 of this report. For complete details regarding the Stage 2 analyses, please refer to *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations* (USEPA, 2002)).

About 1.41% (approximately 199) of ground water and surface water PWSs had estimated mean concentrations of DBCP greater than the MCL (0.0002 mg/L). Approximately 273 (1.94% of) systems in the 16 States had mean concentrations of DBCP exceeding 0.0001 mg/L. When evaluated relative to 0.00002 mg/L, the percentage of systems exceeding the threshold increased to 4.09% (an estimated 574 systems).

Approximately 182 (1.40% of) ground water systems in the 16 States have an estimated mean concentration of DBCP greater than 0.0002 mg/L. An estimated 1.91% of ground water systems (about 249 systems) had mean concentration values greater than 0.0001 mg/L. A total of 517 (3.97% of) PWSs had estimated mean concentration values of DBCP greater than 0.00002 mg/L.

Only 17 (about 1.64% of) surface water systems in the 16 States had estimated mean concentrations greater than the MCL. Approximately 24 (2.33% of) surface water systems had estimated mean concentration values greater than 0.0001 mg/L. Fifty-seven (approximately 5.56% of) surface water systems in the 16 States had estimated mean concentration values of DBCP greater than 0.00002 mg/L.

Table 3.5-4: Stage 2 Estimated DBCP Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.0002	1.40%	1.19% - 1.61%	182	155 - 210
	0.0001	1.91%	1.65% - 2.18%	249	214 - 284
	0.00002	3.97%	3.41% - 4.52%	517	443 - 588

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Surface Water	0.0002	1.64%	1.06% - 2.32%	17	11 - 24
	0.0001	2.33%	1.55% - 3.19%	24	16 - 33
	0.00002	5.56%	4.06% - 7.06%	57	42 - 73
Combined Ground & Surface Water	0.0002	1.41%	1.22% - 1.65%	199	171 - 231
	0.0001	1.94%	1.70% - 2.21%	273	238 - 310
	0.00002	4.09%	3.53% - 4.63%	574	496 - 650

Reviewing DBCP occurrence by PWS population served (Table 3.5-5) shows that approximately 2.60% of population served by all PWSs in the 16 cross-section States (an estimate of approximately 2.3 million people) were potentially exposed to DBCP levels above 0.0002 mg/L. The percentage of population served by PWSs in the 16 States with mean levels of DBCP above 0.0001 mg/L and 0.00002 mg/L were 3.22% (about 2.8 million people) and 5.75% (over 5 million people), respectively.

When the percent of population served by ground water systems in the 16 States was evaluated relative to a threshold of 0.0002 mg/L, 0.0001 mg/L, and 0.00002 mg/L, the percentage of population exposed in the 16 cross-section States was equal to 3.27% (an estimated 1.27 million people), 4.03% (an estimated 1.56 million people) and 6.21% (an estimated 2.4 million people), respectively.

The percentage of population served by surface water systems in the 16 States with mean levels above 0.0002 mg/L was equal to 2.07% (over 1 million people), and the percentage of population served with levels above 0.0001 mg/L was 2.58% (an estimated 1.26 million people). The percentage of the population served by surface water systems with levels above 0.00002 mg/L was 5.39% (over 2.6 million people).

Table 3.5-5: Stage 2 Estimated DBCP Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.0002	3.27%	2.71% - 4.20%	1,267,200	1,050,000 - 1,629,900
	0.0001	4.03%	3.40% - 5.38%	1,563,900	1,318,400 - 2,086,000
	0.00002	6.21%	4.92% - 9.98%	2,409,100	1,907,200 - 3,869,100
Surface Water	0.0002	2.07%	1.51% - 3.97%	1,011,100	738,000 - 1,941,900
	0.0001	2.58%	1.60% - 5.24%	1,264,600	782,100 - 2,565,400
	0.00002	5.39%	2.74% - 14.2%	2,637,300	1,340,000 - 6,929,800

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Combined Ground & Surface Water	0.0002	2.60%	2.11% - 3.77%	2,278,300	1,853,700 - 3,307,300
	0.0001	3.22%	2.49% - 4.96%	2,828,300	2,182,700 - 4,353,900
	0.00002	5.75%	3.99% - 10.4%	5,046,100	3,503,800 - 9,149,900

3.5.4.3 Estimated National Occurrence

Based on the Stage 2 estimated percent of systems (and population served by systems) exceeding each threshold, an estimated 920 PWSs nationally serving approximately 5.5 million people could be exposed to DBCP concentrations above 0.0002 mg/L. About 1,263 systems serving almost 6.9 million people were estimated to have mean concentrations greater than 0.0001 mg/L. Approximately 2,658 systems serving over 12 million people nationally were estimated to have DBCP concentrations greater than 0.00002 mg/L. (See Section 1.4 for a description of how Stage 2 16-State estimates are extrapolated to national values.)

For ground water systems, about 830 PWSs serving almost 2.8 million people nationally were estimated to have mean concentrations greater than 0.0002 mg/L. Approximately 1,136 systems serving about 3.5 million people nationally were estimated to have a mean concentration value of DBCP that exceeded 0.0001 mg/L. About 2,360 ground water systems serving over 5.3 million people were estimated to have mean concentrations greater than 0.00002 mg/L.

Approximately 92 surface water systems serving about 2.6 million people were estimated to have mean concentrations of DBCP above 0.0002 mg/L. An estimated 130 surface water systems serving almost 3.3 million people were estimated to have mean concentrations greater than 0.0001 mg/L. About 311 surface water systems serving almost 6.9 million people were estimated to have mean concentrations greater than 0.00002 mg/L.

Table 3.5-6: Estimated National DBCP Occurrence - Systems and Population Served

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.0002	830	709 - 959	2,799,200	2,319,400 - 3,600,300
	0.0001	1,136	978 - 1,298	3,454,700	2,912,300 - 4,608,000
	0.00002	2,360	2,025 - 2,687	5,321,700	4,213,000 - 8,546,700
Surface Water	0.0002	92	59 - 130	2,630,600	1,920,100 - 5,052,300
	0.0001	130	86 - 178	3,290,100	2,034,700 - 6,674,500
	0.00002	311	227 - 395	6,861,600	3,486,200 - 18,029,400

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Combined Ground & Surface Water	0.0002	920	792 - 1,070	5,531,800	4,500,900 - 8,030,400
	0.0001	1,263	1,102 - 1,436	6,867,400	5,299,600 - 10,571,600
	0.00002	2,658	2,297 - 3,010	12,252,200	8,507,500 - 22,216,800

3.5.5 Additional Drinking Water Occurrence Data

Several regional studies reviewed in the summary document entitled "Occurrence and Human Exposure to Pesticides in Drinking Water, Food, and Air in the United States of America" (USEPA, 1989b) addressed levels of DBCP in samples of drinking water obtained from ground water and surface water sources. Note that the study presented in the following section does not provide the quantitative analytical results or comprehensive coverage that would enable direct comparison to the occurrence findings estimated with the cross-section occurrence data presented in Section 3.5.4. This additional study, however, does enable a broader assessment of the Stage 2 occurrence estimates presented for this Six-Year Review. All the following information in Section 3.5.5 is taken directly from "Occurrence and Human Exposure to Pesticides in Drinking Water, Food and Air in the United States of America" (USEPA, 1989b).

3.5.5.1 Ground Water Sources

Carey and Kutz (1983, as cited in USEPA, 1989b) presented data collected in 1979 on levels of DBCP in ground water samples collected in California, Arizona, Texas, South Carolina, and Alabama. Eight positive ground water samples collected from California and South Carolina showed DBCP concentrations ranging from 0.01 µg/L to 10.8 µg/L, and an average concentration of 2.8 µg/L. Seven of the positive samples were from private wells; one sample containing 0.01 µg/L was from a municipal well. The number of ground water samples tested was not reported.

3.5.5.2 Surface Water Sources

Carey and Kutz (1983, as cited in USEPA, 1989b) also reported on levels of DBCP in samples of surface water collected in California, Arizona, Texas, South Carolina, and Alabama in 1979. Two positive samples collected from municipal water supplies in California showed DBCP concentrations of 0.09 µg/L and 0.1 µg/L. The number of surface water samples tested was not reported.

To assemble a database which would reflect the status of Great Lakes drinking water quality, the Canadian Public Health Association gathered data from October 1984 through August 1985 (Canadian Public Health Association, 1986, as cited in USEPA, 1989b). The data collected covered the period from the mid 1970s to early 1985. The study was funded by the Health Protection Branch of Health and Welfare Canada and the Ontario Ministry of the Environment. A research team, appointed by the Association, reviewed data on the quality of water at 31 representative Canadian and United States communities and 24 offshore sites to evaluate the human health implications.

For each of the 31 communities, data consisted of: 1) background information on the community; 2) treatment plant schematics and associated treatment process information; and 3) water quality data. Water sample types included raw water (treatment plant intake), distribution water (treated water), and tap water. Water quality data collected included general parameters (e.g., alkalinity, turbidity), microbiological and radiological parameters, inorganic parameters, and organic parameters (including volatiles, base/neutrals, pesticides and PCBs, and phenols and acids). For each parameter, the water type, time period, concentration (mean and range), number of samples, and detection limit were recorded.

For most of the volatile organics, including DBCP, the available data indicated that these contaminants did not occur at significant levels in the raw, treated, or tap water. Most of the values found were "not detected" or near the detection limit (Canadian Public Health Association, 1986, as cited in USEPA, 1989b).

3.5.6 Conclusion

DBCP is a pesticide that was used and produced extensively in the United States from 1955 to 1977, when its use was restricted to pineapples in Hawaii. All uses were subsequently canceled in 1985. Until its restriction and cancellation, DBCP was extensively used as a soil fumigant and nematocide on over 40 different crops in the United States. There are no recent statistics available regarding use or production of DBCP, and any production is probably minimal. Industrial releases of DBCP were reported to TRI in 1991 and 1992 from two States. DBCP was not an analyte for any of the ambient occurrence studies. The Stage 2 analysis, based on the 16-State cross-section, estimated that approximately 1.41% of combined ground water and surface water systems serving 2.60% of the population exceeded the MCL of 0.0002 mg/L. Based on this estimate, a national estimate of 920 PWSs, serving approximately 5,531,800 people, are estimated to have levels greater than the MCL.

The 16-State cross-section was designed to be nationally representative based upon VOC, SOC, and IOC pollution potentials as suggested by considerations of manufacturing, agriculture, and geographic diversity factors. Nationally, TRI releases have been reported for DBCP from 2 States, not including any of the cross-section States. The use of DBCP has been canceled nationwide, and any production of DBCP is projected to be very minimal. The cross-section should adequately represent the occurrence of DBCP on a national scale based upon the use, production, and release patterns of the 16-State cross-section in relation to the patterns observed for all 50 States.

3.5.7 References

Agency for Toxic Substances and Disease Registry (ATSDR). 1992. *Toxicological Profile for 1,2-Dibromo-3-chloropropane.* U.S. Department of Health and Human Services, Public Health Service. 152 pp. + Appendices. Available on the Internet at http://www.atsdr.cdc.gov/toxprofiles/tp36.pdf

Albrecht, W.N. 1987. Occupational exposure to 1,3-dichloropropene (Telone II@) in Hawaiian pineapple culture. *Archives of Environmental Health*. v. 42, pp. 286-291.

Anonymous. 1988. DBCP. *Reviews of Environmental Contamination and Toxicology.* v. 104, pp. 73-91.

Canadian Public Health Association. 1986. *Comprehensive Survey of the Status of Great Lakes Drinking Water.* Prepared in cooperation with Health and Welfare Canada and the Ministry of the Environment. Ottawa, Canada: Canadian Public Health Association. August, 1986.

Carey, A.E., and F.W. Kutz. 1983. *Trends in Ambient Concentrations of Agrochemicals in Humans and the Environment of the United States.* Presented at the International Conference on Environmental Hazards of Agrochemicals in Developing Countries, Alexandria, Egypt, November 8-12, 1983.

Carter, G.E., and M.B. Riley. 1981. *Pestic. Monit. J.* v. 15, pp. 139-142.

Cohen, S.Z. 1981. *Summary Report – DBCP in Groundwater in the Southeast.* Washington, DC: Hazard Evaluation Division, U.S. Environmental Protection Agency.

Cohen, S.Z., S.M. Creeger, R.F. Carsel, and C.G. Enfield. 1984. Potential for Pesticide Contamination in Groundwater Resulting from Agricultural Uses. In: *Treatment and Disposal of Pesticide Wastes.* R.F. Kruger and J.W. Seiber (eds.). Washington, DC: American Chemical Society. ACS Symposium Series No. 259: pp. 247-325.

Hawley, G.G. 1981. *The Condensed Chemical Dictionary.* 10th ed. New York, NY: Van Nostrand Reinhold Co., p. 325.

Holden, P.W. 1986. *Pesticides and Groundwater Quality. Issues and Problems in Four States.* Prepared for the Board of Agriculture, National Research Council. Washington, DC: National Academy Press.

International Agency for Research on Cancer (IARC). 1979. *Monograph on the evaluation of the carcinogenic risk of chemicals to humans.* Vol. 20: Some halogenated hydrocarbons. Lyon, France: World Health Organization, pp. l-40, 83-96.

Mink, J.F. 1981. *DBCP and EDB in soil and water at Kuhia, Oahu, Hawaii.* Prepared for Del Monte Corp., Honolulu, Hawaii.

National Toxicology Program (NTP). 1985. *Fourth Annual Report on Carcinogens.* National Toxicology Program, pp. 179-182.

Nelson, S., M. Iskander, M. Volz, S. Khalifa, and R. Haberman. 1981. *Sci. Total. Environ.* v. 21, pp. 35-40.

OPD. 1989. *OPD Chemical Buyers Directory*. 76th ed. New York, NY: Schnell Publishing Co. Inc., pp. 235, 696.

Peoples, S.A., K.T. Maddy, W. Cusick, T. Jackson, C. Cooper, and A.S. Frederickson. 1980. *Bull. Environ. Contam. Toxicol.* v. 24, pp. 611-618.

Pinto, E. 1980. *Report of Groundwater Contamination Study in Wicomico, Maryland.* Wicomico County Health Department, State of Maryland (plus 1981-1982 addenda).

Sax, N.I., and R.J. Lewis. 1987. *Hawley's Condensed Chemical Dictionary*. 10th Ed. New York, NY: Van Nostrand Reinhold Co., p. 367.

USEPA. 1977. U.S. Environmental Protection Agency: Southern Agricultural Insecticides, Inc., *et al.* Suspension order. *Federal Register* 42, pp. 57543-57548.

USEPA. 1979. U.S. Environmental Protection Agency: Dibromochloropropane (DBCP); Suspension order and notice of intent to cancel. *Federal Register* 44, pp. 65135-65176.

USEPA. 1984. Proposal for comment on intent to cancel use of dibromochloropropane in Hawaii. *Federal Register* 46, p. 19594.

USEPA. 1985a. U.S. Environmental Protection Agency: Dibromochloropropane; Intent to cancel registrations of pesticide products containing dibromochloropropane (DBCP). *Federal Register* 50, pp. 1122-1123.

USEPA. 1985b. U.S. Environmental Protection Agency: Dibromochloropropane; Denial of use of existing stocks. *Federal Register* 50, p. 46512.

USEPA. 1989a. Computer printout (CIS): 1977 Non-confidential production data from TSCA inventory. Washington, DC: Office of Pesticides and Toxic Substances, CID, USEPA.

USEPA. 1989b. *Draft Final Report on the Occurrence and Human Exposure to Pesticides in Drinking Water, Food, and Air in the United States of America*. Office of Drinking Water, USEPA. September, 1989.

USEPA. 2000. *TRI Explorer: Trends*. Available on the Internet at: http://www.epa.gov/triexplorer/trends.htm, last updated May 5, 2000.

USEPA. 2002. *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT*. EPA Report/815-D-02-005, Office of Water, 55 pp.

Verschueren, K., ed. 1983. *Handbook of Environmental Data on Organic Chemicals.* New York, NY: Van Nostrand Reinhold Co., pp. 464-465.

3.6 Diquat

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Tables and Figures

3.6.1 Introduction, Use and Production

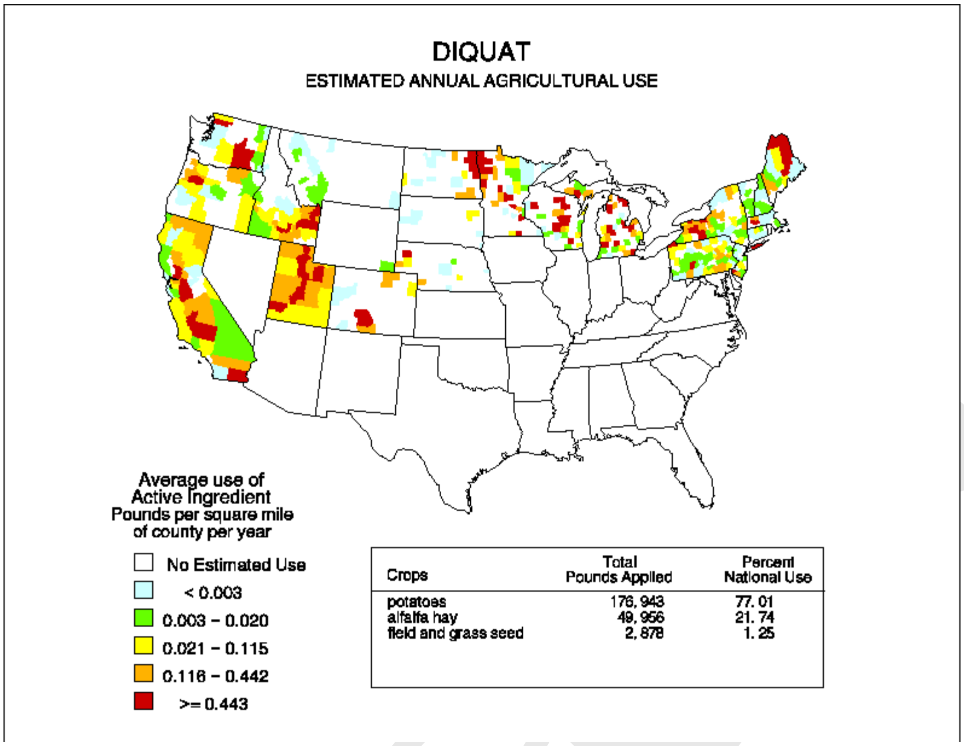
Diquat [6,7-dihydrodipyrido (1,2-a:2',1'-c) pyrazinediium dibromide] is an organic solid of colorless or yellow crystals. It is a quick-acting contact herbicide, causing injury only to the parts of the plant to which it is applied. It is nonselective, meaning that it does not spare ‘nontarget’ plants from its herbicidal effects. Diquat is referred to as a desiccant because it causes a leaf or an entire plant to dry out quickly. It is not residual, so it does not leave any trace of herbicide on or in plants, soil, or water (EXTOXNET, 2001). Diquat is persistent, but essentially immobile, in the environment, indicating that it will most likely be associated with the soil and sediment rather than water (USEPA, 2001b). A trade name for diquat is Reglone.

Diquat is widely used as a herbicide, algicide, and plant growth regulator (EXTOXNET, 2001). Usage in 1980 was estimated to be 200,000 pounds of active ingredient, and 1982 data indicates that diquat was not produced domestically, but imports were nearly 835,000 pounds. Diquat has been in use since the 1950s to control both crop and aquatic weeds. It is used on potatoes; as an aid in harvesting cotton, rapeseed and other oil seed crops; to wilt and dry out silage, standing hay, etc. for storage; a plant growth regulator and sugar cane-flowering suppressant (USEPA, 2001a).

As a herbicide/algicide, diquat is used to control broadleaf and grassy weeds in non-crop (including residential) and aquatic areas. As a desiccant/defoliant, it is used in seed crops and potatoes. Its largest use is as a desiccant on potato crops (USEPA, 1995).

Figure 3.6-1 shows the United States Geological Survey (USGS, 1998a) derived geographic distribution of estimated average annual diquat use in the United States for 1992. A breakdown of use by crop is also included. The USGS (1998a) estimates approximately 230,000 pounds of diquat active ingredient were used in 1992. The two largest concentrations of diquat use are seen in the West and the Northeast. Given the amount of white space on the map, the possibility also exists that some States did not fully report their diquat usage. While non-agricultural uses are not reflected here, and any sharp spatial differences in use within a county are not well represented (USGS, 1998b), existing data suggest that non-agricultural use of diquat is minimal to non-existent (USEPA, 1995). A comparison of this use map with the map of the 16 cross-section States (Figure 1.3-1) shows that States across the range of high of low diquat use are well represented in the cross-section.

Figure 3.6-1: Estimated Annual Agricultural Use for Diquat (1992)



Crops	Total Pounds Applied	Percent National Use
potatoes	176,943	77.01
alfalfa hay	49,956	21.74
field and grass seed	2,878	1.25

Source: USGS 1998a

3.6.2 Environmental Release

Diquat is released directly to the environment in its use as a herbicide, algicide, and plant growth regulator and potentially during its manufacture, handling, and storage. EPA estimated that 200,000 pounds of diquat active ingredient were used in the United States in 1980 (USEPA, 2001a). Diquat is not listed as a Toxics Release Inventory (TRI) contaminant, so no TRI release records are maintained. Therefore, the use of diquat (described in the previous section) may provide the primary indication of where releases are most likely. The areas of highest diquat use are in various potato growing regions of the U.S., including Idaho and other Western States, as well as Maine and other locations in the Northeast. In the Midwest it is most likely used on alfalfa hay crops. These and other use areas are illustrated in Figure 3.6-1.

3.6.3 Ambient Occurrence

To understand the presence of a chemical in the environment, an examination of ambient occurrence is useful. In a drinking water context, ambient water is untreated source water residing in surface waters and aquifers. There are few available data on the occurrence of diquat in ambient waters of the United States. The most comprehensive and nationally consistent data describing ambient water quality in the United States are being produced through the United States Geological Survey's (USGS) National Water Quality Assessment (NAWQA) program. However, national NAWQA data are currently unavailable for diquat.

A summary document entitled “Occurrence and Exposure Assessment of Diquat in Public Drinking Water Supplies” (Wade Miler, 1989), was previously prepared for past USEPA assessments of diquat. However, no national or regional studies were included on the occurrence of diquat in water other than drinking water from ground water or surface water sources.

3.6.4 Drinking Water Occurrence Based on the 16-State Cross-Section

The analysis of diquat occurrence presented in the following section is based on State compliance monitoring data from the 16 cross-section States. The 16-State cross-section is the largest and most comprehensive compliance monitoring data set compiled by EPA to date. These data were evaluated relative to several concentration thresholds of interest: 0.02 mg/L; 0.004 mg/L; and 0.002 mg/L.

All sixteen cross-section State data sets, with the exception of New Jersey and Texas, contained occurrence data for diquat. These data represent more than 36,000 analytical results from approximately 9,000 PWSs during the period from 1984 to 1998 (with most analytical results from 1992 to 1997). The number of sample results and PWSs vary by State, although the State data sets have been reviewed and checked to ensure adequacy of coverage and completeness. The overall modal detection limit for diquat in the 16 cross-section States is equal to 0.0004 mg/L. (For details regarding the 16-State cross-section, please refer to Section 1.3.5 of this report.)

3.6.4.1 Stage 1 Analysis Occurrence Findings

Table 3.6-1 illustrates the low occurrence of diquat in drinking water for the public water systems in the 16-State cross-section relative to three thresholds: 0.02 mg/L (the current MCL), 0.004 mg/L (the modal MRL), and 0.002 mg/L. A total of 2 (approximately 0.0218% of) ground water and surface water PWSs had analytical results exceeding the MCL; 0.0655% of systems (6 systems) had results exceeding 0.004 mg/L; and 0.153% of systems (14 systems) had results exceeding 0.002 mg/L.

Approximately 0.0120% of ground water systems (1 system) had any analytical results greater than the MCL. About 0.0600% of ground water systems (5 systems) had results above 0.004 mg/L. The percentage of ground water systems with at least one result greater than 0.002 mg/L was equal to 0.120% (10 systems).

Only 1 (0.122% of) surface water systems had results greater than the MCL. Also, approximately 1 (0.122% of) surface water systems had at least one analytical result greater than 0.004 mg/L. Four (0.487% of) surface water systems had results exceeding 0.002 mg/L.

Table 3.6-1: Stage 1 Diquat Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Ground Water	0.02	0.0120%	1
	0.004	0.0600%	5
	0.002	0.120%	10

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Surface Water	0.02	0.122%	1
	0.004	0.122%	1
	0.002	0.487%	4
Combined Ground & Surface Water	0.02	0.0218%	2
	0.004	0.0655%	6
	0.002	0.153%	14

Reviewing diquat occurrence in the 16 cross-section States by PWS population served (Table 3.6-2) shows that approximately 0.208% of the population (about 153,400 people) was served by PWSs with at least one analytical result of diquat greater than the MCL (0.02 mg/L). Approximately 171,300 (0.233% of) people were served by systems with an exceedance of 0.004 mg/L. Over 337,000 (0.458% of) people were served by systems with at least one analytical result greater than 0.002 mg/L.

The percentage of population served by ground water systems with analytical results greater than the MCL was equal to 0.441% (approximately 142,000 people). When evaluated relative to 0.004 mg/L and 0.002 mg/L, the percent of population exposed was equal to 0.497% (almost 160,000 people) and 0.664% (almost 214,000 people), respectively.

The percentage of population served by surface water systems with exceedances of 0.02 mg/L and 0.004 mg/L was equal to 0.0275% (11,400 people). When evaluated relative to 0.002 mg/L, the percent of population exposed was equal to 0.298% (over 123,000 people).

Table 3.6-2: Stage 1 Diquat Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Ground Water	0.02	0.441%	142,000
	0.004	0.497%	159,900
	0.002	0.664%	213,817
Surface Water	0.02	0.0275%	11,400
	0.004	0.0275%	11,400
	0.002	0.298%	123,300

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Combined Ground & Surface Water	0.02	0.208%	153,400
	0.004	0.233%	171,300
	0.002	0.458%	337,100

3.6.4.2 Stage 2 Analysis Occurrence Findings

The Stage 2 occurrence findings, based on the cross-section data, are presented in Tables 3.6-3 and 3.6-4. The statistically generated best estimate values, as well as the ranges around the best estimate value, are presented. (For a review of the Stage 2 analytical approach, please refer to Section 1.4 of this report. For complete details regarding the Stage 2 analyses, please refer to *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations* (USEPA, 2002)).

No ground water or surface water PWSs had an estimated mean concentration of diquat exceeding 0.02 mg/L. The percentage of ground and surface water systems with estimated mean concentration greater that 0.004 mg/L and 0.002 mg/L is equal to 0.00096% (less than 1 system) and 0.0202% (2 systems), respectively. Only 1 (0.00101% of) ground water PWS in the 16 States was estimated to have a mean concentration greater than 0.004 mg/L and 2 (0.0204%) are estimated to have a mean concentration greater than 0.002 mg/L. The percentage of surface water systems with estimated mean concentration values greater than 0.004 mg/L was equal to 0.000487% (less than 1 system in the 16 States). Only 1 (0.0173% of) surface water system in the 16 States had an estimated mean concentration value of diquat greater than 0.002 mg/L.

Table 3.6-3: Stage 2 Estimated Diquat Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.02	0.000%	0.000% - 0.000%	0	0 - 0
	0.004	0.00101%	0.000% - 0.0120%	1	0 - 1
	0.002	0.0204%	0.000% - 0.0600%	2	0 - 5
Surface Water	0.02	0.000%	0.000% - 0.000%	0	0 - 0
	0.004	0.000487%	0.000% - 0.000%	0	0 - 0
	0.002	0.0173%	0.000% - 0.122%	1	0 - 1

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Combined Ground & Surface Water	0.02	0.000%	0.000% - 0.000%	0	0 - 0
	0.004	0.000961%	0.000% - 0.0109%	1	0 - 1
	0.002	0.0202%	0.000% - 0.0546%	2	0 - 5

Reviewing diquat occurrence by PWS population served (Table 3.6-4) shows that approximately 0.000470% of population served by all PWSs (an estimate of approximately 300 people in the 16 States) were potentially exposed to diquat levels above 0.004 mg/L. When evaluated relative to a threshold of 0.002 mg/L, the percent of population exposed was equal to 0.0218% (approximately 16,300 people). The percent of population exposed was equal to 0% for all system types when evaluated relative to the MCL (0.02 mg/L).

The percentage of population served by ground water systems in the 16 States with estimated mean concentration values greater than 0.004 mg/L was equal to 0.00101% (an estimate of approximately 300 people) and the percentage served by surface water systems in the 16 States was equal to 0.0000503%. Approximately 14,600 (0.0453% of) people in the 16 cross-section States were served by ground water systems with estimated mean concentration values greater than 0.002 mg/L. The number of people in the 16 cross-section States served by surface water systems with estimated mean concentration values greater than 0.002 mg/L was equal to about 1,500 (0.00356% of) people.

Table 3.6-4: Stage 2 Estimated Diquat Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.020	0.000%	0.000% - 0.000%	0	0 - 0
	0.004	0.00101%	0.000% - 0.00621%	300	0 - 2,000
	0.002	0.0453%	0.000% - 0.404%	14,600	0 - 130,000
Surface Water	0.020	0.000%	0.000% - 0.000%	0	0 - 0
	0.004	0.0000503%	0.000% - 0.000%	0	0 - 0
	0.002	0.00356%	0.000% - 0.0275%	1,500	0 - 11,400
Combined Ground & Surface Water	0.020	0.000%	0.000% - 0.000%	0	0 - 0
	0.004	0.000470%	0.000% - 0.00295%	300	0 - 2,200
	0.002	0.0218%	0.000% - 0.177%	16,300	0 - 130,000

3.6.4.3 Estimated National Occurrence

Based on the Stage 2 estimated percent of systems (and population served by systems) exceeding each threshold, no systems had estimated mean concentration values of diquat greater than the MCL (0.02 mg/L). An estimated 1 system serving approximately 1,000 people had a mean concentration value of diquat greater that 0.004 mg/L. About 13 systems serving about 46,500 people nationally were estimated to have mean diquat concentrations greater than 0.002 mg/L. (See Section 1.4 for a description of how Stage 2 16-State estimates are extrapolated to national values.)

For ground water systems, approximately 1 PWSs serving about 900 people nationally had mean concentrations greater than 0.004 mg/L. An estimated 12 systems serving about 38,800 people nationally had estimated mean concentration values that exceeded 0.002 mg/L.

Only 1 surface water system serving less than 100 people nationally was estimated to have mean concentrations of diquat above 0.004 mg/L. Approximately 1 surface water systems serving 4,500 people had estimated mean concentrations greater than 0.002 mg/L.

Table 3.6-5: Estimated National Diquat Occurrence - Systems and Population Served

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.02	0	0 - 0	0	0 - 0
	0.004	1	0 - 7	900	0 - 5,300
	0.002	12	0 - 36	38,800	0 - 346,000
Surface Water	0.02	0	0 - 0	0	0 - 0
	0.004	1	0 - 0	< 100	0 - 0
	0.002	1	0 - 7	4,500	0 - 35,100
Combined Ground & Surface Water	0.02	0	0 - 0	0	0 - 0
	0.004	1	0 - 7	1,000	0 - 6,300
	0.002	13	0 - 35	46,500	0 - 376,200

3.6.5 Additional Drinking Water Occurrence Data

A summary document entitled “Occurrence and Exposure Assessment of Diquat in Public Drinking Water Supplies” (Wade Miler, 1989), was previously prepared for past USEPA assessments of diquat. However, no national or regional studies were included on the occurrence of diquat in drinking water from ground water or surface water sources.

3.6.6 Conclusion

Diquat is widely used in agriculture and in non-agricultural applications as a herbicide, algicide, and plant growth regulator. In 1982, imports of diquat active ingredient were 835,000 pounds. Information from USGS indicates that use of diquat is most widespread in Western States and the Northeast, with some scattered use in the Midwest. Diquat is not a TRI chemical, so there is no information available on the environmental release of diquat. There are also no ambient data available. The Stage 2 analysis, based on the 16-State cross-section, estimated that zero percent of combined ground water and surface water systems serving zero percent of the population exceeded the MCL of 0.02 mg/L. Based on this estimate, zero PWSs nationally are estimated to have levels greater than the MCL.

The 16-State cross-section was designed to be nationally representative based upon VOC, SOC, and IOC pollution potentials as suggested by considerations of manufacturing, agriculture, and geographic diversity factors. Nationally, according to information from USGS, approximately 25 States consumed diquat for agricultural uses, including 8 of the 16 cross-section States. As there is no TRI or other data, agricultural use seems to be the only basis for comparison between the 16 States and the nation. The cross-section should adequately represent the occurrence of diquat on a national scale based upon the use, production, and release patterns of the 16-State cross-section in relation to the patterns observed for all 50 States.

3.6.7 References

EXTOXNET. 2001. *Pesticide Information Profile: Diquat Bromide*. Ithaca, N Y: Extension Toxicology Network, Pesticide Management Education Program. Available on the Internet at http://pmep.cce.cornell.edu/profiles/extoxnet/dienochlor-glyphosate/diquat-ext.html, last updated March 1, 2001.

USEPA. 1995. *R.E.D. Facts: Diquat Bromide*. EPA Report 738-F-95-015. Washington, DC: Office of Prevention, Pesticides, and Toxic Substances, USEPA. 10 pp. Available on the Internet at: http://www.epa.gov/oppsrrd1/REDs/factsheets/0288fact.pdf

USEPA. 2001a. *Consumer Factsheet on Diquat.* Office of Ground Water and Drinking Water, USEPA. Available on the Internet at: http://www.epa.gov/OGWDW/dwh/c-SOC/diquat.html, last updated April 12, 2001.

USEPA. 2001b. Memorandum: *Tier I Drinking Water and Aquatic Ecological Exposure Assessments for Diquat Dibromide.* From: James Breithaupt, Environmental Risk Branch II/EFED. Washington, D.C., October 2001.

USEPA. 2002. *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT*. EPA Report/815-D-02-005, Office of Water, 55 pp.

USGS. 1998a. *Annual Use Maps*. Available on the Internet at: http://water.wr.usgs.gov/pnsp/use92/, last updated March 20, 1998.

USGS. 1998b. *Sources & Limitations of Data Used to Produce Maps of Annual Pesticide Use*. Available on the Internet at: http://water.wr.usgs.gov/pnsp/use92/mapex.html, last updated March 20, 1998.

Wade Miller Associates, Inc. 1989. *Occurrence and Exposure Assessment of Diquat in Public Drinking Water Supplies - DRAFT*. Draft report submitted to EPA for review April 24, 1989.

3.7 Glyphosate

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Tables and Figures

3.7.1 Introduction, Use and Production

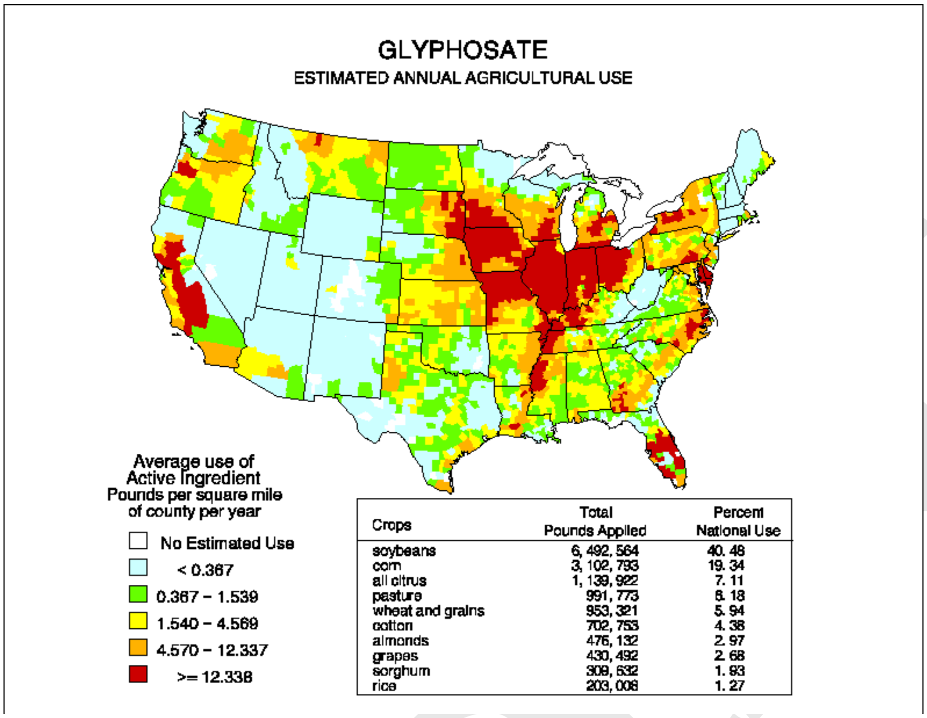
Glyphosate [N-(phosphonomethyl) glycine] is an organic solid of odorless white crystals that is usually formulated as an isopropylamine salt. While it can be described as an organophosphorus compound, glyphosate is not an organophosphate ester but a phosphanoglycine, and it does not inhibit cholinesterase activity (EXTOXNET, 2001). Some trade names for glyphosate include Roundup, Sting, Rodeo, Tumbleweed, Sonic, Glycel, and Rondo (USEPA, 2001).

Glyphosate is a non-selective herbicide used on many food and non-food crops as well as non-crop areas where total vegetation control is desired, such as roadsides (USEPA, 1993). It is useful on essentially all annual and perennial plants, including grasses, sedges, broad-leaved weeds and woody plants (EXTOXNET, 2001). When applied at lower rates, glyphosate serves as a plant growth regulator. The most common uses include control of broadleaf weeks and grasses in: hay and pasture, soybeans, field corn, ornamentals, lawns, turf, forest plantings, greenhouses, and rights-of-way (USEPA, 2001).

Although production data seems to be unavailable, glyphosate is one of the most commonly used pesticides in the U.S. by volume. In 1990 usage was estimated at 11.6 million pounds, and it ranked eleventh in volume among conventional pesticides in 1990 and 1991 (USEPA, 2001). Use from 1989 to 1991 ranged between 11.4 and 18.7 million pounds of glyphosate per year for anywhere from 13 to 20 million acres (USEPA, 1993). Hay/pasture (20%), soybeans (20%), field corn (9%), and other agricultural areas (20%) comprise 71% of the total acreage treated with glyphosate. Non-agricultural areas (33%), soybeans (15%), hay/pasture (11%), and corn (8%) comprise 67% of the total pounds of ai applied (USEPA, 1993).

Figure 3.7-1 shows the USGS (1998) derived geographic distribution of estimated average annual glyphosate use in the United States for 1992. The United States Geological Survey (USGS, 1998) estimates approximately 16 million pounds of glyphosate active ingredient were used in 1992. These estimates were derived using State-level data sets on pesticide use rates available from National Center for Food and Agricultural Policy (NCFAP) combined with county-level data on harvested crop acreage from the Census of Agriculture (Thelin and Gianessi, 2000). A breakdown of use by crop is also included. Soybeans account for the majority of usage (about 6.5 million pounds glyphosate), while intermediate use can be found on several other crops as well (e.g., corn, all citrus, cotton, almonds, grapes). Glyphosate use appears to be geographically distributed across the U.S. The largest concentrations of glyphosate use are seen in the soybean production region of the Midwest and the citrus growing areas in California and Florida. A comparison of this use map with the map of the 16 cross-section States (Figure 1.3-1) shows that States across the range of high of low glyphosate use are well represented in the cross-section.

Figure 3.7-1: Estimated Annual Agricultural Use for Glyphosate (1992)



Crops	Total Pounds Applied	Percent National Use
soybeans	6, 492, 564	40. 48
corn	3, 102, 793	19. 34
all citrus	1, 139, 922	7. 11
pasture	991, 773	6. 18
wheat and grains	953, 321	5. 94
cotton	702, 753	4. 38
almonds	476, 132	2. 97
grapes	430, 492	2. 68
sorghum	309, 632	1. 93
rice	203, 008	1. 27

Source: USGS 1998

3.7.2 Environmental Release

Glyphosate is released directly to the environment when used as a herbicide and potentially during its manufacture, handling and storage. Unfortunately, glyphosate is not listed as a Toxics Release Inventory (TRI) contaminant, so no TRI release records are maintained. The use of glyphosate (described in the previous section) may provide the primary indication of where releases are most likely. The areas of highest glyphosate use are in the soybean and corn production regions of the Midwest and Mid-Atlantic, and on the citrus production areas in the Pacific Northwest, California, and Florida. Many of the highest use States are contained in the 16-State cross-section (i.e., California, Florida, Illinois, Indiana, Kentucky, Michigan, Oregon, and South Dakota).

3.7.3 Ambient Occurrence

To understand the presence of a chemical in the environment, an examination of ambient occurrence is often useful. In a drinking water context, ambient water is untreated source water residing in surface waters and aquifers. There are few available data on the occurrence of glyphosate in ambient waters of the United States. The most comprehensive and nationally consistent data describing ambient water quality in the United States are being produced through the United States Geological Survey's (USGS) National Water Quality Assessment (NAWQA) program. However, national NAWQA data are currently unavailable for glyphosate.

Additional studies of ambient data are also unavailable. A summary document entitled ""Occurrence and Exposure Assessment of Glyphosate in Public Drinking Water Supplies" (Wade Miler, 1989), was previously prepared for past USEPA assessments of glyphosate. However, no national or regional studies were included on the occurrence of glyphosate in water other than drinking water from ground water or surface water sources.

3.7.4 Drinking Water Occurrence Based on the 16-State Cross-Section

The analysis of glyphosate occurrence presented in the following section is based on State compliance monitoring data from the 16 cross-section States. The 16-State cross-section is the largest and most comprehensive compliance monitoring data set compiled by EPA to date. These data were evaluated relative to several concentration thresholds of interest: 0.7 mg/L; 0.06 mg/L; and 0.006 mg/L.

Thirteen of the sixteen cross-section State data sets contained occurrence data for glyphosate. (There were no glyphosate data from Nebraska, New Jersey or Texas.) These data represent more than 33,000 analytical results from approximately 7,800 PWSs during the period from 1984 to 1998 (with most analytical results from 1992 to 1997). The number of sample results and PWSs vary by State, although the State data sets have been reviewed and checked to ensure adequacy of coverage and completeness. The overall modal detection limit for glyphosate in the 16 cross-section States is equal to 0.006 mg/L. (For details regarding the 16-State cross-section, please refer to Section 1.3.5 of this report.)

3.7.4.1 Stage 1 Analysis Occurrence Findings

Table 3.7-1 illustrates the very low occurrence of glyphosate in drinking water for the public water systems in the 16-State cross-section. No ground water or surface water PWSs in the 16 States had any analytical results exceeding 0.7 mg/L or 0.06 mg/L. Only 0.0763% of total ground and surface water systems (6 systems) had analytical results greater than 0.006 mg/L. Five (approximately 0.0707% of) ground water systems had analytical results greater than 0.006 mg/L. The percentage of surface water systems with at least one analytical result greater than 0.006 mg/L was equal to 0.126% (1 system).

Table 3.7-1: Stage 1 Glyphosate Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Ground Water	0.7	0.000%	0
	0.06	0.000%	0
	0.006	0.0707%	5
Surface Water	0.7	0.000%	0
	0.06	0.000%	0
	0.006	0.126%	1
Combined Ground & Surface Water	0.7	0.000%	0
	0.06	0.000%	0
	0.006	0.0763%	6

Table 3.7-2 illustrates glyphosate occurrence in the 16 cross-section States based on the PWS population served. Approximately 0.0270% of the 16-State population was served by PWSs with analytical detections of glyphosate greater than 0.006 mg/L (about 19,000 people). The percentage of population served by ground water systems with at least one analytical result greater than 0.006 mg/L was equal to 0.0347% (almost 11,000 people). A total of 8,300 (0.0210% of) people served by surface water systems were exposed to glyphosate levels greater than 0.006 mg/L. When evaluated relative to 0.7 mg/L and 0.06 mg/L, the percent of population exposed was equal to 0% for all system types.

Table 3.7-2: Stage 1 Glyphosate Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Ground Water	0.7	0.000%	0
	0.06	0.000%	0
	0.006	0.0347%	10,700
Surface Water	0.7	0.000%	0
	0.06	0.000%	0
	0.006	0.0210%	8,300
Combined Ground & Surface Water	0.7	0.000%	0
	0.06	0.000%	0
	0.006	0.0270%	19,000

3.7.4.2 Stage 2 Analysis Occurrence Findings

The Stage 2 occurrence findings, based on the cross-section data, are presented in Tables 3.7-3 and 3.7-4. The statistically generated best estimate values, as well as the ranges around the best estimate value, are presented. (For a review of the Stage 2 analytical approach, please refer to Section 1.4 of this report. For complete details regarding the Stage 2 analyses, please refer to *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations* (USEPA, 2002)).

No ground water or surface water PWSs in the 16 cross-section States had an estimated mean concentration of glyphosate exceeding 0.7 mg/L or 0.06 mg/L. Approximately 0.0000736% of ground and surface water PWSs (less than 1 system in the 16-State cross-section) was estimated to have a mean concentration greater than 0.006 mg/L. The percentage of ground water PWSs with estimated mean concentrations greater than 0.006 mg/L was equal to approximately 0.0000849%. No surface water PWSs had estimated mean concentration exceeding any of the three specified concentration thresholds.

Table 3.7-3: Stage 2 Estimated Glyphosate Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.7	0.000%	0.000% - 0.000%	0	0 - 0
	0.06	0.000%	0.000% - 0.000%	0	0 - 0
	0.006	0.0000849%	0.000% - 0.000%	0	0 - 0
Surface Water	0.7	0.000%	0.000% - 0.000%	0	0 - 0
	0.06	0.000%	0.000% - 0.000%	0	0 - 0
	0.006	0.000%	0.000% - 0.000%	0	0 - 0
Combined Ground & Surface Water	0.7	0.000%	0.000% - 0.000%	0	0 - 0
	0.06	0.000%	0.000% - 0.000%	0	0 - 0
	0.006	0.0000763%	0.000% - 0.000%	0	0 - 0

Approximately 0.0000138% of population served by all PWSs in the 16 States was potentially exposed to glyphosate levels above 0.006 mg/L. The percentage of population served by ground water systems relative to 0.006 mg/L was equal to 0.0000313%. (No surface water systems exceeded any of the specified health thresholds.) When evaluated relative to a threshold of 0.7 mg/L and 0.06 mg/L, the percent of population exposed was equal to 0% for all system types.

Table 3.7-4: Stage 2 Estimated Glyphosate Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.7	0.000%	0.000% - 0.000%	0	0 - 0
	0.06	0.000%	0.000% - 0.000%	0	0 - 0
	0.006	0.0000313%	0.000% - 0.000%	0	0 - 0
Surface Water	0.7	0.000%	0.000% - 0.000%	0	0 - 0
	0.06	0.000%	0.000% - 0.000%	0	0 - 0
	0.006	0.000%	0.000% - 0.000%	0	0 - 0

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Combined Ground & Surface Water	0.7	0.000%	0.000% - 0.000%	0	0 - 0
	0.06	0.000%	0.000% - 0.000%	0	0 - 0
	0.006	0.0000138%	0.000% - 0.000%	0	0 - 0

3.7.4.3 Estimated National Occurrence

As illustrated in Table 3.7-5, the Stage 2 analysis estimates no PWSs nationally (therefore, no population served) were estimated to have a mean concentration value of glyphosate greater than 0.7 mg/L, 0.06 mg/L, or 0.006 mg/L. (See Section 1.4 for a description of how Stage 2 16-State estimates are extrapolated to national values.)

Table 3.7-5: Estimated National Glyphosate Occurrence - Systems and Population Served

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.7	0	0 - 0	0	0 - 0
	0.06	0	0 - 0	0	0 - 0
	0.006	0	0 - 0	0	0 - 0
Surface Water	0.7	0	0 - 0	0	0 - 0
	0.06	0	0 - 0	0	0 - 0
	0.006	0	0 - 0	0	0 - 0
Combined Ground & Surface Water	0.7	0	0 - 0	0	0 - 0
	0.06	0	0 - 0	0	0 - 0
	0.006	0	0 - 0	0	0 - 0

3.7.5 Additional Drinking Water Occurrence Data

Additional studies of ambient data are also unavailable. A summary document entitled “Occurrence and Exposure Assessment of Glyphosate in Public Drinking Water Supplies” (Wade Miler, 1989), was previously prepared for past USEPA assessments of glyphosate. However, no national or regional studies were included on the occurrence of glyphosate in drinking water from ground water or surface water sources.

3.7.6 Conclusion

Glyphosate is a non-selective herbicide used on many food and non-food crops as well as non-crop areas such as roadsides. It is useful on essentially all annual and perennial plants, including grasses, sedges, broad-leaved weeds and woody plants. Recent statistics regarding use of glyphosate indicate production and use are steady, with glyphosate use concentrated in the Midwest, California, and Florida. Glyphosate is not a TRI chemical, so there is no information available on the environmental release of glyphosate. There are also no ambient data available. The Stage 2 analysis, based on the 16-State cross-section, estimated that zero percent of combined ground water and surface water systems serving zero percent of the population exceeded the MCL of 0.7 mg/L. Based on this estimate, zero PWSs nationally are estimated to have levels greater than the MCL.

The 16-State cross-section was designed to be nationally representative based upon VOC, SOC, and IOC pollution potentials as suggested by considerations of manufacturing, agriculture, and geographic diversity factors. Nationally, according to information from USGS, all 50 States used glyphosate for agricultural purposes. The areas of most use are the Midwest, Florida, and California, represented by eight cross-section States. As there is no TRI or other data, agricultural use seems to be the only basis for comparison between the 16 States and the nation. The cross-section should adequately represent the occurrence of glyphosate on a national scale based upon the use, production, and release patterns of the 16-State cross-section in relation to the patterns observed for all 50 States.

3.7.7 References

EXTOXNET. 2001. *Pesticide Information Profile: Glyphosate*. Ithaca, NY: Extension Toxicology Network, Pesticide Management Education Program. Available on the Internet at http://pmep.cce.cornell.edu/profiles/extoxnet/dienochlor-glyphosate/glyphosate-ext.html, accessed July 18, 2001.

Thelin, G.P., and L.P. Gianessi. 2000. *Method for Estimating Pesticide Use for County Areas of the Conterminous United States.* U.S. Geological Survey Open-File Report 00-250. 62 pp. Available on the Internet at: http://water.wr.usgs.gov/pnsp/rep/ofr00250/ofr00250.pdf

USEPA. 1993. *Reregistration Eligibility Decision (RED): Glyphosate*. EPA Report 738-R-93-014. Washington, DC: Office of Prevention, Pesticides, and Toxic Substances, USEPA. 74 pp. + Appendices. Available on the Internet at: http://www.epa.gov/oppsrrd1/REDs/old_reds/glyphosate.pdf

USEPA. 2001. *National Primary Drinking Water Regulations - Consumer Factsheet on: Glyphosate.* Office of Ground Water and Drinking Water, USEPA. Available on the Internet at http://www.epa.gov/safewater/dwh/c-SOC/glyphosa.html, last updated April 12, 2001.

USEPA. 2002. *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT*. EPA Report/815-D-02-005, Office of Water, 55 pp.

USGS. 1998. *Annual Use Maps*. Available on the Internet at: http://water.wr.usgs.gov/pnsp/use92/, last updated March 20, 1998.

Wade Miller Associates, Inc. 1989. *Occurrence and Exposure Assessment of Glyphosate in Public Drinking Water Supplies - DRAFT*. Draft report submitted to EPA for review April 12, 1989.

3.8 Heptachlor & Heptachlor Epoxide

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Tables and Figures

3.8.1 Introduction, Use and Production

Heptachlor is a synthetic chemical that does not occur naturally. It is both a breakdown product and a component of the pesticide chlordane. Pure heptachlor is a white powder that smells like camphor (mothballs). Technical-grade heptachlor is a tan powder and has a lower level of purity than pure heptachlor. Technical-grade heptachlor was the form of heptachlor used most often as a pesticide. Heptachlor does not burn easily, does not explode, nor does it dissolve easily in water (ATSDR, 1993).

Heptachlor epoxide is a biodegradation product of heptachlor. It is not manufactured and was not used as an insecticide like heptachlor. Heptachlor epoxide is made by bacteria in the environment. Like pure heptachlor, heptachlor epoxide is a white powder that does not explode easily. Heptachlor epoxide is frequently detected in areas of heptachlor use and is more likely to be found in the environment than heptachlor. Animals and people also make heptachlor epoxide when heptachlor enters their bodies. About 20% of heptachlor is changed within hours to heptachlor epoxide in the environment and in the body (ATSDR, 1993).

Heptachlor is a chlorinated hydrocarbon insecticide, presently used in the United States only to control fire ants, in buried, pad-mounted electric power transformers, and in underground cable television and telephone cable boxes. The end use product, a granular formulation packaged in small plastic bags, is applied by pouring the contents of the plastic bag directly into a metal or concrete enclosure, which is rarely opened again (USEPA, 1992).

Heptachlor is a persistent dermal insecticide with some fumigant action. It is nonphytotoxic at insecticidal concentrations (Worthing and Walker, 1987, as cited in ATSDR, 1993). Heptachlor is present as an impurity in chlordane; typically, hepatchlor constitutes 10 percent of technical grade chlordane (USEPA, 1980, as cited in USEPA, 1989). Because chlordane is applied by subsurface ground injection, the potential for water contamination in some areas may be high (USEPA, 1989). Heptachlor was used extensively from 1953 to 1974 as a soil and seed treatment to protect corn, small grains, and sorghum from pests. It was used to control ants, cutworms, maggots, termites, thrips, weevils, and wireworms in both cultivated and uncultivated soils. Heptachlor was also used nonagriculturally during this time period to control termites and household insects (USEPA, 1986; Worthington and Walker, 1987, as cited in ATSDR, 1993).

Heptachlor is converted to heptachlor epoxide, and other degradation products, in the environment. Heptachlor epoxide degrades more slowly and, as a result, is more persistent than heptachlor. Heptachlor epoxide has been found in food crops grown in soils treated with heptachlor many years before (ATSDR, 1993).

In 1974, the EPA Administrator issued a notice of intent to suspend the registrations of certain pesticide products containing heptachlor for subsurface control of termites and dipping of roots and tops of nonfood plants (USEPA, 1983, as cited in USEPA, 1989). EPA proposed cancellation of nearly all registered uses of heptachlor because of its potential cancer risk and its persistence and bioaccumulation throughout the food chain. On March 6, 1978, EPA issued a final cancellation order putting into effect the terms of settlement for the cancellation proceedings (USEPA, 1983, as cited in USEPA, 1989). Under this cancellation order, an agreement was outlined to phase out the nontermiticide uses of heptachlor over a 5-year period. All uses permitted during the phase-out period were restricted to treatment by certified applicators or professional commercial seed treatment companies. The few uses that were not canceled in 1974, treatment of field corn, seed (for corn, wheat, oats, barley, rye, and sorghum), citrus, pineapple, and narcissus bulbs, were phased out gradually over a 5-year period ending on July 1, 1983 (USEPA, 1986, as cited in ATSDR, 1993). Certain uses of heptachlor were specifically exempted from EPA's suspension and cancellation actions because they were believed to result in insignificant exposure and, consequently, insignificant risk. Registrations were retained for subsurface termite control, fire ant control in buried cable closures, and dipping of roots or tops of nonfood plants (a use subsequently canceled voluntarily by the registrant, Velsicol Chemical Corporation) (USEPA, 1986, as cited in ATSDR, 1993).

Approximately 30 percent (or 550,000 pounds) of the heptachlor used in 1971 was applied to commercial and residential structures for protection against termites and to nurseries, lawns, and gardens. By 1974, domestic use of heptachlor for termite control had increased to 1.4 million pounds (USEPA, 1976, as cited in USEPA, 1989).

In the early 1980s, heptachlor was used to control subterranean termites. Nearly 10 million pounds of chlordane was applied in the United States in 1980; approximately 1 million pounds of heptachlor would have been present as an impurity in chlordane in that year. EPA (USEPA, 1983, as cited in USEPA, 1989) reported that the largest quantity of chlordane was initially distributed to EPA Region IV, which includes Alabama, Georgia, Florida, Mississippi, North Carolina, South Carolina, Tennessee, and Kentucky.

In 1983, between 1 and 2 million pounds of heptachlor was used in the United States for termite control (USEPA, 1983, as cited in USEPA, 1989). Between 0.75 and 1 million pounds of heptachlor were used in 1986 (Kuch, 1986, as cited in USEPA, 1989). Heptachlor has limited use as a single active ingredient and usually is applied in combination with chlordane (USEPA, 1983, as cited in USEPA, 1989). A second approved use of heptachlor is to control fire ants in sugarcane and pineapple fields in Hawaii.

In 1988, EPA prohibited the sale, distribution, and shipment of existing stocks of all canceled chlordane and heptachlor products. Subsequently, virtually all uses of heptachlor products were voluntarily canceled by the registrant, Velsicol Chemical Corporation (USEPA, 1990, as cited in ATSDR, 1993). The only commercial use of heptachlor products still permitted is fire ant control in power transformers. Use of existing stocks of heptachlor-containing termicide products in the possession of homeowners is also permitted (USEPA, 1990, as cited in ATSDR, 1993).

3.8.2 Environmental Release

Heptachlor is listed as a Toxics Release Inventory (TRI) chemical. Table 3.8-1 illustrates the environmental releases for heptachlor from 1988 to 1996. (Heptachlor data are only available for these years.) Air emissions constitute most of the on-site releases, with a general trend to decrease over the years. Air emissions decreased drastically after 1988, which was the year EPA prohibited the sale, distribution, and shipment of existing stocks of all canceled heptachlor products. The decrease in air emissions are solely responsible for decreases in heptachlor total on- and off-site releases in recent years. Minimal surface water discharges were reported. No underground injection, releases to land (such as spills or leaks within the boundaries of the reporting facility), or off-site releases (including metals or metal compounds transferred off-site) were reported for heptachlor. These TRI data for heptachlor were reported from 5 States (Georgia, Illinois, Tennessee, Florida, and Mississippi), although no more than 2 States reported releases in a given year. Only Tennessee reported releases after 1992 (USEPA, 2000). Of the five States, Illinois and Florida are included in the 16-State cross-section (used for analyses of heptachlor occurrence in drinking water; see Section 3.8.4). (For a map of the 16-State cross-section, see Figure 1.3-1.)

Table 3.8-1: Environmental Releases (in pounds) for Heptachlor in the United States, 1988-1996

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1996	198	5	--	--	--	203
1995	203	6	--	--	--	209
1994	830	3	--	--	--	833
1993	31	2	--	--	--	33
1992	710	1	--	--	--	711
1991	5	0	--	--	--	5
1990	3,797	1	--	--	--	3,798
1989	3,411	2	--	--	--	3,413
1988	54,295	2	--	--	--	54,297

Source: USEPA, 2000

3.8.3 Ambient Occurrence

To understand the presence of a chemical in the environment, an examination of ambient occurrence is useful. In a drinking water context, ambient water is untreated source water residing in surface waters and aquifers. There are few available data on the occurrence of heptachlor in ambient waters of the United States. The most comprehensive and nationally consistent data describing ambient water quality in the United States are being produced through the United States Geological Survey's (USGS) National Water Quality Assessment (NAWQA) program. However, national NAWQA data are currently unavailable for heptachlor.

3.8.3.1 Additional Ambient Occurrence Data

Additional studies of ambient data are summarized below. A summary document entitled "Occurrence and Human Exposure to Pesticides in Drinking Water, Food and Air in the United States of America" (USEPA, 1989), was previously prepared for past USEPA assessments of various pesticides. Three national studies are summarized for the occurrence of heptachlor and heptachlor epoxide in surface waters. Eight regional studies addressed levels of heptachlor and heptachlor epoxide in water other than drinking water. Two of the regional studies addressed levels of heptachlor and heptachlor epoxide in ground water, and six studies provided data on levels of heptachlor and heptachlor epoxide in surface water. The following information is taken directly from "Occurrence and Human Exposure to Pesticides in Drinking Water, Food and Air in the United States of America" (USEPA, 1989).

3.8.3.1.1 Ground Water Sources

Ground water wells in 25 California counties were analyzed as part of the California State Board's Toxics Special Project during 1984 (Cohen and Bowes, 1984, as cited in USEPA, 1989). Heptachlor was found in three samples with a maximum concentration of 0.3 µg/L. The other positive values, total number of samples, and detection limit were not reported.

Tucker and Burke (1978, as cited in USEPA, 1989) presented data on levels of heptachlor and heptachlor epoxide in samples of water collected from 163 wells, including private and public drinking water supplies, industrial sites, and wells in the vicinity of landfills in nine New Jersey counties. The analysis showed that samples of water from three supply wells contained heptachlor and samples from seven wells contained heptachlor epoxide in excess of the minimum reportable concentration of 0.01 µg/L. The maximum values for heptachlor and heptachlor epoxide were 1.0 and 0.6 µg/L, respectively. The maximum concentration for heptachlor epoxide occurred in a public drinking water supply well.

3.8.3.1.2 Surface Water Sources

National studies of surface water analyses for heptachlor and heptachlor epoxide were conducted by USEPA (1976, as cited in USEPA, 1989) and Breidenbach et al. (1967, as cited in USEPA, 1989). The overall mean as reported for both pesticides was 0.0063 µg/L. The minimum values determined for each were 0.001 µg/L and the maximum values were 0.035 µg/L and 0.02 µg/L for heptachlor and heptachlor epoxide, respectively. The number of positive values, total number of samples, and detection limit were not reported.

The National Pesticide Monitoring Network examined rivers nationwide from 1975 to 1980 (Gilliom et al., 1985, as cited in USEPA, 1989). Heptachlor epoxide was reported as being detected in 9 out of 2,946 samples analyzed from 177 locations (detection limit = 0.01 µg/L). The mean and range of values were not reported.

Heptachlor and heptachlor epoxide were analyzed in rivers and streams in upstate New York (Estabrooks, no date, as cited in USEPA, 1989) from 1982 to 1983. No samples for either pesticide were found to be positive, out of 252 samples analyzed. The detection limit was 10.0 µg/L.

Barks (1978, as cited in USEPA, 1989) presented the results of a USGS water quality study conducted from April 1973 to July 1974 in the Ozark National Scenic Riverways, Missouri. During the study, 20 surface water samples were collected from 3 sites on the Current River and 1 site on Jacks Fork and analyzed for pesticide content. The analysis of unfiltered samples found no heptachlor or heptachlor epoxide in excess of the detection limit (the detection limit was not reported).

Englande et al. (1978, as cited in USEPA, 1989) presented the results of extensive chemical analysis of six Advanced Wastewater Treatment (AWT) plant effluents. Four plants were located in California, and one each in the District of Columbia and Texas. None of the 63 AWT effluent samples contained concentrations of heptachlor in excess of the detection limit (the detection limit was not reported).

Truhlar and Reed (1976, as cited in USEPA, 1989) reported on water samples collected from four streams in Pennsylvania and analyzed for chlorinated hydrocarbon pesticides during the period from April 1970 to February 1971. The streams drained four different types of land use areas. Concentrations of heptachlor and heptachlor epoxide were not detected in any of the 25 stream samples.

Schacht (1974, as cited in USEPA, 1989) presented the results of a study to determine the levels of pesticides in the surface water of Lake Michigan and its tributaries. During the period 1970 to 1972, a total of 45 water samples was collected. Concentrations of heptachlor epoxide ranging from "non-detected" to 0.017 µg/L were found in the samples. The detection limit for heptachlor epoxide was reported as less than 0.0002 µg/L

Dappen (1974, as cited in USEPA, 1989) reported the results of a study to determine the pesticide content of urban storm runoff in Nebraska. Runoff samples were collected at three stations in a Nebraska city during and after storms. A total of 80 samples was collected at the first station during 16 different storms. Concentrations of heptachlor and heptachlor epoxide in samples from the first station ranged from 0 to 0.059 µg/L and 0 to 0.2 µg/L, respectively. At the second sampling station, 55 samples were collected during 9 different storms. Concentrations of heptachlor and heptachlor epoxide in samples from the second station ranged from 0 to 0.176 µg/L and 0 to 0.194 µg/L respectively. A total of 14 samples was collected at the third station during 3 storms. Concentrations of heptachlor in samples from the third station ranged from 0 to 0.055 µg/L. No heptachlor epoxide was detected. No detection limits were reported for the study.

3.8.4 Drinking Water Occurrence Based on the 16-State Cross-Section

The analysis of heptachlor and heptachlor epoxide occurrence presented in the following section is based on State compliance monitoring data from the 16 cross-section States. The 16-State cross-section is the largest and most comprehensive compliance monitoring data set compiled by EPA to date. These data were evaluated relative to several concentration thresholds of interest. Heptachlor was reviewed relative to 0.0004 mg/L; 0.0001 mg/L; and 0.00004 mg/L. Heptachlor epoxide was reviewed relative to 0.0002 mg/L; 0.0001; and 0.00002 mg/L.

All sixteen cross-section State data sets, with the exception of New Jersey, contained occurrence data for heptachlor and heptachlor epoxide. Heptachlor and heptachlor epoxide data each represent more than 57,000 analytical results from approximately 14,000 PWSs during the period from 1984 to 1998 (with most analytical results from 1992 to 1997). The number of sample results and PWSs vary by State, although the State data sets have been reviewed and checked to ensure adequacy of coverage and completeness. The overall modal detection limits for heptachlor and heptachlor epoxide in the 16 cross-section States are equal to 0.00004 mg/L and 0.00002 mg/L, respectively. (For details regarding the 16-State cross-section, please refer to Section 1.3.5 of this report.)

3.8.4.1 Stage 1 Analysis Occurrence Findings

Table 3.8-2 illustrates the low occurrence of heptachlor in drinking water for the public water systems in the 16-State cross-section relative to three thresholds: 0.0004 mg/L (the current MCL), 0.0001 mg/L, and 0.00004 mg/L (the modal MRL). Only 1 ground water PWS (approximately 0.00702% of PWSs in the 16 States) had analytical results exceeding the MCL; 0.0562% of systems (8 systems) had results exceeding 0.0001 mg/L; and 0.0702% of systems (10 systems) had results exceeding 0.00004 mg/L.

Approximately 0.00779% of ground water systems (1 system) had any analytical results greater than the MCL. About 0.0545% of ground water systems (7 systems) had results above 0.0001 mg/L. The percentage of ground water systems with at least one result greater than 0.00004 mg/L was equal to 0.0624% (8 systems).

No surface water systems had results greater than the MCL. Only 1 (0.0709% of) surface water systems had at least one analytical result greater than 0.0001 mg/L. Two (0.142% of) surface water systems had results exceeding 0.00004 mg/L.

Table 3.8-2: Stage 1 Heptachlor Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Ground Water	0.0004	0.00779%	1
	0.0001	0.0545%	7

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
	0.00004	0.0624%	8
Surface Water	0.0004	0.000%	0
	0.0001	0.0709%	1
	0.00004	0.142%	2
Combined Ground & Surface Water	0.0004	0.00702%	1
	0.0001	0.0562%	8
	0.00004	0.0702%	10

Reviewing heptachlor occurrence in the 16 cross-section States by PWS population served (Table 3.8-3) shows that approximately 0.000398% of the population (about 400 people) was served by PWSs with at least one analytical result of heptachlor greater than the MCL (0.0004 mg/L). Approximately 160,400 (0.166% of) people were served by systems with an exceedance of 0.0001 mg/L. Over 170,000 (0.176% of) people were served by systems with at least one analytical result greater than 0.00004 mg/L.

The percentage of population served by ground water systems with analytical results greater than the MCL was equal to 0.000945% (approximately 400 people). When evaluated relative to 0.0001 mg/L and 0.00004 mg/L, the percent of population exposed was equal to 0.247% (over 100,000 people) and 0.252% (almost 103,000 people), respectively.

The percent of population served by surface water systems exposed to heptachlor at levels greater than 0.0004 mg/L was equal to 0%. The percentage of population served by surface water systems with exceedances of 0.0001 mg/L and 0.00004 mg/L was equal to 0.107% (60,000 people), and 0.121% (67,800 people), respectively.

Table 3.8-3: Stage 1 Heptachlor Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Ground Water	0.0004	0.000945%	400
	0.0001	0.247%	100,400
	0.00004	0.252%	102,600
Surface Water	0.0004	0.000%	0
	0.0001	0.107%	60,000
	0.00004	0.121%	67,800

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Combined Ground & Surface Water	0.0004	0.000398%	400
	0.0001	0.166%	160,400
	0.00004	0.176%	170,400

Table 3.8-4 illustrates the low occurrence of heptachlor epoxide in drinking water for the public water systems in the 16-State cross-section relative to three thresholds: 0.0002 mg/L (the current MCL), 0.0001 mg/L, and 0.00002 mg/L (the modal MRL). Four (approximately 0.0283% of) ground and surface water PWS had analytical results exceeding 0.0002 mg/L and 0.0001 mg/L. About 0.0566% of systems (8 systems) had results exceeding 0.00002 mg/L.

Approximately 0.0314% of ground water systems (4 systems) had any analytical results greater than 0.0002 mg/L and 0.0001 mg/L. The percentage of ground water systems with at least one result greater than 0.00002 mg/L was equal to 0.0550% (7 systems).

No surface water systems had results greater than 0.0002 mg/L and 0.0001 mg/L. Only 1 (0.0712% of) surface water systems had at least one analytical result greater than 0.00002 mg/L.

Table 3.8-4: Stage 1 Heptachlor Epoxide Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Ground Water	0.0002	0.0314%	4
	0.0001	0.0314%	4
	0.00002	0.0550%	7
Surface Water	0.0002	0.000%	0
	0.0001	0.000%	0
	0.00002	0.0712%	1
Combined Ground & Surface Water	0.0002	0.0283%	4
	0.0001	0.0283%	4
	0.00002	0.0566%	8

Reviewing heptachlor epoxide occurrence in the 16 cross-section States by PWS population served (Table 3.8-5) shows that approximately 0.0291% of the population (about 28,000 people) was served by PWSs with at least one analytical result of heptachlor epoxide greater than the MCL (0.0002 mg/L), and 0.0001 mg/L. Approximately 91,600 (0.0952% of) people were served by systems with at least one analytical result greater than 0.00002 mg/L.

The percentage of population served by ground water systems with analytical results greater than 0.0002 mg/L or 0.0001 mg/L was equal to 0.0695% (approximately 28,000 people). When evaluated relative to 0.00002 mg/L, the percent of population exposed was equal to 0.153% (almost 62,000 people).

The percent of population served by surface water systems exposed to heptachlor epoxide at levels greater than 0.0002 mg/L and 0.0001 mg/L was equal to 0%. The percentage of population served by surface water systems with exceedances of 0.00002 mg/L was equal to 0.0537% (30,000 people).

Table 3.8-5: Stage 1 Heptachlor Epoxide Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Ground Water	0.0002	0.0695%	28,000
	0.0001	0.0695%	28,000
	0.00002	0.153%	61,600
Surface Water	0.0002	0.000%	0
	0.0001	0.000%	0
	0.00002	0.0537%	30,000
Combined Ground & Surface Water	0.0002	0.0291%	28,000
	0.0001	0.0291%	28,000
	0.00002	0.0952%	91,600

3.8.4.2 Stage 2 Analysis Occurrence Findings

The Stage 2 occurrence findings for heptachlor, based on the cross-section data, are presented in Tables 3.8-6 and 3.8-7. The statistically generated best estimate values, as well as the ranges around the best estimate value, are presented. (For a review of the Stage 2 analytical approach, please refer to Section 1.4 of this report. For complete details regarding the Stage 2 analyses, please refer to *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations* (USEPA, 2002)).

No ground water or surface water PWSs had an estimated mean concentration of heptachlor exceeding 0.0004 mg/L. Approximately 0.0000140% of PWSs (less than 1 system in the 16-State cross-section) were estimated to have a mean concentration greater than 0.0001 mg/L. Only 1 (0.00119% of) system had estimated mean concentration values of heptachlor greater than 0.00004 mg/L.

The percentage of ground water systems with estimated mean concentration values of heptachlor greater than 0.0001 mg/L was equal to 0.0000156% (less than 1 system in the 16 States). Approximately 0.00131% of ground water PWSs (about 1 system in the 16 States) had estimated mean concentration values greater than 0.00004 mg/L. The percentage of surface water PWSs with estimated mean concentration exceeding 0.00004 mg/L was equal to 0.000142% (less than 1 system).

Table 3.8-6: Stage 2 Estimated Heptachlor Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	**Range**	**Best Estimate**	**Range**
Ground Water	0.0004	0.000%	0.000% - 0.000%	0	0 - 0
	0.0001	0.0000156%	0.000% - 0.000%	0	0 - 0
	0.00004	0.00131%	0.000% - 0.00779%	1	0 - 1
Surface Water	0.0004	0.000%	0.000% - 0.000%	0	0 - 0
	0.0001	0.000%	0.000% - 0.000%	0	0 - 0
	0.00004	0.000142%	0.000% - 0.000%	0	0 - 0
Combined Ground & Surface Water	0.0004	0.000%	0.000% - 0.000%	0	0 - 0
	0.0001	0.0000140%	0.000% - 0.000%	0	0 - 0
	0.00004	0.00119%	0.000% - 0.00702%	1	0 - 1

Reviewing heptachlor occurrence by PWS population served (Table 3.8-7) shows that approximately 0.000000242% of population served by all PWSs in the 16 States were potentially exposed to heptachlor levels above 0.0001 mg/L. Approximately 0.000350% of the population served by PWSs in the 16 States (about 300 people) was exposed to heptachlor at levels above 0.00004 mg/L. When evaluated relative to a threshold of 0.0004 mg/L, the percent of population exposed was equal to 0%.

The percentage of population served by ground water systems relative to 0.0001 mg/L was equal to 0.000000576%. Approximately 0.000784% of the population was served by ground water systems (about 300 people) with estimated mean concentration values of heptachlor greater than 0.00004 mg/L. The percentage of population served by surface water systems with estimated mean concentration values greater than 0.00004 mg/L was equal to 0.0000341%.

Table 3.8-7: Stage 2 Estimated Heptachlor Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	**Range**	**Best Estimate**	**Range**
Ground Water	0.0004	0.000%	0.000% - 0.000%	0	0 - 0
	0.0001	0.000000576%	0.000% - 0.000%	0	0 - 0
	0.00004	0.000784%	0.000% - 0.0113%	300	0 - 4,600

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Surface Water	0.0004	0.000%	0.000% - 0.000%	0	0 - 0
	0.0001	0.000%	0.000% - 0.000%	0	0 - 0
	0.00004	0.0000341%	0.000% - 0.000%	0	0 - 0
Combined Ground & Surface Water	0.0004	0.000%	0.000% - 0.000%	0	0 - 0
	0.0001	0.000000242%	0.000% - 0.000%	0	0 - 0
	0.00004	0.000350%	0.000% - 0.00476%	300	0 - 4,600

The Stage 2 occurrence findings for heptachlor epoxide, based on the cross-section data, are presented in Tables 3.8-8 and 3.8-9. No ground water or surface water PWSs had an estimated mean concentration of heptachlor epoxide exceeding 0.0002 mg/L or 0.0001 mg/L. Approximately 0.00528% of PWSs (about 1 system in the 16-State cross-section) were estimated to have a mean concentration greater than 0.00002 mg/L.

The percentage of ground water systems with estimated mean concentration values of heptachlor epoxide greater than 0.00002 mg/L was equal to 0.00583% (approximately 1 system in the 16 States). Approximately 0.000285% of surface water PWSs (about 1 system in the 16 States) had estimated mean concentration values greater than 0.00002 mg/L.

Table 3.8-8: Stage 2 Estimated Heptachlor Epoxide Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.0002	0.000%	0.000% - 0.000%	0	0 - 0
	0.0001	0.000%	0.000% - 0.000%	0	0 - 0
	0.00002	0.00583%	0.000% - 0.0236%	1	0 - 3
Surface Water	0.0002	0.000%	0.000% - 0.000%	0	0 - 0
	0.0001	0.000%	0.000% - 0.000%	0	0 - 0
	0.00002	0.000285%	0.000% - 0.000%	1	0 - 0
Combined Ground & Surface Water	0.0002	0.000%	0.000% - 0.000%	0	0 - 0
	0.0001	0.000%	0.000% - 0.000%	0	0 - 0
	0.00002	0.00528%	0.000% - 0.0212%	1	0 - 3

Table 3.8-9 illustrates heptachlor epoxide occurrence by PWS population served in the 16-State cross-section. When evaluated relative to a threshold of 0.0002 mg/L and 0.0001 mg/L, the percent of population exposed to heptachlor epoxide was equal to 0%. Approximately 0.00489% of the population served by PWSs in the 16 States (about 4,700 people) was exposed to heptachlor epoxide at levels above 0.00002 mg/L.

The percentage of population served by ground water systems relative to 0.00002 mg/L was equal to 0.0114% (approximately 4,600 people). The percentage of population served by surface water systems with estimated mean concentration values of heptachlor epoxide greater than 0.00002 mg/L was equal to 0.000215% (about 100 people).

Table 3.8-9: Stage 2 Estimated Heptachlor Epoxide Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.0002	0.000%	0.000% - 0.000%	0	0 - 0
	0.0001	0.000%	0.000% - 0.000%	0	0 - 0
	0.00002	0.0114%	0.000% - 0.0570%	4,600	0 - 23,000
Surface Water	0.0002	0.000%	0.000% - 0.000%	0	0 - 0
	0.0001	0.000%	0.000% - 0.000%	0	0 - 0
	0.00002	0.000215%	0.000% - 0.000%	100	0 - 0
Combined Ground & Surface Water	0.0002	0.000%	0.000% - 0.000%	0	0 - 0
	0.0001	0.000%	0.000% - 0.000%	0	0 - 0
	0.00002	0.00489%	0.000% - 0.0239%	4,700	0 - 23,000

3.8.4.3 Estimated National Occurrence

Based on the Stage 2 estimated percent of systems (and population served by systems) exceeding each threshold, zero systems nationally had estimated mean concentration values of heptachlor greater than the MCL (0.0004 mg/L) and 0.0001 mg/L. An estimated 1 ground water system serving approximately 700 people was exposed to heptachlor concentrations greater than 0.00004 mg/L. (See Section 1.4 for a description of how Stage 2 16-State estimates are extrapolated to national values.)

Table 3.8-10: Estimated National Heptachlor Occurrence - Systems and Population Served

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.0004	0	0 - 0	0	0 - 0
	0.0001	0	0 - 0	0	0 - 0
	0.00004	1	0 - 5	700	0 - 9,700
Surface Water	0.0004	0	0 - 0	0	0 - 0
	0.0001	0	0 - 0	0	0 - 0
	0.00004	0	0 - 0	0	0 - 0
Combined Ground & Surface Water	0.0004	0	0 - 0	0	0 - 0
	0.0001	0	0 - 0	0	0 - 0
	0.00004	1	0 - 5	700	0 - 10,100

The Stage 2 analysis estimated zero systems nationally with mean concentration values of heptachlor epoxide greater than 0.0002 mg/L and 0.0001 mg/L. An estimated 3 ground water systems serving approximately 9,800 people were exposed to heptachlor epoxide concentrations greater than 0.00002 mg/L. Approximately 1 surface water system serving 300 people nationally had estimated mean concentration values of heptachlor epoxide greater than 0.00002 mg/L.

Table 3.8-11: Estimated National Heptachlor Epoxide Occurrence - Systems and Population Served

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.0002	0	0 - 0	0	0 - 0
	0.0001	0	0 - 0	0	0 - 0
	0.00002	3	0 - 14	9,800	0 - 48,800
Surface Water	0.0002	0	0 - 0	0	0 - 0
	0.0001	0	0 - 0	0	0 - 0
	0.00002	1	0 - 0	300	0 - 0
Combined Ground & Surface Water	0.0002	0	0 - 0	0	0 - 0
	0.0001	0	0 - 0	0	0 - 0
	0.00002	3	0 - 14	10,400	0 - 50,800

3.8.5 Additional Drinking Water Occurrence Data

Several additional data sources regarding the occurrence of heptachlor and heptachlor epoxide in drinking water are also reviewed. Previously compiled occurrence heptachlor and heptachlor epoxide information, from an OGWDW summary document entitled “Occurrence and Human Exposure to Pesticides in Drinking Water, Food and Air in the United States of America” (USEPA, 1989), is presented in following section. This variety of studies and information are presented regarding levels of heptachlor and heptachlor epoxide in drinking water, with the scope of the reviewed studies ranging from national to regional. Note that none of the studies presented in the following section provide the quantitative analytical results or comprehensive coverage that would enable direct comparison to the occurrence findings estimated with the cross-section occurrence data presented in Section 3.8.4. These additional studies, however, do enable a broader assessment of the Stage 2 occurrence estimates presented for this Six-Year Review. All the following information in Section 3.8.5 is taken directly from “Occurrence and Human Exposure to Pesticides in Drinking Water, Food and Air in the United States of America” (USEPA, 1989).

3.8.5.1 Ground Water Sources

Twelve towns in Connecticut were sampled during 1984 to 1985 for heptachlor and heptachlor epoxide by the Connecticut Agricultural Experiment Station, New Haven, Connecticut (Waggoner, 1985, as cited in USEPA, 1989). These towns, combined, serve a population of over 570,000 people. Drinking water wells were sampled at 42 locations, and no samples were positive for either heptachlor or heptachlor epoxide (detection limits were 0.2 µg/L and 0.47 µg/L, respectively).

Shallow drinking water wells in 10 counties in northwest Mississippi were analyzed from 1983 to 1984 during a Mississippi State University study on pesticide hazard assessment (MSU, 1984, as cited in USEPA, 1989). No positive samples were found for either heptachlor or heptachlor epoxide out of 143 samples analyzed (detection limit = 0.001 µg/L).

Similarly, no positive results were obtained from 67 samples analyzed in Long Island, New York, for either heptachlor or heptachlor epoxide. These results were from a 1984 study reported by the Suffolk County Department of Health Services (Holden, 1986, as cited in USEPA, 1989). No detection limit(s) was reported.

Drinking water supplies of the Floridian aquifer were analyzed at 96 locations in 1984 by the Florida Department of Environmental Regulation and the U.S. Geological Survey (Holden, 1986, as cited in USEPA, 1989). These supplies serve a combined population of over 3 million people. Less than 8 percent of the samples were positive for any of the pesticides sampled for, including heptachlor and heptachlor epoxide. No other information was reported.

Irwin and Healy (1978, as cited in USEPA, 1989) summarized data collected in 1976 during a water quality reconnaissance of public water supplies in Florida. None of the 100 water supplies sampled using the five aquifers in Florida contained heptachlor and heptachlor epoxide in excess of the detection limits. The detection limits were not reported.

Drinking water wells were sampled in Idaho for heptachlor epoxide by the Idaho Department of Health and Welfare (1984, as cited in USEPA, 1989). One sample, out of 107, was positive, with a concentration of 0.015 µg/L (no detection limit was reported).

Sandhu et al. (1978, as cited in USEPA, 1989) summarized the results from a study conducted in two rural counties in South Carolina. Water supplies sampled were outside incorporated municipalities. Samples were taken randomly from wells where there was no pretreatment prior to use. It was not noted whether these supplies were public or private. Also, data were collected on drinking water from different land use areas in each county (i.e., agricultural, forest, and residential). The number of samples taken and the number of positive samples were not reported: however, the percent of samples exceeding the detection limit of 0.01 µg/L was reported by the county.

Results indicated that 62.5 percent of the samples taken in Chesterfield County had detectable levels of heptachlor, and 42 percent had detectable levels of heptachlor epoxide. The sample means were 0.015 and 0.008 µg/L for heptachlor and heptachlor epoxide, respectively. In Hampton County, 45.5 percent of the samples contained heptachlor and 64 percent of the samples contained heptachlor epoxide in excess of the detection limit. The sample means for the Hampton County samples were 0.009 and 0.018 µg/L for heptachlor and heptachlor epoxide, respectively. (These percentages included samples taken from forest land use areas.) Concentrations of heptachlor in drinking water samples from agricultural areas in Chesterfield and Hampton counties ranged from not detected to 0.16 µg/L with a mean of <0.01 µg/L (not detected). For heptachlor epoxide, concentrations ranged from not detected to 0.09 µg/L with a mean of <0.01 µg/L (not detected). In residential areas in both counties, concentrations of heptachlor and heptachlor epoxide in drinking water samples ranged from not detected to 0.045 µg/L and not detected to 0.01 µg/L respectively. Sample means were <0.01 µg/L (not detected) in all cases.

Tucker and Burke (1978, as cited in USEPA, 1989) reported that heptachlor epoxide was detected at a level of 0.6 µg/L in water from a public drinking water supply well in Camden County, New Jersey.

3.8.5.2 Surface Water Sources

Irwin and Healy (1978, as cited in USEPA, 1989) reported that none of 16 surface water supplies sampled in Florida contained heptachlor or heptachlor epoxide in excess of the detection limits. The detection limits were not reported.

To assemble a database which would reflect the status of Great Lakes drinking water quality, the Canadian Public Health Association gathered data from October 1984 through August 1985 (Canadian Public Health Association, 1986, as cited in USEPA, 1989). The data collected covered the period from the mid 1970s to early 1985. The study was funded by the Health Protection Branch of Health and Welfare Canada, and the Ontario Ministry of the Environment. A research team, appointed by the Association, reviewed data on the quality of water at 31 representative Canadian and United States communities and 24 offshore sites to evaluate the human health implications.

For each of the 31 communities, data consisted of: 1) background information on the community; 2) treatment plant schematics and associated treatment process information; and 3) water quality data. Water sample types included raw water (treatment plant intake), distribution water (treated water), and tap water. Water quality data collected included general parameters (e.g., alkalinity, turbidity), microbiological and radiological parameters, inorganic parameters, and organic parameters (including volatiles, base/neutrals, pesticides and PCBs, and phenols and acids). For each parameter, the water type, time period, concentration (mean and range), number of samples, and detection limit were recorded.

For most of the synthetic organics, including heptachlor and heptachlor epoxide, the available data indicated that there were very low levels of these contaminants in the raw, treated, or tap water. Most of the values found were “not detected” or near the detection limit (Canadian Public Health Association, 1986, as cited in USEPA, 1989).

3.8.5.3 Unspecified Sources

Pellizzari et al. (1979, as cited in USEPA, 1989) presented monitoring data on halogenated hydrocarbons in drinking water from the northern New Jersey area and the Buffalo/Niagara, New York area. The limits of detection ranged from 0.005 to 0.025 µg/L for both studies. Of 22 drinking water samples taken from the northern New Jersey area, two samples (9%) contained heptachlor at levels of 0.007 and 0.02 µg/L, and none contained heptachlor epoxide. None of the 16 drinking water samples from the Buffalo/Niagara area were found to contain heptachlor or heptachlor epoxide in excess of the detection limits.

In a report on source identification of pollutants entering a sewage treatment plant, Levins et al. (1979, as cited in USEPA, 1989) sampled two drinking water sources in a drainage basin in Georgia. Although detection limits were not reported, heptachlor and heptachlor epoxide were not detected in either of the drinking water samples.

3.8.6 Conclusion

Heptachlor is synthetically produced and exists at low levels in soil, water, air, and food. It was used as an insecticide until 1988. Recent statistics regarding environmental release of heptachlor indicate use has rapidly declined since the late 1980s, when it was banned for sale, distribution, and shipment. Reported industrial releases of heptachlor have been reported to TRI since 1988 in 5 States, with most releases coming from Tennessee. Heptachlor ambient occurrence was not analyzed in any available studies. Because heptachlor epoxide is a biodegradation product of heptachlor, it is frequently detected in areas of heptachlor use and is more likely to be found in the environment than heptachlor. However, little production and use information is available on heptachlor epoxide.

The Stage 2 analysis of heptachlor, based on the 16-State cross-section, estimated that approximately zero percent of combined ground water and surface water systems serving zero percent of the population exceeded the MCL of 0.0004 mg/L. Based on this estimate, zero PWSs nationally are estimated to have heptachlor levels greater than the MCL. The Stage 2 analysis of heptachlor epoxide, based on the 16-State cross-section, estimated that approximately zero percent of combined ground water and surface water systems serving zero percent of the population exceeded the MCL of 0.0002 mg/L. Based on this estimate, zero PWSs nationally are estimated to have heptachlor epoxide levels greater than the MCL.

The 16-State cross-section was designed to be nationally representative based upon VOC, SOc, and IOC pollution potentials as suggested by considerations of manufacturing, agriculture, and geographic diversity factors. Nationally, TRI releases have been reported for heptachlor from 5 States, including 2 of 16 cross-section States. Heptachlor use has been severely restricted, and its production has been banned nationwide. The cross-section should adequately represent the occurrence of heptachlor and heptachlor epoxide on a national scale based upon the use, production, and release patterns of the 16-State cross-section in relation to the patterns observed for all 50 States.

3.8.7 References

Agency for Toxic Substances and Disease Registry (ATSDR). 1993. *Toxicological Profile for Heptachlor and Heptachlor Epoxide*. U.S. Department of Health and Human Services, Public Health Service. 131 pp. + Appendices. Available on the Internet at: http://www.atsdr.cdc.gov/toxprofiles/tp12.pdf

Barks, J.H. 1978. *Water Quality in the Ozark National Scenic Riverways, Missouri.* Washington, DC: U.S. Geological Survey, U.S. Department of Interior. U.S. Geological Survey Water-Supply Paper 2048.

Breidenbach, A.W., *et al.* 1967. Chlorinated hydrocarbon pesticides in major river basins, 1957-65. *Pub. Health Rep.* v. 82, p. 139.

Canadian Public Health Association. 1986. *Comprehensive Survey of the Status of Great Lakes Drinking Water.* Prepared in cooperation with Health and Welfare Canada and the Ministry of the Environment. Ottawa, Canada: Canadian Public Health Association. August 1986.

Cohen, D.B., and G.W. Bowes. 1984. *Water Quality and Pesticides: A California Risk Assessment Program (Volume 1).* Sacramento, CA: State Water Resources Control Board, Toxic Substances Control Program.

Dappen, G. 1974. *Pesticide Analysis from Urban Storm Runoff.* Prepared by University of Nebraska, Lincoln, Nebraska, for Office of Water Research and Technology, Nebraska Wesleyan University. Project No. A-025-NEB(2).

Englande, A.J., J.K. Smith, and J.N. English. 1978. Potable water quality of advanced wastewater treatment plant effluents. *Prog. Wat. Tech.* v. 10, no. ½, pp. 17-39.

Estabrooks, F. No date. Memorandum of pesticide information in New York surface water. From: Frank Estabrooks, U.S. Department of Environmental Conservation. Albany, NY.

Gilliom, R.J., R.B. Alexander, and R.A. Smith. 1985. *Pesticides in the Nation's Rivers, 1975-1980, and Implications for Future Monitoring.* U.S. Geological Survey Water-Supply Paper 2271. U.S. Government Printing Office, U.S. Department of Interior.

Holden, P.W. 1986. *Pesticides and Groundwater Quality. Issues and Problems in Four States*. Prepared for the Board of Agriculture, National Research Council. Washington, DC: National Academy Press.

Idaho Department of Health and Welfare. 1984. Letter to Charles Berry, Office of Drinking Water, U.S. Environmental Protection Agency, summarizing data on groundwater contamination incidents. Sent by: Charles D. Brokopp, State Epidemiologist, Division of Health, Idaho Department of Health and Welfare.

Irwin, G.A., and H.G. Healy. 1978. *Chemical and Physical Quality of Selected Public Water Supplies in Florida, August-September 1976.* Tallahassee, FL: Water Resources Division, U.S. Geological Survey. USGS/WRI 78-21.

Kuch, P. 1986. Letter to Frederic A. Zafran, SAIC, McLean, VA. October 28, 1986.

Levins, P., J. Adams, P. Brenner, S. Coons, K. Thrun, and J. Varone. 1979. *Sources of Toxic Pollutants found in Influents to Sewage Treatment Plants. IV.* R.M. Clayton Drainage Basin, Atlanta report. Prepared by Arthur D. Little, Inc., for Office of Water Planning and Standards, U.S. Environmental Protection Agency, Washington, DC. EPA Contract No. 68-01-3857.

Mississippi State University (MSU). 1984. *Cooperative Agreement Progress Report: Mississippi Pesticide Hazard Assessment Project. Pesticide Residue Monitoring of Drinking Water from Shallow Wells in the Mississippi Delta.* Prepared by: Larry Lane, Principal Investigator, Mississippi State Chemical Laboratory, Mississippi State University

Pellizzari, E.D., M.D. Erickson, and R.A. Zweidinger. 1979. *Formulation of a Preliminary Assessment of Halogenated Organic Compounds in Man and Environmental Media.* EPA Report 560-13-79-006. Prepared by Research Triangle Institute, Research Triangle Park, North Carolina, for Office of Toxic Substances, U.S. Environmental Protection Agency, Washington, DC.

Sandhu, S.S., W.J. Warren, and P. Nelson. 1978. Pesticidal residue in rural potable water. *Journal of the American Water Works Association.* v. 70, no. 1, pp. 41-45.

Schacht, R.A. 1974. *Pesticides in the Illinois Waters of Lake Michigan.* EPA Report 660-3-74-002. Prepared by Illinois Environmental Protection Agency, Chicago, Illinois, for Office of Research and Development, Office of Ground Water and Drinking Water, U.S. Environmental Protection Agency, Washington, DC.

Truhlar, J.F., and L.A. Reed. 1976. Occurrence of pesticide residues in four streams draining different land-use areas in Pennsylvania, 1969-1971. *Pestic. Monit. J.* v. 10, no. 3, pp. 101-110.

Tucker, R.K., and T.A. Burke. 1978. *A Second Preliminary Report on the Findings of the State Groundwater Monitoring Project.* New Jersey: Department of Environmental Protection.

USEPA. 1976. *EPA Actions to Cancel and Suspend Uses of Chlordane and Heptachlor as Pesticides – Economic and Social Implications.* EPA Report 540-4-76-004. Washington, DC: Office of Pesticide Programs, USEPA.

USEPA. 1980. *Ambient Water Quality Criteria for Heptachlor.* EPA Report 440-4-80-052. Washington, DC: Office of Water Regulations and Standards, USEPA.

USEPA. 1983. *Analysis of the risks and benefits of seven chemicals used for subterranean termite control.* EPA Report 540-9-83-005. Washington, DC: Office of Pesticide Programs, USEPA.

USEPA. 1986. *Guidance for the Reregistration of Pesticide Products Containing Heptachlor as the Active Ingredient.* EPA Report 540-RS-87-018. Washington, DC: Office of Pesticides and Toxic Substances, USEPA.

USEPA. 1989. *Occurrence and Human Exposure to Pesticides in Drinking Water, Food and Air in the United States of America (Draft Final Report)*. Office of Drinking Water, USEPA. September, 1989.

USEPA. 1990. *Suspended, Canceled , and Restricted Pesticides.* Office of Pesticides and Toxic Substances, USEPA.

USEPA. 1992. *R.E.D. Facts: Heptachlor*. EPA Report 738-F-00-013. Washington, DC: Office of Prevention, Pesticides, and Toxic Substances, USEPA. 4 pp. Available on the Internet at: http://www.epa.gov/oppsrrd1/REDs/factsheets/0175fact.pdf, last updated June 21, 2001.

USEPA. 2000. *TRI Explorer: Trends*. Available on the Internet at: http://www.epa.gov/triexplorer/trends.htm, last updated May 5, 2000.

USEPA. 2002. *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT*. EPA Report/815-D-02-005, Office of Water, 55 pp.

Waggoner, P.E. 1985. Memorandum from the Connecticut Agricultural Experiment Station on Pesticides in Connecticut Groundwater. P. Gough, (ed.). New Haven, CT: News of Science.

Worthing, C.R., Walker, S.B., eds. 1987. *The Pesticide Manual: A World Compendium*. 8th ed. Suffolk, Great Britain: The British Crop Protection Council. pp. 455-456.

3.9 Hexachlorobenzene

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Tables and Figures

3.9.1 Introduction, Use and Production

Hexachlorobenzene, also known as HCB, is a chlorinated hydrocarbon fungicide used as a seed treatment, especially on wheat. It may be used with or without other seed treatments. Hexachlorobenzene is a white crystalline solid that is not very soluble in water. It does not occur naturally in the environment. It is formed as a by-product while making other chemicals, in the waste streams of chloralkali and wood-preserving plants, and when burning municipal waste (ATSDR, 2000).

Currently, hexachlorobenzene is not manufactured as a commercial end product in the U.S. and also has no commercial end uses. It does not occur naturally in the environment, and is mostly formed as a byproduct in the manufacture of chlorinated solvents, in the waste streams of chloralkali and wood-preserving plants, in fly ash, and in flue gas effluents from municipal incineration. Hexachlorobenzene has not been commercially produced since the late 1970s. In 1975 about 3,200 pounds were produced, and in 1984 between 7,700 and 25,350 pounds were produced as a byproduct in chemical production (ATSDR, 2000).

Until 1984 hexachlorobenzene was widely used as a pesticide to protect the seeds of onions, sorghum, wheat and other grains against fungus. In 1984 the last registered use of hexachlorobenzene as a pesticide was voluntarily canceled. It was also used to make fireworks, ammunition and synthetic rubber; as a porosity controller in the manufacture of electrodes; as a chemical intermediate in dye manufacturing; and as a wood preservative (ATSDR, 2000).

Table 3.9-1 shows the number of facilities in each State that manufacture and process hexachlorobenzene, the intended uses of the product, and the range of maximum amounts derived from the Toxics Release Inventory (TRI) of EPA (ATSDR, 2000).

Table 3.9-1: Hexachlorobenzene Manufacturers and Processors by State

State[a]	Number of facilities	Range of maximum amounts on site in	Activities and uses[c]
CA	3	100-99,999	1,4,5
IL	1	1,000-9,999	13
KS	1	100-199	13
KY	1	10,000-99,999	1,3,7
LA	4	0-99,999	1,2,3,5,7,8
NJ	1	1,000-9,999	13
TN	1	1,000-9,999	1,6
TX	4	1,000-999,999	1,5,6,10,13

[a] Post office State abbreviations used

[b] Data in TRI are maximum amounts on site at each facility

[c] Activities/Uses include:

1. Produce
2. Import
3. For on-site use/processing
4. For sale/distribution
5. As a byproduct
6. As an impurity
7. As a reactant
8. As a formulation component
9. As an article component
10. For repackaging only
11. As a chemical processing aid
12. As a manufacturing aid
13. Ancillary or other uses

Source: ATSDR, 2000 compilation of TRI98 2000 data

3.9.2 Environmental Release

Hexachlorobenzene is listed as a Toxics Release Inventory (TRI) chemical. Table 3.9-2 illustrates the environmental releases for hexachlorobenzene from 1988 through 1999. (There are only hexachlorobenzene data for these years.) Although there is no detectable trend in virtually any category of release for hexachlorobenzene, total on- and off-site releases have moderated and decreased in recent years. Previous to 1995, levels had ranged from over 1 million pounds to around 30,000 pounds; recent levels hover well under 20,000 pounds. Off-site releases comprise the vast majority of total releases, and air emissions are, in most years, the most significant source of on-site releases. Releases to land remained at or near zero until just recently, and both surface water discharges and underground injection normally contributed less than 1,000 pounds to the overall total. These TRI data for hexachlorobenzene were reported from 11 States, with four States (Texas, Tennessee, Louisiana, and California) reporting every year (USEPA, 2000). Out of those 11 States, 6 are included in the 16-State cross section (used for analyses of hexachlorobenzene occurrence in drinking water; see Section 3.9.4). (For a map of the 16-State cross-section, see Figure 1.3-1.)

Table 3.9-2: Environmental Releases (in pounds) for Hexachlorobenzene in the United States, 1988-1999

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1999	1,524	7	--	23	13,550	15,104
1998	371	4	--	96	13,251	13,722
1997	154	276	139	0	12,038	12,607
1996	220	274	717	0	23,449	24,660
1995	566	6,458	480	0	6,975	14,479
1994	458	269	204	0	940,478	941,409
1993	636	476	548	0	648,010	649,670
1992	4,471	227	794	0	28,380	33,872
1991	841	111	60	1	1,064,793	1,065,806
1990	1,468	124	220	--	34,011	35,823
1989	4,613	338	710	0	1,008,186	1,013,847
1988	4,045	4	410	0	443,541	448,000

Source: USEPA, 2000

3.9.3 Ambient Occurrence

The most comprehensive and nationally consistent data describing ambient water quality in the United States are being produced through the United States Geological Survey's (USGS) National Water Quality Assessment (NAWQA) program. However, national NAWQA data, as well as NURP and NPDES data, are currently unavailable for hexachlorobenzene.

3.9.3.1 Additional Ambient Occurrence Data

Additional studies of ambient data are summarized below. A summary document entitled "Occurrence and Exposure Assessment of Hexachlorobenzene in Public Drinking Water Supplies" (Wade Miller, 1989), was previously prepared for past USEPA assessments of hexachlorobenzene. Several studies included in that document have addressed concentrations of hexachlorobenzene in ambient surface water. (No studies were found that addressed the occurrence of hexachlorobenzene in ambient ground water sources.) The following information is taken directly from "Occurrence and Exposure Assessment of Hexachlorobenzene in Public Drinking Water Supplies" (Wade Miller, 1989).

The USEPA's computerized water quality data base known as STORET was devised to assist Federal and State institutions meet objectives of Public Law 92-500 to maintain and enhance the physical, chemical, and biological quality of the nation's ambient waterways by providing for the collection and dissemination of basic water quality data (Staples et al., 1985, as cited in Wade Miller, 1989). Data are collected by States, EPA regional offices, and other government agencies and are maintained in the STORET system.

Before presenting a summary of the ambient water data in STORET, it is important to note that there are significant limitations in using the data base to estimate representative concentrations of a contaminant such as hexachlorobenzene. Data entered into STORET are gathered from an array of studies conducted for various purposes. Analyses are conducted in a number of different laboratories employing different methodologies with a range of detection limits. In many cases, detection limits are not reported, making the reliability of the data highly questionable. Where detection limits have been reported, STORET assigns the detection limit value to those observations reported as not detected. This can lead to errors in interpretation and overestimation of concentrations in cases in which there is a preponderance of nondetectable values. Additionally, a few high values can inflate mean values and result in large standard deviations relative to the means (Staples et al., 1985, as cited in Wade Miller, 1989). Very high values may not be correct, as they may reflect sample contamination or analytical error and can significantly distort assessment of average concentrations. Staples et al. (1985, as cited in Wade Miller, 1989) also notes that the use of data collected prior to the 1980s is not recommended, since such data was obtained using less sensitive laboratory techniques and quality assurance procedures were not yet mandated for the data entered into the system.

The STORET water quality data base provides information on the occurrence of contaminants at ambient water stations in U.S. waterways. A summary of this information was obtained for hexachlorobenzene in ambient waters. Ambient sites include streams, lakes, ponds, wells, reservoirs, canals, estuaries, and oceans. While the preponderance of data were collected from surface water sources, the number of samples collected from ground water wells, relative to the total number of samples collected from all ambient sites combined, is unspecified (Staples et al., 1985, as cited in Wade Miller, 1989). Staples et al. (1985, as cited in Wade Miller, 1989) have summarized data from the 1980's only; that is, data from 1980 through 1983. This was done based on the number of data points and the likelihood that better quality assurance practices have been employed in more recent years. In the absence of sophisticated statistical analyses to eliminate improbable data, median values have been reported. The median value is sensitive to extreme values, and reflects a measure of central tendency more accurately than the mean value in the presence of these extreme values (Staples et al., 1985, as cited in Wade Miller, 1989).

For a total of 1,786 observations from ambient water stations, the median concentration of hexachlorobenzene was 0.020 µg/L. Of the total number of observations, 26.0% were reported as detected. However, detection limits and other sampling information were not reported. Clark et al. (1988, as cited in Wade Miller, 1989) reported that hexachlorobenzene concentrations ranging from 0.00001 to 0.00012 µg/L were detected in water samples collected from Lakes Ontario and Michigan. No other information was reported.

3.9.4 Drinking Water Occurrence Based on the 16-State Cross-Section

The analysis of hexachlorobenzene occurrence presented in the following section is based on State compliance monitoring data from the 16 cross-section States. The 16-State cross-section is the largest and most comprehensive compliance monitoring data set compiled by EPA to date. These data were evaluated relative to several concentration thresholds of interest: 0.001 mg/L; 0.0005 mg/L; and 0.0001 mg/L.

All sixteen cross-section State data sets, with the exception of New Jersey, contained occurrence data for hexachlorobenzene. These data represent approximately 53,000 analytical results from more than 14,000 PWSs during the period from 1984 to 1998 (with most analytical results from 1992 to 1997). The number of sample results and PWSs vary by State, although the State data sets have been reviewed and checked to ensure adequacy of coverage and completeness. The overall modal detection limit for hexachlorobenzene in the 16 cross-section States is equal to 0.0001 mg/L. (For details regarding the 16-State cross-section, please refer to Section 1.3.5 of this report.)

3.9.4.1 Stage 1 Analysis Occurrence Findings

Table 3.9-3 illustrates the low occurrence of hexachlorobenzene in drinking water for the public water systems in the 16-State cross-section relative to three thresholds: 0.001 mg/L (the current MCL), 0.0005 mg/L, and 0.0001 mg/L. One ground water PWSs (approximately 0.00714% of all PWSs in the 16 States) had at least one analytical result exceeding 0.001 mg/L, 0.0005 mg/L, and 0.0001 mg/L. No surface water systems had any analytical results greater than any of the three thresholds.

Table 3.9-3: Stage 1 Hexachlorobenzene Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Ground Water	0.001	0.00792%	1
	0.0005	0.00792%	1
	0.0001	0.00792%	1
Surface Water	0.001	0.000%	0
	0.0005	0.000%	0
	0.0001	0.000%	0
Combined Ground & Surface Water	0.001	0.00714%	1
	0.0005	0.00714%	1
	0.0001	0.00714%	1

Reviewing hexachlorobenzene occurrence in the 16 cross-section States by PWS population served (Table 3.9-4) shows that approximately 0.0399% of the population (about 37,500 people) was served by one ground water PWS with at least one analytical result of hexachlorobenzene greater than 0.001 mg/L, 0.0005 mg/L, and 0.0001 mg/L. No people served by surface water systems were exposed to hexachlorobenzene at levels greater than any of the three thresholds.

Table 3.9-4: Stage 1 Hexachlorobenzene Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Ground Water	0.001	0.0951%	37,500
	0.0005	0.0951%	37,500
	0.0001	0.0951%	37,500
Surface Water	0.001	0.000%	0
	0.0005	0.000%	0
	0.0001	0.000%	0
Combined Ground & Surface Water	0.001	0.0399%	37,500
	0.0005	0.0399%	37,500
	0.0001	0.0399%	37,500

3.9.4.2 Stage 2 Analysis Occurrence Findings

The Stage 2 occurrence findings, based on the cross-section data, are presented in Tables 3.9-5 and 3.9-6. The statistically generated best estimate values, as well as the ranges around the best estimate value, are presented. (For a review of the Stage 2 analytical approach, please refer to Section 1.4 of this report. For complete details regarding the Stage 2 analyses, please refer to *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations* (USEPA, 2002)).

No ground water or surface water PWSs had an estimated mean concentration of hexachlorobenzene exceeding 0.001 mg/L or 0.0005 mg/L. Approximately 1 (0.00307% of) ground water PWS and 1 (0.00101% of) surface water PWS in the 16 States were estimated to have a mean concentration greater than 0.0001 mg/L.

Table 3.9-5: Stage 2 Estimated Hexachlorobenzene Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.001	0.000%	0.000% - 0.000%	0	0 - 0
	0.0005	0.000%	0.000% - 0.000%	0	0 - 0
	0.0001	0.00307%	0.000% - 0.0158%	1	0 - 2
Surface Water	0.001	0.000%	0.000% - 0.000%	0	0 - 0
	0.0005	0.000%	0.000% - 0.000%	0	0 - 0
	0.0001	0.00101%	0.000% - 0.000%	1	0 - 0
Combined Ground & Surface Water	0.001	0.000%	0.000% - 0.000%	0	0 - 0
	0.0005	0.000%	0.000% - 0.000%	0	0 - 0
	0.0001	0.00287%	0.000% - 0.0143%	1	0 - 2

Reviewing hexachlorobenzene occurrence by PWS population served (Table 3.9-6) shows that approximately 0.0176% of population served by all PWSs in the 16 States (an estimate of approximately 16,600 people) were potentially exposed to hexachlorobenzene levels above 0.0001 mg/L. The percent of population exposed was equal to 0% for all system types when evaluated relative to 0.001 mg/L and 0.0005 mg/L.

The percentage of population served by ground water systems in the 16 States with estimated mean concentration values greater than 0.0001 mg/L was equal to 0.0384% (an estimate of approximately 15,200 people). Approximately 1,400 (0.00260% of) people in the 16 cross-section States were served by surface water systems with estimated mean concentration values greater than 0.0001 mg/L.

Table 3.9-6: Stage 2 Estimated Hexachlorobenzene Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.001	0.000%	0.000% - 0.000%	0	0 - 0
	0.0005	0.000%	0.000% - 0.000%	0	0 - 0
	0.0001	0.0384%	0.000% - 0.214%	15,200	0 - 84,300

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Surface Water	0.001	0.000%	0.000% - 0.000%	0	0 - 0
	0.0005	0.000%	0.000% - 0.000%	0	0 - 0
	0.0001	0.00260%	0.000% - 0.000%	1,400	0 - 0
Combined Ground & Surface Water	0.001	0.000%	0.000% - 0.000%	0	0 - 0
	0.0005	0.000%	0.000% - 0.000%	0	0 - 0
	0.0001	0.0176%	0.000% - 0.0896%	16,600	0 - 84,300

3.9.4.3 Estimated National Occurrence

Based on the Stage 2 estimated percent of systems (and population served by systems) exceeding each threshold, no systems had estimated mean concentration values of hexachlorobenzene greater than 0.001 mg/L or 0.0005 mg/L. An estimated 2 systems nationally serving approximately 37,600 people were expected to have estimated mean concentrations of hexachlorobenzene greater than 0.0001 mg/L. (See Section 1.4 for a description of how Stage 2 16-State estimates are extrapolated to national values.)

For ground water systems, approximately 2 PWSs serving about 32,900 people nationally were estimated to have a mean concentration greater than 0.0001 mg/L. Only 1 surface water systems serving approximately 3,300 people was estimated to have a mean concentration of hexachlorobenzene above 0.0001 mg/L.

Table 3.9-7: Estimated National Hexachlorobenzene Occurrence - Systems and Population Served

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.001	0	0 - 0	0	0 - 0
	0.0005	0	0 - 0	0	0 - 0
	0.0001	2	0 - 9	32,900	0 - 183,100
Surface Water	0.001	0	0 - 0	0	0 - 0
	0.0005	0	0 - 0	0	0 - 0
	0.0001	1	0 - 0	3,300	0 - 0
Combined Ground & Surface Water	0.001	0	0 - 0	0	0 - 0
	0.0005	0	0 - 0	0	0 - 0
	0.0001	2	0 - 9	37,600	0 - 190,900

3.9.5 Additional Drinking Water Occurrence Data

Several additional data sources regarding the occurrence of fluoride in drinking water are also reviewed. Previously compiled occurrence information, from an OGWDW summary document entitled "Occurrence and Exposure Assessment of Hexachlorobenzene in Public Drinking Water Supplies" (Wade Miller, 1989), is presented in the following section. This variety of studies and information are presented regarding levels of fluoride in drinking water nationally. (No regional studies were included.) Note that none of the studies presented in the following section provide the quantitative analytical results or comprehensive coverage that would enable direct comparison to the occurrence findings estimated with the cross-section occurrence data presented in Section 3.9.4. These additional studies, however, do enable a broader assessment of the Stage 2 occurrence estimates presented for this Six-Year Review. All the following information in Section 3.9.5 is taken directly from "Occurrence and Exposure Assessment of Hexachlorobenzene in Public Drinking Water Supplies" (Wade Miller, 1989).

3.9.5.1 Ground Water Sources – National Studies

The National Screening Program for Organics in Drinking Water (NSP), conducted by SRI International from June 1977 to March 1981, examined both raw and finished drinking water samples from 166 water systems in 33 States for 51 organic chemical contaminants, including hexachlorobenzene. Analyses were made using gas chromatography/mass spectrometry (Boland, 1981, as cited in Wade Miller, 1989). The NSP data extracted from Boland (1981, as cited in Wade Miller, 1989) showed that none of the 12 ground water supplies sampled contained detectable levels of hexachlorobenzene. The minimum quantifiable concentration for hexachlorobenzene was 0.1 µg/L.

3.9.5.2 Surface Water Sources – National Studies

The National Screening Program for Organics in Drinking Water (NSP) (see section 3.9.5.1) also reported the occurrence of hexachlorobenzene in finished drinking water from surface water sources. The NSP data extracted from Boland (1981, as cited in Wade Miller, 1989) showed that none of the 104 surface water supplies sampled contained detectable levels of hexachlorobenzene. The minimum quantifiable concentration for hexachlorobenzene was 0.1 µg/L.

3.9.5.3 Unspecified Water Sources

Several studies provided data on the occurrence of hexachlorobenzene in drinking water supplies but failed to specify water sources. Drinking water supplies from 83 locations in USEPA Region V were analyzed for various pesticides and other organic chemicals. Hexachlorobenzene was detected in two finished supplies at concentrations of 0.004 µg/L and 0.006 µg/L (USEPA, 1986, as cited in Wade Miller, 1989).

In another study reported by USEPA (1986, as cited in Wade Miller, 1989), three samples of Lake Ontario water were analyzed for the presence of hexachlorobenzene. Hexachlorobenzene was detected in all three samples at concentrations ranging from 0.00006 to 0.0002 µg/L, with a mean concentration of 0.0001 µg/L. In Dade County, FL, hexachlorobenzene was detected in 4 out of 10 drinking water samples analyzed for the presence of hexachlorobenzene. The mean and maximum concentrations were 0.014 and 0.68 µg/L, respectively. The detection limit was approximately 0.006 µg/L.

3.9.5.4 Ground Water and Surface Water Sources – STORET

The STORET system contains approximately 80 million pieces of data, including data for drinking water from ground water and surface water sources. The limitations with these data are the same as described for ambient water in Section 3.9.3.1.

With these limitations in mind, a summary of the most recently obtained data for drinking water from ground water sources is presented here (USEPA, 1988, as cited in Wade Miller, 1989). According to STORET, there were a total of 1,053 observations for hexachlorobenzene in ground water from February 1978 to November 1987. In 27 of these samples, hexachlorobenzene was not detected; however, for these the detection limit values were assigned. In the remaining 1,026 samples, hexachlorobenzene was reported to have been detected, but known to have been present below the reporting value. Based on the assigned and reported values for all 1,053 samples, STORET reported a mean value of 3.80 µg/L and a range of 0.5 to 10.0 µg/L. The standard deviation for all observations was 1.90 µg/L. Detection limits and other sampling information were not reported.

The USEPA STORET database similarly contains data on the occurrence of hexachlorobenzene in drinking water from surface water sources (USEPA, 1988, as cited in Wade Miller, 1989). Between February 1978 and July 1987, there were 54 observations for hexachlorobenzene in surface water. One positive observation was reported in March 1978 at a value of 0.10 µg/L. In 5 samples, hexachlorobenzene was not detected, but were assigned to the detection limit values. In the remaining 48 observations, hexachlorobenzene was reported as being detected but was known to be present at levels below the reported value. Based on the reported and assigned values for all 54 samples, STORET reported an overall mean value of 7.17 µg/L and a range of 0.1 to 10.0 µg/L. The standard deviation for all observations was 3.03 µg/L. Detection limits and other sampling information were not reported.

3.9.6 Conclusion

In summary, hexachlorobenzene is not manufactured as a commercial end product in the U.S. and also has no commercial end uses. It does not occur naturally in the environment, and is mostly formed as a byproduct in the manufacture of chlorinated solvents, in the waste streams of chloralkali and wood-preserving plants, in fly ash, and in flue gas effluents from municipal incineration. Hexachlorobenzene was at one time used as a pesticide, but that use was canceled in 1984. Although data indicates that there are manufacturers and processors of hexachlorobenzene, it has not been commercially produced since the 1970s. Industrial releases of hexachlorobenzene have been reported to TRI from 11 States since 1988. There is no ambient occurrence survey data available for hexachlorobenzene. The Stage 2 analysis of hexachlorobenzene, based on the 16-State cross-section, estimated that approximately zero percent of combined ground water and surface water systems serving zero percent of the population exceeded the MCL of 0.001 mg/L. Based on this estimate, zero PWSs nationally are estimated to have hexachlorobenzene epoxide levels greater than the MCL.

The 16-State cross-section was designed to be nationally representative based upon VOC, SOC, and IOC pollution potentials as suggested by considerations of manufacturing, agriculture, and geographic diversity factors. Nationally, TRI releases have been reported for hexachlorobenzene from 11 States, including 6 of 16 cross-section States. The use and commercial production of hexachlorobenzene has been eliminated nationwide. Five of the eight States listed in ATSDR as manufacturers and/or processors of hexachlorobenzene are cross-section States. The cross-section should adequately represent the occurrence of hexachlorobenzene on a national scale based upon the use, production, and release patterns of the 16-State cross-section in relation to the patterns observed for all 50 States.

3.9.7 References

Agency for Toxic Substances and Disease Registry (ATSDR). 2000. *Toxicological Profile for Hexachlorobenzene*. U.S. Department of Health and Human Services, Public Health Service. 308 pp. + Appendices. Available on the Internet at: http://www.atsdr.cdc.gov/toxprofiles/tp90.pdf

Boland, P.A. 1981. *National Screening Program for Organics in Drinking Water.* Prepared by SRI International for the Office of Drinking Water, U.S. Environmental Protection Agency, Washington, DC. Contract No. 68-01-4666.

Clark, T., K. Clark, S. Paterson, D. MacKay, and R.J. Norstrom. 1988. Wildlife monitoring, modelling, and fugacity. *Environ. Sci. Technol.* v. 22, no. 2, pp. 120-127.

Staples, C.A., A.F. Werner, and T.J. Hoogheem. 1985. Assessment of priority pollutant concentrations in the United States using STORET data base. *Environ. Toxicol. Chem.* v. 4, pp. 131-142.

USEPA. 1986. *Exposure Assessment for Hexachlorobenzene. Final Report.* EPA Report 560-5-86-019. Washington, DC: Office of Pesticides and Toxic Substances, USEPA.

USEPA. 1988. Computer printout of STORET water quality data base. Retrieval conducted March 23, 1988 by Science Applications International Corporation. Data available through Office of Water Regulations and Standards, USEPA, Washington, DC.

USEPA. 2000. *TRI Explorer: Trends*. Available on the Internet at: http://www.epa.gov/triexplorer/trends.htm, last updated May 5, 2000.

USEPA. 2002. *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT.* EPA Report/815-D-02-005, Office of Water, 55 pp.

Wade Miller Associates, Inc. 1989. *Occurrence and Exposure Assessment of Hexachlorobenzene in Public Drinking Water Supplies - DRAFT.* Draft report submitted to EPA for review May 15, 1989.

3.10 Hexachlorocyclopentadiene

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Tables and Figures

3.10.1 Introduction, Use and Production

Hexachlorocyclopentadiene, also known as HEX or HCCPD, is a manufactured chemical that does not occur naturally. It is a light, lemon-yellow liquid that has a sharp musty odor. Hexachlorocyclopentadiene easily evaporates into the air and its vapor looks like a blue haze. Most hexachlorocyclopentadiene in the environment results from releases during its production and disposal (ATSDR, 1999).

The greatest use of hexachlorocyclopentadiene is as a raw material in manufacturing other chemicals, including pesticides, flame retardants, resins, dyes, pharmaceuticals, plastics, etc. Hexachlorocyclopentadiene has no end uses of its own (USEPA, 2001).

Hexachlorocyclopentadiene is a key intermediate in the production of chlorinated cyclodiene pesticides, including aldrin, dieldrin, endrin, chlordane, hepachlor, kepone, endosulfan, pentac, isodrin, and mirex. It is also used as an intermediate in the manufacture of flame retardants and, to a lesser extent, in the manufacture of nonflammable resins, polyester resins, pharmaceuticals, unbreakable plastics, acids, esters, ketones, fluorocarbons, and dyes. It has previously been used as a biocide (ATSDR, 1999).

The only current commercial producer of hexachlorocyclopentadiene is the Velsicol Chemical Company in Memphis, TN. Because production is limited to a single producer, information on the current production volume of hexachlorocyclopentadiene is not available. Estimates of past production, based on production volumes of chlorinated cyclodiene pesticides, indicate that production volume for hexachlorocyclopentadiene was about 50 million pounds per year in the early 1970s. Due to regulatory restrictions on many of the organochlorine pesticides using hexachlorocyclopentadiene as a chemical intermediate, production volume dropped to between 8 to 15 million pounds per year in the late 1970s. It has also been estimated that 18 million pounds of hexachlorocyclopentadiene were produced in 1983, but more recent data is not available (ATSDR, 1999). Only two pesticides which use hexachlorocyclopentadiene as an intermediate, endosulfan and pentac, are currently registered for use in the U.S.

Table 3.10-1 shows the facilities that manufacture or process hexachlorocyclopentadiene, the activities and uses of the product, and the range of maximum amounts on site derived from the Toxics Release Inventory (TRI) of EPA (ATSDR, 1999).

Table 3.10-1: Facilities that Manufacture or Process Hexachlorocyclopentadiene

Facility	Location[a]	Range of maximum amounts on site in pounds	Activities and uses
Occidental Chemical	Niagra Falls, NY	100,000-999,999	Reactant
Morton Intl. Inc.	West Alexandria,	10,000-99,999	Reactant
Velsicol Chemical Corp.	Memphis, TN	1,000,000-9,999,999	Produce, on-site use/processing, sale/distribution,
Basf Corp	Beaumont, TX	10,000-99,999	Reactant

[a] Post office State abbreviations used

Source: ATSDR, 1999 compilation of TRI96 1998 data

3.10.2 Environmental Release

Hexachlorocyclopentadiene is listed as a Toxics Release Inventory (TRI) chemical. Table 3.10-2 illustrates the environmental releases for hexachlorocyclopentadiene from 1988 - 1999. (There are only hexachlorocyclopentadiene data for these years.) Air emissions, which constitute most of the on-site releases, decreased substantially from 1989 through 1993, and then rose briefly before declining to their lowest level on record in 1999. Surface water discharges have been consistently at very low levels, and have been at or near zero since 1992. Although underground injection has varied from 5 to 2,131 pounds, levels remained at 250 pounds from 1993 to 1998. No information on releases to land was reported prior to 1998, and since then readings have shown no trend. Off-site releases have generally decreased, from a high of 28,000 pounds in 1988 to a low of 567 pounds in 1998. Overall, total on- and off-site releases have mostly mirrored the changes in air emissions, with mild fluctuations and a declining trend. These TRI data for hexachlorocyclopentadiene were reported from nine States, with three States (Texas, Tennessee, and New York) reporting every year (USEPA, 2000). Four of the nine States are in the 16-State cross-section (used for analyses of hexachlorocyclopentadiene occurrence in drinking water; see Section 3.10.4). (For a map of the 16-State cross-section, see Figure 1.3-1.)

Table 3.10-2: Environmental Releases (in pounds) for Hexachlorocyclopentadiene in the United States, 1988-1999

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1999	1,098	1	--	0	903	2,002
1998	5,791	0	250	5,520	567	12,128
1997	6,927	3	250	--	930	8,110
1996	7,966	0	250	--	1,000	9,216
1995	8,311	6	250	--	2,995	11,562
1994	8,923	1	250	--	--	9,174
1993	3,765	1	250	--	--	4,016
1992	8,380	0	5	--	2,740	11,125
1991	25,461	23	5	--	3,000	28,489
1990	84,585	10	5	--	5,000	89,600
1989	89,246	6	250	--	1,204	90,706
1988	78,317	6	2,131	--	28,470	108,924

Source: USEPA, 2000

3.10.3 Ambient Occurrence

The most comprehensive and nationally consistent data describing ambient water quality in the United States are being produced through the United States Geological Survey's (USGS) National Water Quality Assessment (NAWQA) program. However, national NAWQA data, as well as NURP and NPDES data, are currently unavailable for hexachlorocyclopentadiene.

3.10.3.1 Additional Ambient Occurrence Data

Additional studies of ambient surface water data are summarized below. (No data were available on the occurrence of hexachlorocyclopentadiene in ground water sources.) A summary document entitled "Occurrence and Exposure Assessment of Hexachlorocyclopentadiene in Public Drinking Water Supplies" (Wade Miller, 1989), was previously prepared for past USEPA assessments of hexachlorocyclopentadiene. The following information is taken directly from that document.

The USEPA's computerized water quality data base known as STORET was devised to assist Federal and State institutions meet objectives of Public Law 92-500 to maintain and enhance the physical, chemical, and biological quality of the nation's ambient waterways by providing for the collection and dissemination of basic water quality data (Staples et al., 1985, as cited in Wade Miller, 1989). Data are collected by States, EPA regional offices, and other government agencies and are maintained in the STORET system.

Before presenting a summary of the ambient water data in STORET, it is important to note that there are significant limitations in using the data base to estimate representative concentrations of a contaminant such as hexachlorocyclopentadiene. Data entered into STORET are gathered from an array of studies conducted for various purposes. Analyses are conducted in a number of different laboratories employing different methodologies with a range of detection limits. In many cases, detection limits are not reported, making the reliability of the data highly questionable. Where detection limits have been reported, STORET assigns the detection limit value to those observations reported as not detected. This can lead to errors in interpretation and overestimation of concentrations in cases in which there is a preponderance of nondetectable values. Additionally, a few high values can inflate mean values and result in large standard deviations relative to the means (Staples et al., 1985, as cited in Wade Miller, 1989). Very high values may not be correct, as they may reflect sample contamination or analytical error and can significantly distort assessment of average concentrations. Staples et al. (1985, as cited in Wade Miller, 1989) also notes that the use of data collected prior to the 1980s is not recommended, since such data was obtained using less sensitive laboratory techniques and quality assurance procedures were not yet mandated for the data entered into the system.

The STORET water quality data base provides information on the occurrence of contaminants at ambient water stations in U.S. waterways. A summary of this information was obtained for hexachlorocyclopentadiene in ambient waters. Ambient sites include streams, lakes, ponds, wells, reservoirs, canals, estuaries, and oceans. While the preponderance of data were collected from surface water sources, the number of samples collected from ground water wells, relative to the total number of samples collected from all ambient sites combined, is unspecified (Staples et al., 1985, as cited in Wade Miller, 1989). Staples et al. (1985, as cited in Wade Miller, 1989) have summarized data from the 1980's only; that is, data from 1980 through 1983. This was done based on the number of data points and the likelihood that better quality assurance practices have been employed in more recent years. In the absence of sophisticated statistical analyses to eliminate improbable data, median values have been reported. The median value is sensitive to extreme values, and reflects a measure of central tendency more accurately than the mean value in the presence of these extreme values (Staples et al., 1985, as cited in Wade Miller, 1989).

For a total of 854 observations from ambient water stations, the median concentration of hexachlorocyclopentadiene was 10.0 μg/L. Of the total number of observations, 0.1 percent were reported as detectable. Detection limits and other sampling information were not reported.

3.10.4 Drinking Water Occurrence Based on the 16-State Cross-Section

The analysis of hexachlorocyclopentadiene occurrence presented in the following section is based on State compliance monitoring data from the 16 cross-section States. The 16-State cross-section is the largest and most comprehensive compliance monitoring data set compiled by EPA to date. These data were evaluated relative to several concentration thresholds of interest: 0.05 mg/L; 0.04 mg/L; and 0.005 mg/L.

All sixteen cross-section State data sets, with the exception of New Jersey, contained occurrence data for hexachlorocyclopentadiene. These data represent more than 52,000 analytical results from approximately 14,000 PWSs during the period from 1984 to 1998 (with most analytical results from 1992 to 1997). The number of sample results and PWSs vary by State, although the State data sets have been reviewed and checked to ensure adequacy of coverage and completeness. The overall modal detection limit for hexachlorocyclopentadiene in the 16 cross-section States is equal to 0.005 mg/L. (For details regarding the 16-State cross-section, please refer to Section 1.3.5 of this report.)

3.10.4.1 Stage 1 Analysis Occurrence Findings

Table 3.10-3 illustrates the very low occurrence of hexachlorocyclopentadiene in drinking water for the public water systems in the 16-State cross-section. No ground water or surface water PWSs had any analytical results exceeding the MCL (0.05 mg/L) or 0.04 mg/L. Only 1 (0.0722% of) surface water system had any analytical results greater than the modal detection limit (0.005 mg/L). No ground water systems had analytical results greater than any of the three thresholds.

Table 3.10-3: Stage 1 Hexachlorocyclopentadiene Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Ground Water	0.05	0.000%	0
	0.04	0.000%	0
	0.005	0.000%	0
Surface Water	0.05	0.000%	0
	0.04	0.000%	0
	0.005	0.0722%	1
Combined Ground & Surface Water	0.05	0.000%	0
	0.04	0.000%	0
	0.005	0.00718%	1

Reviewing hexachlorocyclopentadiene occurrence in the 16 cross-section States by PWS population served (Table 3.10-4) shows that approximately 0.0296% of the total 16-State population was served by PWSs with analytical detections of hexachlorocyclopentadiene greater than 0.005 mg/L (about 27,700 people, all served by one surface water system).

Table 3.10-4: Stage 1 Hexachlorocyclopentadiene Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Ground Water	0.05	0.000%	0
	0.04	0.000%	0
	0.005	0.000%	0
Surface Water	0.05	0.000%	0
	0.04	0.000%	0
	0.005	0.0509%	27,700
Combined Ground & Surface Water	0.05	0.000%	0
	0.04	0.000%	0
	0.005	0.0296%	27,700

3.10.4.3 Stage 2 Analysis Occurrence Findings

The Stage 2 occurrence findings, based on the cross-section data, are presented in Tables 3.10-5 and 3.10-6. The statistically generated best estimate values, as well as the ranges around the best estimate value, are presented. (For a review of the Stage 2 analytical approach, please refer to Section 1.4 of this report. For complete details regarding the Stage 2 analyses, please refer to *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations* (USEPA, 2002)).

No ground water or surface water PWSs (therefore, no population served by systems) had an estimated mean concentration of hexachlorocyclopentadiene exceeding 0.05 mg/L, 0.04 mg/L or 0.005 mg/L.

Table 3.10-5: Stage 2 Estimated Hexachlorocyclopentadiene Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.05	0.000%	0.000% - 0.000%	0	0 - 0
	0.04	0.000%	0.000% - 0.000%	0	0 - 0
	0.005	0.000%	0.000% - 0.000%	0	0 - 0

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Surface Water	0.05	0.000%	0.000% - 0.000%	0	0 - 0
	0.04	0.000%	0.000% - 0.000%	0	0 - 0
	0.005	0.000%	0.000% - 0.000%	0	0 - 0
Combined Ground & Surface Water	0.05	0.000%	0.000% - 0.000%	0	0 - 0
	0.04	0.000%	0.000% - 0.000%	0	0 - 0
	0.005	0.000%	0.000% - 0.000%	0	0 - 0

Table 3.10-6: Stage 2 Estimated Hexachlorocyclopentadiene Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.05	0.000%	0.000% - 0.000%	0	0 - 0
	0.04	0.000%	0.000% - 0.000%	0	0 - 0
	0.005	0.000%	0.000% - 0.000%	0	0 - 0
Surface Water	0.05	0.000%	0.000% - 0.000%	0	0 - 0
	0.04	0.000%	0.000% - 0.000%	0	0 - 0
	0.005	0.000%	0.000% - 0.000%	0	0 - 0
Combined Ground & Surface Water	0.05	0.000%	0.000% - 0.000%	0	0 - 0
	0.04	0.000%	0.000% - 0.000%	0	0 - 0
	0.005	0.000%	0.000% - 0.000%	0	0 - 0

3.10.4.3 Estimated National Occurrence

As illustrated in Table 3.10-7, the Stage 2 analysis estimated zero systems serving none of the national population to have an estimated mean concentration values of hexachlorocyclopentadiene greater than 0.05 mg/L, 0.04 mg/L, or 0.005 mg/L. (See Section 1.4 for a description of how Stage 2 16-State estimates are extrapolated to national values.)

Table 3.10-7: Estimated National Hexachlorocyclopentadiene Occurrence - Systems and Population Served

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.05	0	0 - 0	0	0 - 0
	0.04	0	0 - 0	0	0 - 0
	0.005	0	0 - 0	0	0 - 0
Surface Water	0.05	0	0 - 0	0	0 - 0
	0.04	0	0 - 0	0	0 - 0
	0.005	0	0 - 0	0	0 - 0
Combined Ground & Surface Water	0.05	0	0 - 0	0	0 - 0
	0.04	0	0 - 0	0	0 - 0
	0.005	0	0 - 0	0	0 - 0

3.10.5 Additional Drinking Water Occurrence Data

Several additional data sources regarding the occurrence of fluoride in drinking water are also reviewed. For a previous summary document entitled "Occurrence and Exposure Assessment of Hexachlorocyclopentadiene in Public Drinking Water Supplies" (Wade Miller, 1989), an extensive search of the scientific and regulatory literature was conducted in an effort to obtain information on the occurrence of hexachlorocyclopentadiene in drinking water from ground water and surface water sources. In addition, knowledgeable sources within the Office of Drinking Water were contacted. Except for data obtained from the STORET data base, no national, regional or State studies were found which analyzed the occurrence of hexachlorocyclopentadiene in drinking water supplies. The STORET data are discussed below. Note that STORET data do not provide the quantitative analytical results or comprehensive coverage that would enable direct comparison to the occurrence findings estimated with the cross-section occurrence data presented in Section 3.10.4. These additional studies, however, do enable a broader assessment of the Stage 2 occurrence estimates presented for this Six-Year Review. All the following information in Section 3.1.5 is taken directly from "Occurrence and Exposure Assessment of Hexachlorocyclopentadiene in Public Drinking Water Supplies" (Wade Miller, 1989).

3.10.5.1 Ground Water and Surface Water Sources - STORET

The STORET system contains approximately 80 million pieces of data, including data for drinking water from ground water and surface water sources. The limitations with these data are the same as described for ambient water in Section 3.10.3.1.

With these limitations in mind, a summary of the most recently obtained data for drinking water from ground water sources is presented here (USEPA, 1988, as cited in Wade Miller, 1989). According to STORET, there were a total of 1,042 observations for hexachlorocyclopentadiene in ground water from February 1978 to November 1987. In 27 of these samples, hexachlorocyclopentadiene was not detected;

however, for these the detection limit values were assigned. In the remaining 1,015 samples, hexachlorocyclopentadiene was reported to have been detected, but known to have been present below the reported value. Based on the assigned and reported values for all 1,042 samples, STORET reported a mean value of 14.35 µg/L and a range of 1.0 to 40.0 µg/L. The standard deviation for all observations was 7.23 µg/L. Detection limits and other sampling information were not reported.

STORET also contains data on the occurrence of hexachlorocyclopentadiene in drinking water from surface water sources (USEPA, 1988, as cited in Wade Miller, 1989). Between February 1978 and July 1987, there were 62 observations for hexachlorocyclopentadiene in surface water. In 16 samples, hexachlorocyclopentadiene was not detected, but were assigned the detection limit values. In the remaining 46 observations hexachlorocyclopentadiene was reported as being detected but was known to be present at levels below the reported values. Based on the reported and assigned values for all 62 samples, STORET reported an overall mean value of 8.95 µg/L and a range of 4.0 to 30.0 µg/L. The standard deviation for all observations was 4.61 µg/L. Detection limits and other sampling information were not reported.

3.10.5.2 National Estimates of the Occurrence of Hexachlorocyclopentadiene and Population Exposure for Public Water Supplies

No Federal survey data on the occurrence of hexachlorocyclopentadiene in public drinking water supplies are available. Information on the occurrence of hexachlorocyclopentadiene in public drinking water supplies is available from the STORET data base; however, there are significant limitations involved with utilizing these data. These limitations are discussed in detail in Section 3.10.5.1. Consequently, national estimates of occurrence and population exposure could not be made for hexachlorocyclopentadiene.

3.10.6 Conclusion

Hexachlorocyclopentadiene is a manufactured chemical that does not occur naturally. Its greatest use is as a raw material in manufacturing other chemicals, including pesticides, flame retardants, resins, dyes, pharmaceuticals, plastics, etc. The only commercial producer of hexachlorocyclopentadiene is Velsicol Chemical Corp. in Memphis, Tennessee, and other production or processing of hexachlorocyclopentadiene is relatively limited. Industrial releases of hexachlorocyclopentadiene have been reported to TRI from nine States since 1988. Ambient occurrence data was not available for hexachlorocyclopentadiene. The Stage 2 analysis, based on the 16-State cross-section, estimated that zero percent of combined ground water and surface water systems serving zero percent of the population exceeded the MCL of 0.05 mg/L. Based on this estimate, zero PWSs nationally are estimated to have hexachlorocyclopentadiene levels greater than the MCL.

The 16-State cross-section was designed to be nationally representative based upon VOC, SOC, and IOC pollution potentials as suggested by considerations of manufacturing, agriculture, and geographic diversity factors. Nationally, hexachlorocyclopentadiene is manufactured and/or processed in 4 States and has TRI releases in 9 States. Hexachlorocyclopentadiene is manufactured and/or processed in 1 out of the 16 cross-section States and has TRI releases in 4 of the 16 cross-section States. The cross-section should adequately represent the occurrence of hexachlorocyclopentadiene on a national scale based upon the use, production, and release patterns of the 16-State cross-section in relation to the patterns observed for all 50 States.

3.10.7 References

Agency for Toxic Substances and Disease Registry (ATSDR). 1999. *Toxicological Profile for Hexachlorocyclopentadiene.* U.S. Department of Health and Human Services, Public Health Service. 185 pp. + Appendices. Available on the Internet at: http://www.atsdr.cdc.gov/toxprofiles/tp112.pdf

Staples, C.A., A.F. Werner, and T.J. Hoogheem. 1985. Assessment of Priority Pollutant Concentrations in the United States Using STORET Data Base. *Environ. Toxicol. Chem.* v. 4, pp. 131-142.

USEPA. 1988. Computer Printout of STORET Water Quality Data Base. Retrieval conducted March 23, 1988 by Science Applications International Corporation. Data available through Office of Water Regulations and Standards, USEPA, Washington, DC.

USEPA. 2000. *TRI Explorer: Trends*. Available on the Internet at: http://www.epa.gov/triexplorer/trends.htm, last updated May 5, 2000.

USEPA. 2001. *National Primary Drinking Water Regulations - Consumer Factsheet on: Hexachlorocyclopentadiene.* Office of Ground Water and Drinking Water, USEPA. Available on the Internet at: http://www.epa.gov/safewater/dwh/c-soc/hexachl2.html, last updated April 12, 2001.

USEPA. 2002. *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT*. EPA Report/815-D-02-005, Office of Water, 55 pp.

Wade Miller Associates, Inc. 1989. *Occurrence and Exposure Assessment of Hexachlorocyclopentadiene in Public Drinking Water Supplies - DRAFT*. Draft report submitted to EPA for review May 15, 1989.

3.11 Oxamyl

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Tables and Figures

3.11.1 Introduction, Use and Production

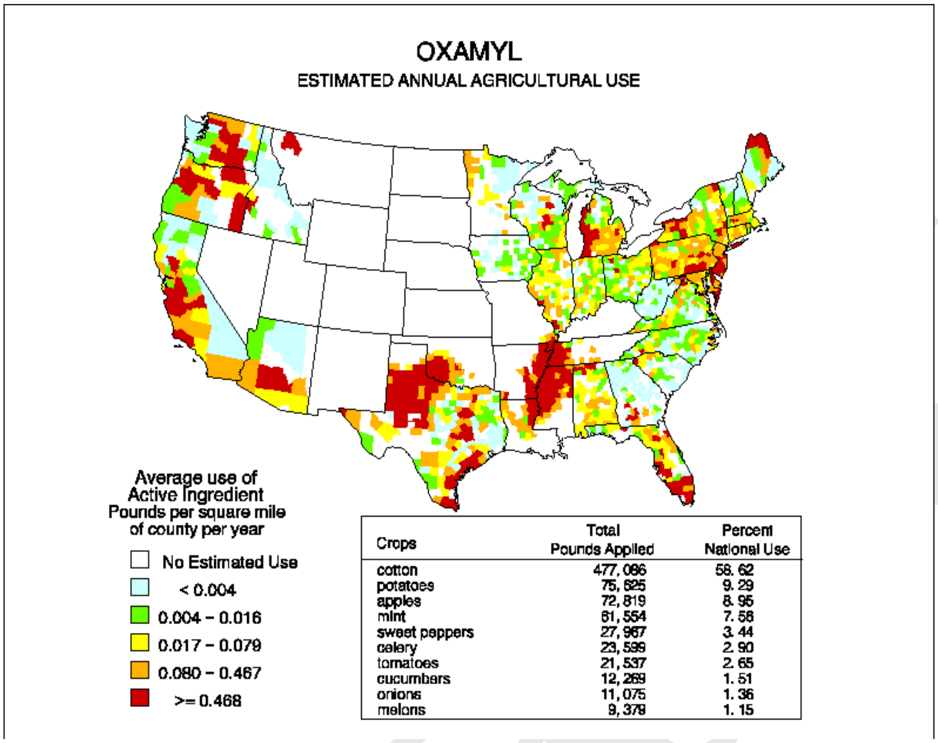
Pure oxamyl, also known as Vydate (or methyl-N’,N’-dimethyl-N-[methylcarbamoyl)oxy]-1-thio-oxamimidate) is an off-white crystalline powder or a white crystalline solid with a slight sulfurous odor. While oxamyl, a carbamate, is stable in solid form and in most solutions, it decomposes to innocuous materials in natural waters and in soils. These insecticides work by blocking the normal functioning of cholinesterase, an essential nervous system enzyme. Aeration, sunlight, alkalinity, and higher temperatures increase its rate of decomposition. Toxic fumes of nitrogen oxides and sulfur oxides are emitted if oxamyl is heated to decomposition. Oxamyl is noncorrosive. It is available in a variety of formulations, such as a 24% water- soluble liquid and 10% granules (EXTOXNET, 1998). Oxamyl is used to kill and control a broad spectrum of insects, as an acaricide to control mites and ticks, and as a nematicide against roundworms. Its action is both systemic and contact. Oxamyl may be applied directly on plants or on the soil surface (USEPA, 2001).

In 1982, U.S. production of oxamyl was reported to be 400,000 pounds (USEPA, 2001), but production appears to have dropped off by the late 1980s (Wade Miller, 1989). A systemic and contact insecticide/acaricide and nematocide, oxamyl is a restricted use pesticide used on apples, bananas, carrots, celery, citrus, cotton, cucumbers, eggplants, garlic, ginger, muskmelon (including cantaloupe and honeydew melon), onion (dry bulb), peanuts, pears, peppers, peppermint, pineapples, plantains, potatoes, pumpkins, soybeans, spearmint, squash, sweet potatoes, tobacco, tomatoes, watermelons, and yams. Oxamyl is also used on non-bearing apple, cherry, citrus, peach, pear, and tobacco (USEPA, 2001).

Recent national estimates of agricultural use for oxamyl are available. The United States Geological Survey (USGS, 1998a) estimates approximately 750,000 pounds of oxamyl active ingredient were used in 1992, and were applied to roughly 1.6 million acres (USGS, 2000). These estimates were derived using State-level data sets on pesticide use rates available from National Center for Food and Agricultural Policy (NCFAP) combined with county-level data on harvested crop acreage from the Census of Agriculture (Thelin and Gianessi, 2000). EPA estimates that on average approximately 800,000 pounds of oxamyl active ingredient (ai) are used per year (USEPA, 2000a). Cotton accounts for the majority of usage (600,000 pounds oxamyl ai), while intermediate use can be found on several other crops as well (e.g., apples, celery, potatoes, and tomatoes, see Figure 3.11-1). Although cotton accounts for most of the oxamyl usage, it is used on only 7% of cotton produced annually in the United States (USEPA, 2000a). Cotton application is 1 to 2 times per season, usually at a rate of about 0.4 lb oxamyl ai per acre. When oxamyl is used on other crops, it is generally applied 1 to 3 times per season at between 0.2 and 1.0 lb ai per acre (the current label rates do allow for higher use rates on some crops) (USEPA, 2000a).

Figure 3.11-1 shows the USGS (1998a) derived geographic distribution of estimated average annual oxamyl use in the United States for 1992. Oxamyl is used in cotton production as well as on a variety of fruit and root crops, its use is geographically distributed across the United States. The two largest concentrations of oxamyl use are seen in the cotton production regions of the Texas panhandle and the lower Mississippi River Valley, including Alabama. Texas ranks as one of the largest producers of cotton, and therefore has the highest oxamyl usage (USEPA, 2000a). Oxamyl’s application on potato, fruit, and vegetable production is apparent with high oxamyl use identified in the Pacific Northwest, California, and Florida (Figure 3.11-1). While non-agricultural uses are not reflected here (USGS, 1998b), existing data suggest that non-agricultural use of oxamyl is minimal to non-existent (USEPA, 2000b). In addition, the map does not provide any further resolution that county-level, obscuring any intra-county usage differences (USGS, 1998b). A comparison of this use map with the map of the 16 cross-section States (Figure 1.3-1) shows that States across the range of high of low oxamyl use are well represented in the cross-section.

Figure 3.11-1: Estimated Annual Agricultural Use for Oxamyl (1992)



Crops	Total Pounds Applied	Percent National Use
cotton	477,086	58.62
potatoes	75,625	9.29
apples	72,819	8.95
mint	61,554	7.58
sweet peppers	27,967	3.44
celery	23,599	2.90
tomatoes	21,537	2.65
cucumbers	12,269	1.51
onions	11,075	1.36
melons	9,379	1.15

Source: USGS 1998a

3.11.2 Environmental Release

Oxamyl is released directly to the environment when used as an insecticide and potentially during its manufacture, handling and storage. EPA estimated that 400,000 pounds of oxamyl were produced in the U.S. in 1982 (USEPA, 2001). Oxamyl is not listed as a Toxics Release Inventory (TRI) contaminant, so no TRI release records are maintained. Therefore, the use of oxamyl (described in the previous section) may provide the primary indication of where releases are most likely. The areas of highest oxamyl use are in the cotton production regions of the Texas panhandle, the lower Mississippi River Valley, and on the fruit and vegetable production areas in the Pacific Northwest, California, and Florida. These and other agricultural use areas are illustrated in Figure 3.11-1.

3.11.3 Ambient Occurrence

Oxamyl is an analyte for both surface and ground water NAWQA studies, with a method detection limit (MDL) of 0.018 µg/L. Additional information on analytical methods used in the NAWQA study units, including method detection limits, are described by Gilliom and others (1998).

Oxamyl is an analyte for both surface and ground water NAWQA studies. Table 3.11-1 summarizes the findings of USGS NAWQA sampling for oxamyl within the first 20 NAWQA study basins. Oxamyl concentrations in all of the surface water samples were below the detection limit in most sites, although it was detected in at least one sample. No oxamyl was detected in any of the ground water NAWQA study sites.

Table 3.11-1: Oxamyl Detections and Concentrations in Surface Water and Ground Water

	Detection frequency (% of samples)			Concentration percentiles (all samples; µg/L)			
	all samples	> 0.01 µg/L	> 0.05 µg/L	10th	median	95th	max
surface water							
agricultural	ND	--	ND	<MDL	<MDL	<MDL	<MDL
urban	ND	--	ND	<MDL	<MDL	<MDL	<MDL
integrator	ND	--	ND	<MDL	<MDL	<MDL	<MDL
all sites	0.03%	--	0.03%	<MDL	<MDL	<MDL	0.07
ground water							
agricultural	ND	--	ND	<MDL	<MDL	<MDL	--
urban	ND	--	ND	<MDL	<MDL	<MDL	--
major aquifers	ND	--	ND	<MDL	<MDL	<MDL	--
all sites	ND	--	ND	<MDL	<MDL	<MDL	–

ND=No detect
Source: USGS, 1998c

3.11.3.2 Additional Ambient Occurrence Data

A summary document entitled "Occurrence and Exposure Assessment of Oxamyl in Public Drinking Water Supplies" (Wade Miller, 1989), was previously prepared for past USEPA assessments of oxamyl. One regional study was reviewed in that document that addressed levels of oxamyl in water withdrawn from ground water sources. The following information is taken directly from that document.

Cohen et al. (1984, as cited in Wade Miller, 1989) summarized unpublished data from EPA's pesticide registration files. Oxamyl was detected in ground water samples collected from Long Island, New York, at concentrations ranging from 5 to 65 µg/L. The detection limit, number of samples tested, and the number of positive samples were not reported.

The Pesticides in Groundwater Data Base, developed by EPA's Offices of Pesticide Programs (OPP), contains information derived from monitoring studies conducted by pesticide registrants, universities, and government agencies. The data are presented in several categories, including all information collected to date (excluding data known to be of poor quality and data that is from point source contamination); data derived from scientifically confirmed agricultural use; and confirmed information attributed to known point sources and documented misuse. While extreme care was taken to confirm detections of pesticides in ground water , the authors caution that the studies investigated have not been limited to drinking water supplies and some studies included samples from many types of wells including observation and irrigation wells. In addition, many studies have focused on shallow ground water, which may not be representative of drinking water sources in the area. As such, the results cannot be used to estimate human exposure to pesticides in drinking water, but do provide an additional assessment of possible oxamyl occurrence.

3.11.4 Drinking Water Occurrence Based on the 16-State Cross-Section

The analysis of oxamyl occurrence in drinking water presented in the following section is based on State compliance monitoring data from the 16 cross-section States. The 16-State cross-section is the largest and most comprehensive compliance monitoring data set compiled by EPA to date. These data were evaluated relative to several concentration thresholds of interest: 0.2 mg/L; 0.04 mg/L; 0.03 mg/L; 0.02 mg/L; and 0.007 mg/L.

All sixteen cross-section State data sets, with the exception of New Jersey, contained occurrence data for oxamyl. These data represent more than 47,000 analytical results from approximately 13,000 PWSs during the period from 1984 to 1998 (with most analytical results from 1992 to 1997). The number of sample results and PWSs vary by State, although the State data sets have been reviewed and checked to ensure adequacy of coverage and completeness. The overall modal detection limit for oxamyl in the 16 cross-section States is equal to 0.002 mg/L. (For details regarding the 16-State cross-section, please refer to Section 1.3.5 of this report.)

3.11.4.1 Stage 1 Analysis Occurrence Findings

Table 3.11-2 illustrates the very low occurrence of oxamyl in drinking water for the public water systems in the 16-State cross-section . No ground water or surface water PWSs had any analytical results greater than 0.2 mg/L, 0.04 mg/L, or 0.03 mg/L. About 0.00760% of total ground and surface water systems had analytical results greater than 0.02 mg/L (approximately 1 system). Approximately 0.0304% of systems (4 systems) had any analytical detections greater than 0.007 mg/L. Only 1 (0.00848% of) ground water system had any exceedances of 0.02 mg/L. Four (0.0339% of) ground water systems had at least one analytical result greater than 0.007 mg/L. No surface water systems had analytical results greater than any of the thresholds.

Table 3.11-2: Stage 1 Oxamyl Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Ground Water	0.2	0.000%	0
	0.04	0.000%	0
	0.03	0.000%	0
	0.02	0.00848%	1
	0.007	0.0339%	4
Surface Water	0.2	0.000%	0
	0.04	0.000%	0
	0.03	0.000%	0
	0.02	0.000%	0
	0.007	0.000%	0

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Combined Ground & Surface Water	0.2	0.000%	0
	0.04	0.000%	0
	0.03	0.000%	0
	0.02	0.00760%	1
	0.007	0.0304%	4

Reviewing oxamyl occurrence in the 16 cross-section States by PWS population served (Table 3.11-3) shows that approximately 0.00162% of the population (about 1,500 people) was served by PWSs with analytical detections of oxamyl greater than 0.02 mg/L. The number of people exposed to oxamyl drastically increased to about 51,300 (approximately 0.0555%) when evaluated relative to 0.007 mg/L. Approximately 0.00391% of people served by ground water systems were exposed to oxamyl at levels greater than 0.02 mg/L. The percentage of population served by ground water systems exposed to oxamyl at levels greater than 0.007 mg/L was equal to 0.134%. When evaluated relative to 0.2 mg/L, 0.04 mg/L, or 0.03 mg/L, the percent of population exposed to oxamyl was equal to 0% for all system types. No surface water systems exceeded any of the specified health thresholds.

Table 3.11-3: Stage 1 Oxamyl Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Ground Water	0.2	0.000%	0
	0.04	0.000%	0
	0.03	0.000%	0
	0.02	0.00391%	1,500
	0.007	0.134%	51,300
Surface Water	0.2	0.000%	0
	0.04	0.000%	0
	0.03	0.000%	0
	0.02	0.000%	0
	0.007	0.000%	0
Combined Ground & Surface Water	0.2	0.000%	0
	0.04	0.000%	0
	0.03	0.000%	0
	0.02	0.00162%	1,500
	0.007	0.0555%	51,300

3.11.4.2 Stage 2 Analysis Occurrence Findings

The Stage 2 occurrence findings, based on the cross-section data, are presented in Tables 3.11-4 and 3.11-5. The statistically generated best estimate values, as well as the ranges around the best estimate value, are presented. (For a review of the Stage 2 analytical approach, please refer to Section 1.4 of this report. For complete details regarding the Stage 2 analyses, please refer to *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations* (USEPA, 2002)).

No ground water or surface water PWSs had an estimated mean concentration of oxamyl exceeding 0.2 mg/L, 0.04 mg/L, 0.03 mg/L, or 0.02 mg/L. Approximately 0.0000456% of all PWSs in the 16 States (less than 1 system) had estimated mean concentration values of oxamyl greater than 0.007 mg/L. The percentage of ground water PWSs in the 16 States estimated to have a mean concentration greater than 0.007 mg/L was equal to 0.0000509%. No surface water PWSs had estimated mean concentration exceeding any of the five specified concentration thresholds.

Table 3.11-4: Stage 2 Estimated Oxamyl Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.2	0.000%	0.000% - 0.000%	0	0 - 0
	0.04	0.000%	0.000% - 0.000%	0	0 - 0
	0.03	0.000%	0.000% - 0.000%	0	0 - 0
	0.02	0.000%	0.000% - 0.000%	0	0 - 0
	0.007	0.0000509%	0.000% - 0.000%	0	0 - 0
Surface Water	0.2	0.000%	0.000% - 0.000%	0	0 - 0
	0.04	0.000%	0.000% - 0.000%	0	0 - 0
	0.03	0.000%	0.000% - 0.000%	0	0 - 0
	0.02	0.000%	0.000% - 0.000%	0	0 - 0
	0.007	0.000%	0.000% - 0.000%	0	0 - 0
Combined Ground & Surface Water	0.2	0.000%	0.000% - 0.000%	0	0 - 0
	0.04	0.000%	0.000% - 0.000%	0	0 - 0
	0.03	0.000%	0.000% - 0.000%	0	0 - 0
	0.02	0.000%	0.000% - 0.000%	0	0 - 0
	0.007	0.0000456%	0.000% - 0.000%	0	0 - 0

Reviewing oxamyl occurrence by PWS population served (Table 3.11-5) shows that approximately 0.0000323% of population served by all PWSs in the 16-State cross-section were potentially exposed to oxamyl levels above 0.007 mg/L. The percentage of population served by ground water systems in the 16 States relative to 0.007 mg/L was equal to 0.0000777%. (No surface water systems exceeded any of the specified health thresholds.) When evaluated relative to a threshold of 0.2 mg/L, 0.04 mg/L, 0.03 mg/L, and 0.02 mg/L, the percent of population exposed was equal to 0% for all system types.

Table 3.11-5: Stage 2 Estimated Oxamyl Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.2	0.00000%	0.000% - 0.000%	0	0 - 0
	0.04	0.00000%	0.000% - 0.000%	0	0 - 0
	0.03	0.00000%	0.000% - 0.000%	0	0 - 0
	0.02	0.00000%	0.000% - 0.000%	0	0 - 0
	0.007	0.0000777%	0.000% - 0.000%	0	0 - 0
Surface Water	0.2	0.000%	0.000% - 0.000%	0	0 - 0
	0.04	0.000%	0.000% - 0.000%	0	0 - 0
	0.03	0.000%	0.000% - 0.000%	0	0 - 0
	0.02	0.000%	0.000% - 0.000%	0	0 - 0
	0.007	0.000%	0.000% - 0.000%	0	0 - 0
Combined Ground & Surface Water	0.2	0.000%	0.000% - 0.000%	0	0 - 0
	0.04	0.000%	0.000% - 0.000%	0	0 - 0
	0.03	0.000%	0.000% - 0.000%	0	0 - 0
	0.02	0.000%	0.000% - 0.000%	0	0 - 0
	0.007	0.0000323%	0.000% - 0.000%	0	0 - 0

3.11.4.3 Estimated National Occurrence

As illustrated in Table 3.11-6, the Stage 2 analysis estimates zero systems serving none of the national population have estimated mean concentration values of oxamyl greater than 0.2 mg/L, 0.04 mg/L, 0.03 mg/L, or 0.02 mg/L. Approximately 1 ground water system serving less than 100 people nationally was estimated to have a mean concentration value of oxamyl greater than 0.007 mg/L. (See Section 1.4 for a description of how Stage 2 16-State estimates are extrapolated to national values.)

Table 3.11-6: Estimated National Oxamyl Occurrence - Systems and Population Served

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.2	0	0 - 0	0	0 - 0
	0.04	0	0 - 0	0	0 - 0
	0.03	0	0 - 0	0	0 - 0
	0.02	0	0 - 0	0	0 - 0
	0.007	1	0 - 0	< 100	0 - 0
Surface Water	0.2	0	0 - 0	0	0 - 0
	0.04	0	0 - 0	0	0 - 0
	0.03	0	0 - 0	0	0 - 0
	0.02	0	0 - 0	0	0 - 0
	0.007	0	0 - 0	0	0 - 0
Combined Ground & Surface Water	0.2	0	0 - 0	0	0 - 0
	0.04	0	0 - 0	0	0 - 0
	0.03	0	0 - 0	0	0 - 0
	0.02	0	0 - 0	0	0 - 0
	0.007	1	0 - 0	< 100	0 - 0

3.11.5 Additional Drinking Water Occurrence Data

For previously prepared USEPA assessments of oxamyl, discussed in Section 3.11.3.1, a literature search was conducted and knowledgeable sources within the Office of Water were contacted. No national studies were found on the occurrence of oxamyl in drinking water from ground water or surface water sources nor were any regional or State studies found that addressed the occurrence of oxamyl in drinking water from surface water sources (Wade Miller, 1989). Although the studies reviewed include oxamyl occurrence information and/or data, none of the studies discussed provide the quantitative analytical results or comprehensive coverage that would enable direct comparison to the occurrence findings estimated with the cross-section occurrence data and presented in Section 3.11.4. All the following information in Section 3.11.5 is taken directly from “Occurrence and Exposure Assessment of Oxamyl in Public Drinking Water Supplies” (Wade Miller, 1989).

One county-level study was identified. Summary data were obtained from a drinking water well pesticide sampling program conducted by Suffolk County Department of Health Services of Massachusetts during 1980 to 1985. Oxamyl residues were detected at 0.001 to 0.049 mg/L in 2.9 percent (455) of the 15,535 samples tested. The average concentration was 0.01 mg/L. During the five year period less than 0.1 percent (11) of the samples exceeded 0.05 mg/L (Dougherty, 1987, as cited in Wade Miller, 1989). Additional summary data were obtained from a Massachusetts interagency pesticide monitoring program of 341 public and private water sources in 27 communities. Of the 146 wells sampled for oxamyl, 1 was positive at the detection limit of 0.001 µg/L (Dougherty, 1987, as cited in Wade Miller, 1989).

3.11.6 Conclusion

A systemic and contact insecticide/acaricide and nematocide, oxamyl is a restricted use pesticide used on apples, bananas, carrots, celery, citrus, cotton, cucumbers, eggplants, garlic, ginger, muskmelon (including cantaloupe and honeydew melon), onion (dry bulb), peanuts, pears, peppers, peppermint, pineapples, plantains, potatoes, pumpkins, soybeans, spearmint, squash, sweet potatoes, tobacco, tomatoes, watermelons, and yams. Oxamyl is also used on non-bearing apple, cherry, citrus, peach, pear, and tobacco. Recent national estimates of agricultural use for oxamyl are available. The United States Geological Survey estimates approximately 750,000 pounds of oxamyl active ingredient were used in 1992, and were applied to roughly 1.6 million acres. Oxamyl is not a TRI chemical, so there is no information available on releases. Oxamyl was an analyte for the NAWQA ambient occurrence studies. In the NAWQA study, the median value of oxamyl for both ground water and surface water was less than the detection limit. The Stage 2 analysis, based on the 16-State cross-section, estimated that zero percent of combined ground water and surface water systems serving zero percent of the population exceeded the MCL of 0.2 mg/L. Based on this estimate, zero PWSs nationally are estimated to have oxamyl levels greater than the MCL.

The 16-State cross-section was designed to be nationally representative based upon VOC, SOC, and IOC pollution potentials as suggested by considerations of manufacturing, agriculture, and geographic diversity factors. According to information from USGS, 12 of the 16 cross-section States use oxamyl, although most States in light to moderate amounts. Oxamyl is used most heavily in California, Texas, Florida, and the Northeast; these States/regions are represented by five of the cross-section States. As there is no TRI or other data, agricultural use seems to be the only basis for comparison between the 16 States and the nation. In the case of oxamyl, the cross-section should adequately represent the occurrence of oxamyl on a national scale based upon the use, production, and release patterns of the 16-State cross-section in relation to the patterns observed for all 50 States.

3.11.7 References

Cohen S.Z., S.M. Creeger, R.F. Carsel, and C.G. Enfield. 1984. Potential Pesticide Contamination of Ground Water Resulting from Agricultural Uses. In: *Treatment and Disposal of Pesticide Wastes.* Washington, DC. R.F. Kruger and J.W. Seiber (eds.). ACS Symposium Series No. 259: pp. 247-325.

Dougherty, T.M. 1987. Oxamyl - EAB science chapter for the registration standard. Memorandum from Therese M. Dougherty, Exposure Assessment Branch, to Dennis Edwards, Insecticide - Rodenticide Branch, Office of Pesticide Programs, U.S. Environmental Protection Agency, Arlington, VA. February 11, 1987.

EXTOXNET. 1996. *Pesticide Information Profile: Oxamyl*. Ithaca, NY: Extension Toxicology Network, Pesticide Management Education Program. Available on the Internet at http://ace.ace.orst.edu/info/extoxnet/pips/oxamyl.htm, revised June, 1996.

Gilliom, R.J., D.K. Mueller, and L.H. Nowell. 1998. *Methods for comparing water-quality conditions among National Water-Quality Assessment Study Units, 1992-95*. U.S. Geological Survey Open-File Report 97-589. Available on the Internet at: http://ca.water.usgs.gov/pnsp/rep/ofr97589, last updated October 9, 1998.

Thelin, G.P., and L.P. Gianessi. 2000. *Method for Estimating Pesticide Use for County Areas of the Conterminous United States.* U.S. Geological Survey Open-File Report 00-250. 62 pp. Available on the Internet at: http://water.wr.usgs.gov/pnsp/rep/ofr00250/ofr00250.pdf

USEPA. 2000a. *Interim Reregistration Eligibility Decision (IRED): Oxamyl.* EPA Report 738-R-00-015. Washington, DC: Office of Prevention, Pesticides, and Toxic Substances, USEPA. 135 pp. October 2000. Available on the Internet at: http://www.epa.gov/REDs/0253ired.pdf

USEPA. 2000b. *R.E.D. Facts: Oxamyl*. EPA Report 738-F-00-013. Washington, DC: Office of Prevention, Pesticides, and Toxic Substances, USEPA. 4 pp. November 2000. Available on the Internet at: http://www.epa.gov/oppsrrd1/REDs/factsheets/0253iredfact.pdf, last updated June 21, 2001.

USEPA. 2001. *National Primary Drinking Water Regulations - Consumer Factsheet on: OXAMYL (VYDATE)*. Available on the Internet at: http://www.epa.gov/safewater/dwh/c-soc/oxamyl.html, last updated April 12, 2001.

USEPA. 2002. *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT*. EPA Report/815-D-02-005, Office of Water, 55 pp.

USGS. 1998a. *Annual Use Maps*. Available on the Internet at: http://water.wr.usgs.gov/pnsp/use92/, last updated March 20, 1998.

USGS. 1998b. *Sources & Limitations of Data Used to Produce Maps of Annual Pesticide Use*. Available on the Internet at: http://water.wr.usgs.gov/pnsp/use92/mapex.html, last updated March 20, 1998.

USGS. 1998c. *Pesticides in Surface and Ground Water of the United States: Summary of Results of the National Water Quality Assessment Program (NAWQA). PROVISIONAL DATA -- SUBJECT TO REVISION*. Available on the Internet at: http://water.wr.usgs.gov/pnsp/allsum/, last updated October 9, 1998.

USGS. 2000. *PESTICIDES ANALYZED IN NAWQA SAMPLES: Use, Chemical Analyses, and Water-Quality Criteria* (PROVISIONAL DATA -- SUBJECT TO REVISION). Available on the Internet at: http://water.wr.usgs.gov/pnsp/anstrat/, last updated August 20, 1999.

Wade Miller Associates, Inc. 1989. *Occurrence and Exposure Assessment of Oxamyl in Public Drinking Water Supplies - DRAFT*. Draft report submitted to EPA for review April 12, 1989.

3.12 Picloram

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Tables and Figures

3.12.1 Introduction, Use and Production

Picloram, (4-amino-3,5,6-trichloropicolinic acid) in the pyridine family of compounds, is a crystalline organic solid with a chlorine-like odor. Picloram is formulated either as an acid (technical product) or as a potassium salt. In salt form, it is used as a systemic herbicide. It is used for controlling annual weeds on crops, and in combination with 2,4-D or 2,4,5-T against perennials on non-croplands for brush control. It also controls a wide range of broad-leaved weeds excepting mustards (crucifers). Most grasses are resistant to picloram so it is used in range management programs. Picloram is used to control bitterweed, knapweed, leafy spurge, locoweed, larkspur, mesquite, prickly pear, and snakeweed on rangeland in the western States (USEPA, 2001). Commercial products containing picloram have trade names including Grazon and Tordon. The compound may be used in formulations with other herbicides such as bromoxynil, atropine, diuron, 2,4-D, MCPA, triclorpyr, and atrazine among others. Picloram is also compatible with fertilizers (EXTOXNET, 2001).

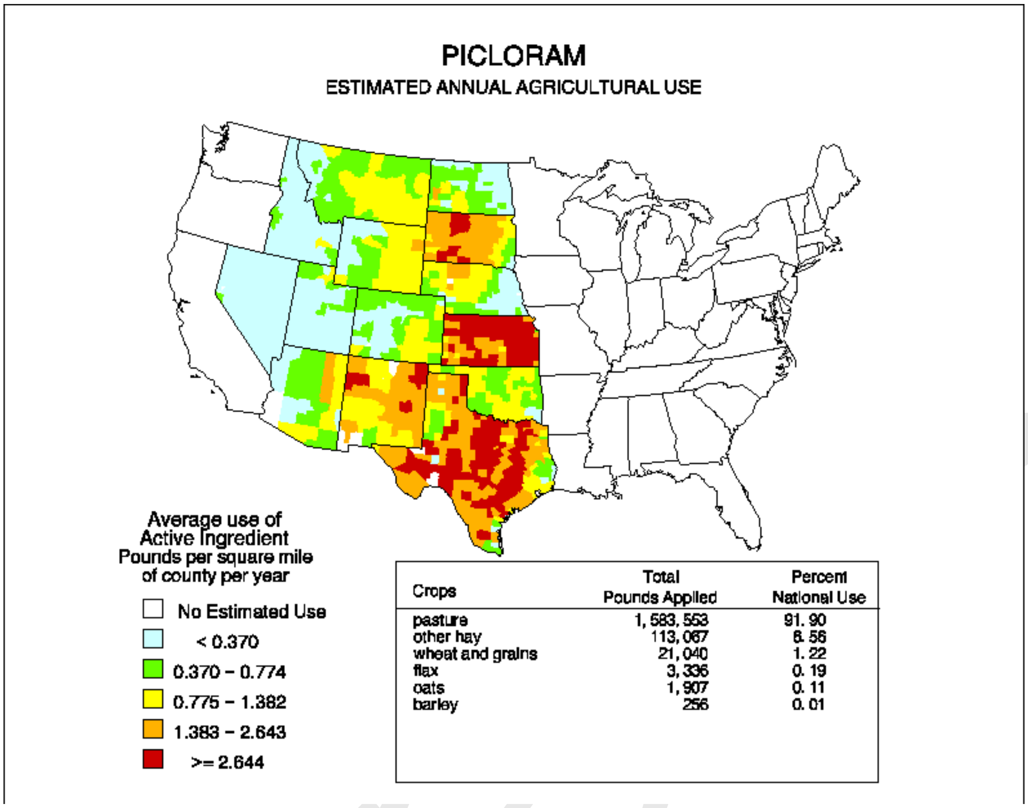
Picloram is a systemic herbicide used to control deeply rooted herbaceous weeds and woody plants in rights-of-way, forestry, rangelands, pastures, and small grain crops (USEPA, 1995). It is applied in the greatest amounts to pasture and rangeland, followed by forestry. Picloram acid is a manufacturing use product with no end uses. Picloram products have no household or residential uses. All picloram products are classified as Restricted Use Pesticides, based on hazard to nontarget plants, and may be applied only by or under the direct supervision of certified applicators (USEPA, 1995).

No information was found that suggested any natural production of picloram. Picloram is produced domestically for commercial markets by Dow Chemical USA, and by Union Carbide (Wade Miller, 1989). Picloram is produced by chlorination of a-picoline (2-methylpyridine) and reaction with ammonia, followed by hydrolysis of the intermediate 4-amino-3,5,6, a, a, a-hexachloropicoline (Kirk-Othmer, 1980, as cited in Wade Miller, 1989). Domestic production of picloram was estimated to be between 2.2 and 2.9 million pounds in 1981; approximately 1.4 to 1.9 million pounds were exported (Schutte, 1982, as cited in Wade Miller, 1989).

Picloram is registered for use on pastureland and rangeland grasses in the following States: Alabama, Arkansas, Colorado, Georgia, Kansas, Kentucky, Louisiana, Mississippi, Missouri, New Mexico, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia (USEPA, 1981, as cited in Wade Miller, 1989). Picloram is registered for use on uncultivated agricultural areas, rights-of-way, commercial and industrial premises, forests, and drainage ditch banks in the following States: California, Colorado, Hawaii, Idaho, Minnesota, Nebraska, Oregon, South Dakota, Utah, Washington, West Virginia, and Wyoming (USEPA, 1981, as cited in Wade Miller, 1989).

Recent national estimates of agricultural use for picloram are available. The United States Geological Survey (USGS) estimates approximately 1.7 million pounds of picloram active ingredient used for the year 1992, with roughly 7 million acres treated (USGS, 1999). These estimates were derived using State-level data sets on pesticide use rates available from NCFAP combined with county-level data on harvested crop acreage from the Census of Agriculture (CA) (Thelin and Gianessi, 2000). Figure 3.12-1 shows the geographic distribution of estimated average annual picloram use in the United States for 1992 (USGS, 1998a). A breakdown of use by crop is also included. By far, the greatest amount of picloram is used in pasture (92%). A comparison of this use map with the map of the 16 cross-section States (Figure 1.3-1) shows that States across the range of high of low picloram use are well represented in the cross-section.

Figure 3.12-1: Picloram Estimated Annual Agricultural Use



Crops	Total Pounds Applied	Percent National Use
pasture	1,583,553	91.90
other hay	113,067	6.56
wheat and grains	21,040	1.22
flax	3,336	0.19
oats	1,907	0.11
barley	256	0.01

Source: USGS, 1998a

3.12.2 Environmental Release

Picloram is listed as a Toxics Release Inventory (TRI) chemical. Table 3.12-1 illustrates the environmental releases for picloram from 1995 - 1999. (There are only picloram data for these years.) Air emissions and surface water discharges are the sole contributors to total on- and off-site releases. Between 1995 and 1999, the releases of air emissions fluctuated greatly, with a dramatic increase in 1997 and 1999. Surface water discharges were generally very low, with the exception of a huge peak in 1998 (almost 400,000 pounds). No underground injection, releases to land (such as spills or leaks within the boundaries of the reporting facility), or off-site releases (including metals or metal compounds transferred off-site) were reported for picloram. These TRI data for picloram were reported from only Michigan and Texas (USEPA, 2000), both of which are included in the 16-State cross-section (used for analyses of picloram occurrence in drinking water; see Section 3.12.4). (For a map of the 16-State cross-section, see Figure 1.3-1.)

Table 3.12-1: Environmental Releases (in pounds) for Picloram in the United States, 1995-1999

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1999	2,800	10	--	--	--	2,810
1998	460	380,006	--	--	--	380,466
1997	2,900	0	--	--	--	2,900
1996	522	0	--	--	--	522
1995	220	1	--	--	--	221

Source: USEPA, 2000

3.12.3 Ambient Occurrence

Picloram is an analyte for both surface and ground water NAWQA studies, with a method detection limit (MDL) of 0.05 µg/L. Table 3.12-2 summarizes the findings of USGS NAWQA sampling for picloram within the first 20 NAWQA study basins. Picloram concentrations at all of the surface water sites were below the detection limit in most sites, although it was detected in at least one sample. Also, picloram concentrations at all of the ground water sites were below the detection limit in most sites, although it was detected in at least one sample.

Table 3.12-2: Picloram Detections and Concentrations in Surface Water and Ground Water

	Detection frequency (% of samples)			Concentration percentiles (all samples; µg/L)			
	all samples	> 0.01 µg/L	> 0.05 µg/L	10th	median	95th	max
surface water							
agricultural	ND	--	ND	<MDL	<MDL	<MDL	<MDL
urban	ND	--	ND	<MDL	<MDL	<MDL	<MDL
integrator	ND	--	ND	<MDL	<MDL	<MDL	<MDL
all sites	0.15%	--	0.12%	<MDL	<MDL	<MDL	2.7
ground water							
agricultural	0.11%	--	ND	<MDL	<MDL	<MDL	2.2
urban	ND	--	ND	<MDL	<MDL	<MDL	--
major aquifers	ND	--	ND	<MDL	<MDL	<MDL	--
all sites	0.20%	--	0.20%	<MDL	<MDL	<MDL	2.2

ND=No detect
Source: USGS, 1998b

3.12.3.2 Additional Ambient Occurrence Data

A summary document entitled “Occurrence and Exposure Assessment of Picloram in Public Drinking Water Supplies” (Wade Miller, 1989), was previously prepared for past USEPA assessments of picloram. In that review, several national studies were included on the occurrence of picloram in both ground water and surface water non-drinking water sources. The following information is taken directly from “Occurrence and Exposure Assessment of Picloram in Public Drinking Water Supplies” (Wade Miller, 1989).

3.12.3.2.1 Groundwater Sources

Picloram was detected in five out of 77 groundwater samples collected at 49 locations throughout the United States. Picloram was detected in seven States. The 85th percentile of all nonzero samples was 1.0 µg/1 in groundwater sources. The maximum concentration found was 1.0 µg/L (USEPA, 1987, as cited in Wade Miller, 1989). No other sampling information was provided.

The Pesticides in Groundwater Data Base, developed by EPA’s Offices of Pesticide Programs (OPP), contains information derived from monitoring studies conducted by pesticide registrants, universities, and government agencies (Williams et al., 1988, as cited in Wade Miller, 1989). The data are presented in several categories, including all information collected to date (excluding data known to be of poor quality and data that is from point source contamination); data derived from scientifically confirmed agricultural use; and confirmed information attributed to known point sources and documented misuse. Three States have confirmed detections of picloram in groundwater attributed to normal agricultural use with a maximum concentration of 49 µg/L and a median concentration of 1.4 µg/L.

While extreme care was taken to confirm detections of pesticides in ground water, the reader is warned that the studies investigated have not been limited to drinking water supplies. Some studies included samples from many types of wells including observation and irrigation wells. In addition, many studies have focused on shallow ground water which may not be representative of drinking water sources in the area. As such, the results cannot be used to estimates human exposure to pesticides in drinking water, but do provide an additional assessment of possible picloram occurrence.

3.12.3.2.2 Surface Water Sources

Picloram was detected in 359 out of 653 surface water samples collected at 124 locations throughout the United States. Picloram was detected in seven States. The 85th percentile of all nonzero samples was 0.13 µg/L in surface water. The maximum concentration found was 4.6 µg/L (USEPA, 1987, as cited in Wade Miller, 1989). No other sampling information was provided.

3.12.4 Drinking Water Occurrence Based on the 16-State Cross-Section

The analysis of picloram occurrence presented in the following section is based on State compliance monitoring data from the 16 cross-section States. The 16-State cross-section is the largest and most comprehensive compliance monitoring data set compiled by EPA to date. These data were evaluated relative to several concentration thresholds of interest: 1 mg/L; 0.5 mg/L; and 0.05 mg/L.

All sixteen cross-section State data sets, with the exception of New Jersey, contained occurrence data for picloram. These data represent almost 46,000 analytical results from approximately 13,000 PWSs during the period from 1983 to 1998 (with most analytical results from 1992 to 1997). The number of sample results and PWSs vary by State, although the State data sets have been reviewed and checked to ensure adequacy of coverage and completeness. The overall modal detection limit for picloram in the 16 cross-section States is equal to 0.0001 mg/L. (For details regarding the 16-State cross-section, please refer to Section 1.3.5 of this report.)

3.12.4.1 Stage 1 Analysis Occurrence Findings

Table 3.12-3 illustrates the very low occurrence of picloram in drinking water for the public water systems in the 16-State cross-section. No ground water or surface water PWSs (therefore, no population served by systems, as seen in Table 3.12-4) had any analytical results exceeding 1 mg/L, 0.5 mg/L, or 0.005 mg/L.

Table 3.12-3: Stage 1 Picloram Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Ground Water	1	0.000%	0
	0.5	0.000%	0
	0.05	0.000%	0
Surface Water	1	0.000%	0
	0.5	0.000%	0
	0.05	0.000%	0
Combined Ground & Surface Water	1	0.000%	0
	0.5	0.000%	0
	0.05	0.000%	0

Table 3.12-4: Stage 1 Picloram Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Ground Water	1	0.000%	0
	0.5	0.000%	0
	0.05	0.000%	0
Surface Water	1	0.000%	0
	0.5	0.000%	0
	0.05	0.000%	0

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Combined Ground & Surface Water	1	0.000%	0
	0.5	0.000%	0
	0.05	0.000%	0

3.12.4.2 Stage 2 Analysis Occurrence Findings

The Stage 2 occurrence findings, based on the cross-section data, are presented in Tables 3.12-5 and 3.12-6. The statistically generated best estimate values, as well as the ranges around the best estimate value, are presented. (For a review of the Stage 2 analytical approach, please refer to Section 1.4 of this report. For complete details regarding the Stage 2 analyses, please refer to *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations* (USEPA, 2002)).

No ground water or surface water PWSs (therefore, no population served by systems) had an estimated mean concentration of picloram exceeding 1 mg/L, 0.5 mg/L or 0.05 mg/L.

Table 3.12-5: Stage 2 Estimated Picloram Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	1	0.000%	0.000% - 0.000%	0	0 - 0
	0.5	0.000%	0.000% - 0.000%	0	0 - 0
	0.05	0.000%	0.000% - 0.000%	0	0 - 0
Surface Water	1	0.000%	0.000% - 0.000%	0	0 - 0
	0.5	0.000%	0.000% - 0.000%	0	0 - 0
	0.05	0.000%	0.000% - 0.000%	0	0 - 0
Combined Ground & Surface Water	1	0.000%	0.000% - 0.000%	0	0 - 0
	0.5	0.000%	0.000% - 0.000%	0	0 - 0
	0.05	0.000%	0.000% - 0.000%	0	0 - 0

Table 3.12-6: Stage 2 Estimated Picloram Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	1	0.000%	0.000% - 0.000%	0	0 - 0
	0.5	0.000%	0.000% - 0.000%	0	0 - 0
	0.05	0.000%	0.000% - 0.000%	0	0 - 0
Surface Water	1	0.000%	0.000% - 0.000%	0	0 - 0
	0.5	0.000%	0.000% - 0.000%	0	0 - 0
	0.05	0.000%	0.000% - 0.000%	0	0 - 0
Combined Ground & Surface Water	1	0.000%	0.000% - 0.000%	0	0 - 0
	0.5	0.000%	0.000% - 0.000%	0	0 - 0
	0.05	0.000%	0.000% - 0.000%	0	0 - 0

3.12.4.3 Estimated National Occurrence

As illustrated in Table 3.12-7, the Stage 2 analysis estimates zero systems serving zero people nationally have estimated mean concentration values of picloram greater than 1 mg/L, 0.5 mg/L, or 0.05 mg/L. (See Section 1.4 for a description of how Stage 2 16-State estimates are extrapolated to national values.)

Table 3.12-7: Estimated National Picloram Occurrence - Systems and Population Served

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	1	0	0 - 0	0	0 - 0
	0.5	0	0 - 0	0	0 - 0
	0.05	0	0 - 0	0	0 - 0
Surface Water	1	0	0 - 0	0	0 - 0
	0.5	0	0 - 0	0	0 - 0
	0.05	0	0 - 0	0	0 - 0

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Combined Ground & Surface Water	1	0	0 - 0	0	0 - 0
	0.5	0	0 - 0	0	0 - 0
	0.05	0	0 - 0	0	0 - 0

3.12.5 Additional Drinking Water Occurrence Data

For a previous USEPA assessment of picloram occurrence in drinking water, a literature search was conducted and knowledgeable sources within the Office of Water were contacted. No national studies were found on the occurrence of picloram in drinking water from ground water or surface water sources, nor were any regional or State studies found that addressed the occurrence of picloram in drinking water from surface water sources (Wade Miller, 1989). However, some regional studies of ground water were found. Note that none of the studies presented in the following section provide the quantitative analytical results or comprehensive coverage that would enable direct comparison to the occurrence findings estimated with the cross-section occurrence data presented in Section 3.12.4. These additional studies, however, do enable a broader assessment of the Stage 2 occurrence estimates presented for this Six-Year Review. All the following information in Section 3.12.5 is taken directly from “Occurrence and Exposure Assessment of Picloram in Public Drinking Water Supplies” (Wade Miller, 1989).

EPA has developed contamination incidence surveys, which were subsequently distributed to States by their Federal/State Toxicological and Regulatory Alliance Committee (FSTRAC). As of April 1988, the contamination incidence surveys of 11 States have been returned and summarized by EPA, Region VII (Schlachter, 1988, as cited in Wade Miller, 1989). These States include: California, Iowa, Massachusetts, Michigan, Minnesota, Nebraska, Pennsylvania, Rhode Island, South Dakota, Texas, and Wisconsin. The summary provided limited information on the occurrence of picloram in public ground water supplies. Picloram was only detected in South Dakota in two samples from 17 sites, though at values of 520 and 8,300 µg/L (mean = 4,410 µg/L). No detection limit or other sampling information was reported.

From July 1985 to June 1987, the Minnesota Departments of Health (MDH) and Agriculture (MDA) conducted cooperative surveys of observation, irrigation, and drinking water wells for selected pesticides (MDH and MDA, 1988, as cited in Wade Miller, 1989). These studies were designed to provide information on the extent of agricultural pesticide contamination in Minnesota's ground water and drinking water. In the first survey (MDA), picloram was not detected in any of the 100 samples taken. The detection limit for the MDA survey was 1.8 µg/L. In the second survey (MDH), picloram was found in five samples from three wells, out of 400 wells sampled, at a median concentration of 0.16 µg/L (range = 0.08-0.63 µg/L). The detection limit for the MDH survey was 0.04 µg/L. The summary report did not distinguish between observation, irrigation, and drinking water wells.

3.12.6 Conclusion

Picloram is a systemic herbicide used to control deeply rooted herbaceous weeds and woody plants in rights-of-way, forestry, rangelands, pastures, and small grain crops. Picloram products are all restricted use pesticides. Approximately 1.7 million pounds of picloram were used in 1992 on pastureland and for other agricultural applications. The greatest concentrations of use are in Texas, New Mexico, and the upper Midwest. Industrial releases of picloram have been reported to TRI from two States since 1995. Picloram was also an analyte for the NAWQA occurrence studies. In the NAWQA study, picloram was detected in ground and surface water; however, none of the median values exceeded the detection limit. The Stage 2 analysis, based on the 16-State cross-section, estimated that zero percent of combined ground water and surface water systems serving zero percent of the population exceeded the MCL of 0.5 mg/L. Based on this estimate, zero PWSs nationally are estimated to have picloram levels greater than the MCL.

The 16-State cross-section was designed to be nationally representative based upon VOC, SOC, and IOC pollution potentials as suggested by considerations of manufacturing, agriculture, and geographic diversity factors. Nationally, according to information from USGS, 14 States use picloram agriculturally, including 5 of the cross-section States. Picloram use is heaviest in Texas, New Mexico, and Kansas, two of which are cross-section States. Nationally, TRI releases have been reported for picloram from 2 States, both of which are cross-section States. The cross-section should adequately represent the occurrence of picloram on a national scale based upon the use, production, and release patterns of the 16-State cross-section in relation to the patterns observed for all 50 States.

3.12.7 References

Gilliom, R.J., D.K. Mueller, and L.H. Nowell. 1998. *Methods for comparing water-quality conditions among National Water-Quality Assessment Study Units, 1992-95*. U.S. Geological Survey Open-File Report 97-589. Available on the Internet at: http://ca.water.usgs.gov/pnsp/rep/ofr97589/, last updated October 9, 1998.

EXTOXNET. 2001. *Pesticide Information Profile: Picloram*. Ithaca, NY: Extension Toxicology Network, Pesticide Management Education Program. Available on the Internet at http://ace.ace.orst.edu/info/extoxnet/pips/picloram.htm, revised March, 2001.

Kirk-Othmer. 1980. Herbicides. In: *Kirk-Othmer Encyclopedia of Chemical Technology.* Vol. 12, 3rd ed. New York, NY: John Wiley and Sons. pp. 297-351.

Minnesota Department of Health (MDH) and Minnesota Department of Agriculture (MDA). 1988. *Pesticides and Groundwater: Surveys of Selected Minnesota Wells.* Prepared by Tomas G. Klaseus (MDH), Greg C. Buzicky (MDA), and Edward C. Schneider (MDH) for Legislative Commission on Minnesota Resources. February 1988.

Schlachter, J. 1988. Memorandum on Program Improvement Subcommittee, FSTRAC, Preparation for April Meeting. Sent by Jacquelyn D. Schlachter, Chairman - Program Improvement Subcommittee, U.S. Environmental Protection Agency, Region VII, Kansas City, KS. Sent to Dennis Alt, IA; Pam Bonrud, SD; Bill Lee, NE; Kathy Miller, MT; Jennifer Orme, HQ; Sheila Sullivan, EPA Region V; and Dan Wilson, WI.

Schutte, W.D. 1982. *Preliminary Quantitative Usage Analysis of Picloram.* Economic Analysis Branch, Office of Pesticide Programs, U.S. Environmental Protection Agency, Arlington, VA. June, 1982.

Thelin, G.P., and L.P. Gianessi. 2000. *Method for Estimating Pesticide Use for County Areas of the Conterminous United States.* U.S. Geological Survey Open-File Report 00-250. 62 pp. Available on the Internet at: http://water.wr.usgs.gov/pnsp/rep/ofr00250/ofr00250.pdf

USEPA. 1981. *EPA Index to Pesticide Chemicals. Picloram, Potassium, Salt.* Washington, DC: Office of Pesticide Programs, USEPA.

USEPA. 1987. *Picloram Health Advisory.* Washington, DC: Office of Drinking Water, USEPA. August, 1987.

USEPA. 1995. *Registration Eligibility Decision (RED): Picloram*. EPA Report 738-R-95-019. Washington, DC: Office of Prevention, Pesticides, and Toxic Substances, USEPA. 283 pp. Available on the Internet at: http://www.epa.gov/oppsrrd1/REDs/, last updated June 21, 2001.

USEPA. 2000. *TRI Explorer: Trends*. Available on the Internet at: http://www.epa.gov/triexplorer/trends.htm, last updated May 5, 2000.

USGS. 1998a. *Annual Use Maps*. Available on the Internet at: http://water.wr.usgs.gov/pnsp/use92/, last updated March 20, 1998.

USEPA. 2001. *National Primary Drinking Water Regulations - Consumer Factsheet on: PICLORAM.* Available on the Internet at: http://www.epa.gov/safewater/dwh/c-soc/picloram.html, last updated April 12, 2001.

USEPA. 2002. *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT*. EPA Report/815-D-02-005, Office of Water, 55 pp.

USGS. 1998b. *Pesticides in Surface and Ground Water of the United States: Summary of Results of the National Water Quality Assessment Program (NAWQA). PROVISIONAL DATA -- SUBJECT TO REVISION*. Available on the Internet at: http://water.wr.usgs.gov/pnsp/allsum/ last updated October 9, 1998.

USGS. 1999. *PESTICIDES ANALYZED IN NAWQA SAMPLES: Use, Chemical Analyses, and Water-Quality Criteria* (PROVISIONAL DATA -- SUBJECT TO REVISION). Available on the Internet at: http://water.wr.usgs.gov/pnsp/anstrat/, last updated August 20, 1999.

Wade Miller Associates, Inc. 1989. *Occurrence and Exposure Assessment of Picloram in Public Drinking Water Supplies.* Prepared for and submitted to EPA on April 24, 1989.

Williams, W.M., P.W. Holden, D.W. Parsons, and M.N. Lorber. 1988. *Pesticides in groundwater Data Base.* Washington, DC: Office of Pesticide Programs, U.S. Environmental Protection Agency.

3.13 Simazine

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Tables and Figures

3.13.1 Introduction, Use and Production

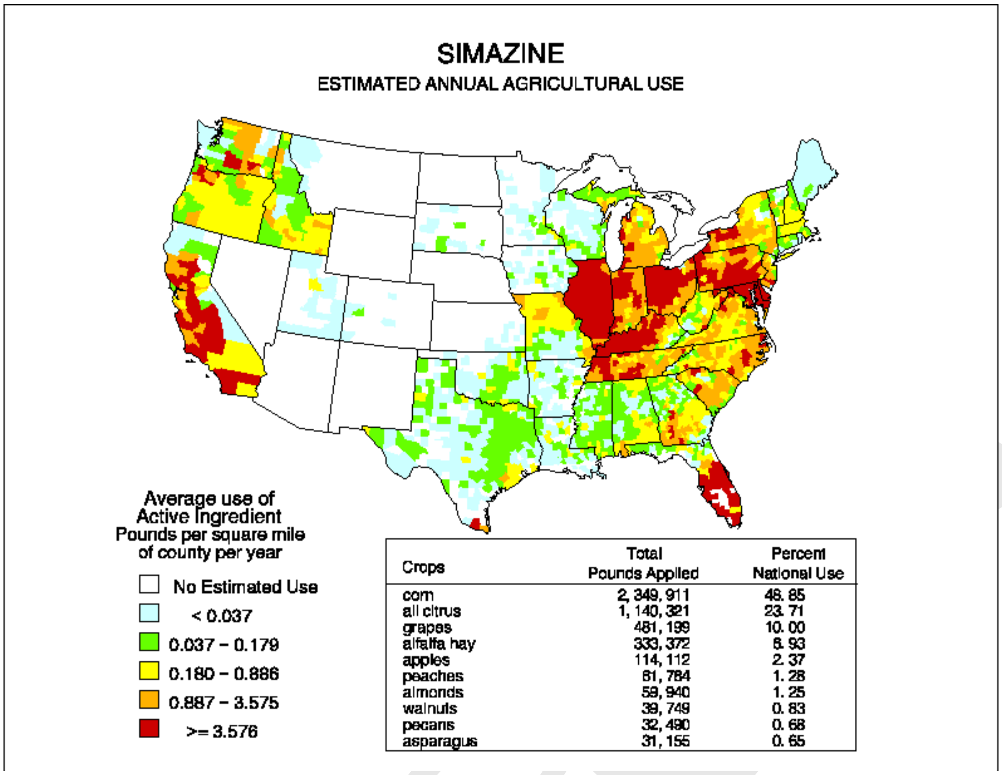
Simazine [2-chloro-4,6-bis(ethylamino)-s-triazine], is an organic white solid. It is available in wettable powder, water dispersible granule, liquid, and granular formulations. It may also be soil-applied (EXTOXNET, 1996). Simazine is used on a variety of deep-rooted crops such as artichokes, asparagus, berry crops, broad beans, citrus, etc., and on non-crop areas such as farm ponds and fish hatcheries. Its major use is on corn where it is often combined with AAtrex. Other herbicides with which simazine is combined include: paraquat, on apples, peaches; Roundup or Oust for non-crop use; Surflan on Christmas trees; Dual on corn and ornamentals (USEPA, 2001).

Simazine is a selective triazine herbicide (EXTOXNET, 1996). It is used as a pre-emergence herbicide for control of broad-leaved and grassy weeds on a variety of deep-rooted crops such as artichokes, asparagus, berry crops, broad beans, citrus, etc., and on non-crop areas. Its major use is on corn (USEPA, 2001). At higher rates, simazine is used for nonselective weed control in industrial areas. Before 1992, it was used to control submerged weeds and algae in large aquariums, farm ponds, fish hatcheries, swimming pools, ornamental ponds, and cooling towers (EXTOXNET, 1996). In 1975, the consumption pattern of simazine was approximately as follows: 49%, corn; 8%, citrus; 6%, deciduous fruits; 5%, field crops; 3%, vegetables; 17%, industrial commercial uses; and 13%, aquatic uses (HSDB, 2001).

Two manufacturers of simazine are Drexel Chemical Company in Memphis, TN and Novartis Corporation in Summit, NJ. Although production data is seemingly scarce, there is information on consumption of simazine in the U.S. Agricultural use of simazine by year is approximately as follows: in 1989, 3.96 million pounds active ingredient (ai); 1982, 3.98 million pounds ai; 1976, 3.25 million pounds ai; 1971, 1.74 million pounds ai; and 1966, 193,000 pounds ai (HSDB, 2001).

Recent national estimates of agricultural use for simazine are available. Figure 3.13-1 illustrates the USGS (1998a) derived geographic distribution of estimated average annual simazine use in the United States for 1992. USGS (1998a) estimates approximately 4.81 million pounds of simazine active ingredient were used in 1992. A breakdown of use by crop is also included. Corn accounts for the majority of usage (2.35 million pounds simazine active ingredient), while intermediate use can be found on several other crops as well (e.g., citrus, grapes, alfalfa, apples, peaches, almonds, etc.) (USGS, 1998a). The two largest concentrations of simazine use are seen in the corn growing area of the Midwest and the citrus areas in California and Florida, with some concentration also in the Mid-Atlantic States and Washington State (Figure 3.13-1). Note that non-agricultural uses are not reflected here, and any sharp spatial differences in use within a county may not be well represented (USGS, 1998b). A comparison of this use map with the map of the 16 cross-section States (Figure 1.3-1) shows that States across the range of high of low simazine use are well represented in the cross-section.

Figure 3.13-1: Estimated Annual Agricultural Use for Simazine (1992)



Crops	Total Pounds Applied	Percent National Use
corn	2, 349, 911	48. 85
all citrus	1, 140, 321	23. 71
grapes	481, 199	10. 00
alfalfa hay	333, 372	6. 93
apples	114, 112	2. 37
peaches	61, 784	1. 28
almonds	59, 940	1. 25
walnuts	39, 749	0. 83
pecans	32, 490	0. 68
asparagus	31, 155	0. 65

Source: USGS, 1998a

3.13.2 Environmental Release

Simazine is listed as a Toxics Release Inventory (TRI) chemical. Table 3.13-1 illustrates the environmental releases for simazine from 1995 - 1999. (There are only simazine data for these years.) From 1995 to 1999, the releases of air emissions has generally decreased. Surface water discharges generally hovered around 300 pounds. No underground injection or releases to land (with the exception of 5 pounds reported in 1995) were reported for simazine. The amount of off-site releases (including metals or metal compounds transferred off-site) has steadily decreased since 1995, with a dramatic decrease in 1998. Decreases in air emissions and off-site releases have predominantly contributed to the decreasing amount of total on- and off-site simazine releases. These TRI data for simazine were reported from 8 States. Four of these 8 States reported TRI data every year (USEPA, 2000). Two of the 8 States (Alabama and Nebraska) are included in the 16-State cross-section (used for analyses of simazine occurrence in drinking water; see Section 3.13.4). (For a map of the 16-State cross-section, see Figure 1.3-1.)

Table 3.13-1: Environmental Releases (in pounds) for Simazine in the United States, 1995-1999

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1999	3,928	385	--	0	2,385	6,698
1998	3,321	332	--	0	4,497	8,150
1997	2,939	348	0	0	48,629	51,916
1996	4,591	93	0	0	54,457	59,141
1995	4,990	232	--	5	26,231	31,458

Source: USEPA, 2000

3.13.3 Ambient Occurrence

Simazine is an analyte for both surface and ground water NAWQA studies, with a method detection limit (MDL) of 0.005 µg/L. Additional information on analytical methods used in the NAWQA study units, including method detection limits, are described by Gilliom and others (1998).

Table 3.13-2 summarizes the findings of USGS NAWQA sampling for simazine within the first 20 NAWQA study basins (USGS, 1998c). Simazine concentrations at ground and surface sites exceed the detection limit in all sites. High percentages of both ground and surface water samples exceed detection frequencies of 0.01 and 0.05 µg/L, although surface water sample percentages are notably higher than ground water sample percentages. Within surface water sites, urban sites have consistently higher percentage exceeding the detection frequencies then agricultural or integrator sites. Within ground water sites, agricultural sites have consistently higher percentage exceeding the detection frequencies then urban or integrator sites. The 95th percentile value and maximum concentration also exceed the detection limit in all ground and surface water sites. The median concentration values exceed the detection limit for all surface water sites, while none of the median concentration values exceed the detection limit for any ground water sites.

Table 3.13-2: Simazine Detections and Concentrations in Surface Water and Ground Water

	Detection frequency (% of samples)			Concentration percentiles (all samples; µg/L)			
	all samples	> 0.01 µg/L	> 0.05 µg/L	10th	median	95th	max
surface water							
agricultural	61.74%	44.76%	16.98%	<MDL	0.007	0.27	5.76E
urban	87.77%	80.73%	40.67%	<MDL	0.039	0.67	8.2E
integrator	82.93%	64.63%	27.64%	<MDL	0.017	0.21	1.3
all sites	65.61%	53.86%	25.35%	<MDL	0.012	0.38	20E

	Detection frequency (% of samples)			Concentration percentiles (all samples; µg/L)			
ground water							
agricultural	22.38%	13.30%	4.54%	<MDL	<MDL	0.042	1.3
urban	15.28%	11.30%	3.65%	<MDL	<MDL	0.03	1.1
major aquifers	6.32%	3.00%	0.75%	<MDL	<MDL	0.003	0.11
all sites	15.91%	9.52%	3.27%	<MDL	<MDL	0.024	1.3

Note: Individual maximum values with an "E-code" have much greater uncertainty because the values were beyond the calibration range.
Source: USGS, 1998c

Simazine was also an analyte in the 1999 Pilot Monitoring Program (Blomquist et. al, 2001). Simazine was detected in almost 30% of the 323 raw water samples and in about 84% of the 228 finished water samples. The 95th percentile value was equal to 0.028 µg/L and 0.385 µg/L for raw and finished water samples, respectively. The maximum concentration of simazine in raw water was 1.520 µg/L. In finished water, the maximum concentration of simazine was 0.571 µg/L.

3.13.3.1 Additional Ambient Occurrence Data

A summary document entitled "Occurrence and Exposure Assessment of Simazine in Public Drinking Water Supplies" (Wade Miller, 1989), was previously prepared for past USEPA assessments of simazine. In that review, several national and regional studies were included on the occurrence of simazine in both ground water and surface water non-drinking water sources. The following information is taken directly from "Occurrence and Exposure Assessment of Simazine in Public Drinking Water Supplies" (Wade Miller, 1989).

3.13.3.1.1 Groundwater Sources – National Studies

Simazine has been found in 229 of 2,282 groundwater samples (USEPA, 1987, as cited in Wade Miller, 1989). Samples were collected at 1,730 groundwater locations, and simazine was detected in 22 States. The 85th percentile of all nonzero samples was 1.60 µg/L in groundwater sources. The maximum concentration found in groundwater was 800 µg/L. No further information was provided.

The USEPA Office of Pesticide Programs developed a data base containing information derived from monitoring studies conducted by pesticide registrants, universities, and government agencies (Williams et al., 1988, as cited in Wade Miller, 1989). Six categories were designed to present the data; category 2 which includes all information collected except for data known to be of poor quality and data that is from known point source contamination; category 5 which includes data derived from scientifically confirmed studies where contamination is known to be solely due to normal agricultural use; and category 6 which includes confirmed information attributed to known sources or documented misuse. Seven States are reported to have confirmed detections of simazine in groundwater due to normal agricultural use. The maximum concentration reported was 9.1 µg/L. The median concentration reported was 0.3 µg/L.

The authors (Wade Miller, 1989) note that because studies included in the data base have not been confined to drinking water supplies, some studies include samples from many types of wells including observation and irrigation wells. In addition, since many studies have focused on shallow ground water, they may not be representative of drinking water sources in the area. For these reasons, use of these data for the estimation of human exposure to pesticides in drinking water is not advised.

3.13.3.1.2 Groundwater Sources – Regional Studies

The U.S. Environmental Protection Agency has developed contamination incidence surveys, that have been subsequently distributed to States by their Federal/State Toxicological and Regulatory Alliance Committee (FSTRAC). As of April 1988, the contamination incidence surveys of 11 States had been returned and summarized by EPA, Region VII (Schlachter, 1988, as cited in Wade Miller, 1989). These States include: California, Iowa, Massachusetts, Michigan, Minnesota, Nebraska, Pennsylvania, Rhode Island, South Dakota, Texas and Wisconsin. The summary provided limited information on the occurrence of simazine in ground water. Simazine was only detected in Wisconsin in four samples from 28 sites, at a range of 1.0-15.0 µg/L. No other sampling information was reported. It is unclear whether these detections are representative of ambient water or drinking water.

In a recent California study on the movement of pesticides and herbicides to groundwater (Cohen et al., 1984, as cited in Wade Miller, 1989), collected samples to determine the levels of simazine in groundwater. In analyses of samples collected from 166 wells, 6 wells were found to be contaminated with simazine at levels between 0.5 µg/L and 3.5 µg/L. The limits of detection were not reported.

3.13.3.1.3 Surface Water Sources – National Studies

Simazine has been found in 877 of 5,067 surface water samples analyzed throughout the United States (USEPA, 1987, as cited in Wade Miller, 1989). Samples were collected at 472 surface water locations, and simazine was detected in 22 States. The 85th percentile of all nonzero samples was 2.18 µg/L. The maximum concentration found in surface water was 1,300 µg/L.

Carey and Kutz (1983, as cited in Wade Miller, 1989) summarized a study on water samples collected and analyzed for pesticides and herbicides as part of the National Surface Water Monitoring Program. During the collection period (1976 to 1980), 0.4 percent of the samples tested contained levels of simazine in excess of the detection limit, with a maximum reported value of 1.13 µg/L. The detection limits were not reported.

3.13.3.1.4 Surface Water Sources – Regional Studies

In a partial overview of activities performed by the International Joint Commission's Pollution from Land Use Activities Reference Group (PLUARG), Baker (1987, as cited in Wade Miller, 1989) reported on rural nonpoint pollution in three northwest Ohio rivers. From 1983 to 1985, mean simazine values were not detected, 0.12 and 0.18 µg/L, respectively. The number of samples taken for these three years were 145, 183, and 188, respectively. Peak observed concentrations for the three years were 0.01, 1.25, and 0.98 µg/L, all of which were from the Sandusky River. No other sampling information was reported.

In a study on sediment, nutrient, and pesticide transport in lower Great Lakes tributaries, Baker (1986, as cited in Wade Miller, 1989) included a summary of an investigation of nonpoint source pollution of tributaries for Lake Erie and Lake Ontario for the years 1982-1985. Biweekly samples were collected each year between April 15 and August 15, when pesticide use was the greatest. The range of time weighted mean values reported for simazine was 0.0 - 0.84 µg/L. The number of positive samples was not reported; however, a total of 1,785 samples were taken from eight locations. The highest observed concentrations for simazine were 10.77 µg/L in the Cuyahoga River in 1982 and 6.93 µg/L in the Maumee River in 1982. The detection limit was reported to be 0.25 µg/L.

Baker (1983b, as cited in Wade Miller, 1989) assessed the results of a pesticide monitoring program conducted in Ohio. A total of 258 samples were collected from six streams of different watershed size during the April and August 1982 sampling period to compare peak pesticide concentrations. The range of peak concentrations was 2.52 to 10.7 µg/L of simazine, with an average peak value of 4.65 µg/L.

In a subsequent related report, Baker (1983a, as cited in Wade Miller, 1989) reported the average herbicide concentrations in samples collected from two rivers in Ohio from May 28 to July 27, 1983. Of the 23 surface water samples collected from each river, the average reported concentrations of simazine were 0.26 and 0.44 µg/L, respectively. The detection limits were not reported.

Baker et al. (1981, as cited in Wade Miller, 1989) assessed the results of a study to determine the concentrations of various pesticides in Northwestern Ohio rivers. Samples were collected from June 1981 to September 1981 during periods of peak pesticide usage and maximum pesticide export due to large amounts of runoff. The authors reported that the concentrations observed at the stream stations were generally higher than those reported in other areas. Low levels of simazine were detected in 100% of the 135 surface water samples collected from nine streams. The values ranged from 0.03 to 2.55 µg/L for simazine, with an average value of 0.60 µg/L. The detection limit for the analysis was not reported.

3.13.4 Drinking Water Occurrence Based on the 16-State Cross-Section

The analysis of simazine occurrence presented in the following section is based on State compliance monitoring data from the 16 cross-section States. The 16-State cross-section is the largest and most comprehensive compliance monitoring data set compiled by EPA to date. These data were evaluated relative to several concentration thresholds of interest: 0.004 mg/L; 0.002 mg/L; and 0.001 mg/L.

All sixteen cross-section State data sets, with the exception of New Jersey, contained occurrence data for simazine. These data represent more than 68,000 analytical results from approximately 15,000 PWSs during the period from 1984 to 1998 (with most analytical results from 1992 to 1997). The number of sample results and PWSs vary by State, although the State data sets have been reviewed and checked to ensure adequacy of coverage and completeness. The overall modal detection limit for simazine in the 16 cross-section States is equal to 0.001 mg/L. (For details regarding the 16-State cross-section, please refer to Section 1.3.5 of this report.)

3.13.4.1 Stage 1 Analysis Occurrence Findings

Table 3.13-3 illustrates the low occurrence of simazine in drinking water for the public water systems in the 16-State cross-section relative to three thresholds: 0.004 mg/L (the current MCL), 0.002 mg/L, and 0.001 mg/L (the modal MRL). A total of 8 (approximately 0.0550% of) ground water and surface water PWSs had analytical results exceeding the MCL; 0.144% of systems (21 systems) had results exceeding 0.002 mg/L; and 0.358% of systems (52 systems) had results exceeding 0.001 mg/L.

Zero ground water systems had analytical results greater than the MCL. Approximately 0.0152% of ground water systems (2 systems) had results above 0.002 mg/L. The percentage of ground water systems with at least one result greater than 0.001 mg/L was equal to 0.129% (17 systems).

The percentage of surface water systems with results greater than the MCL was equal to 0.573% (8 systems). Approximately 19 (1.36% of) surface water systems had at least one analytical result greater than 0.002 mg/L. Thirty-five (2.51% of) surface water systems had results exceeding 0.001 mg/L.

Table 3.13-3: Stage 1 Simazine Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Ground Water	0.004	0.000%	0
	0.002	0.0152%	2
	0.001	0.129%	17
Surface Water	0.004	0.573%	8
	0.002	1.36%	19
	0.001	2.51%	35
Combined Ground & Surface Water	0.004	0.0550%	8
	0.002	0.144%	21
	0.001	0.358%	52

Reviewing simazine occurrence in the 16 cross-section States by PWS population served (Table 3.13-4) shows that approximately 0.0471% of the 16-State population (about 46,300 people) was served by PWSs with at least one analytical result of simazine greater than the MCL (0.004 mg/L). Approximately 113,000 (0.115% of) people were served by systems with an exceedance of 0.002 mg/L. Over 1 million (1.06% of) people were served by systems with at least one analytical result greater than 0.001 mg/L.

The percentage of population served by ground water systems in the 16 States with analytical results greater than the MCL was equal to 0%. When evaluated relative to 0.002 mg/L and 0.001 mg/L, the percent of population exposed was equal to 0.0150% (about 6,200 people) and 0.823% (almost 342,000 people), respectively.

The percentage of population served by surface water systems in the 16 States with exceedances of 0.004 mg/L and 0.002 mg/L was equal to 0.0817% (46,300 people) and 0.189% (106,800 people) respectively. When evaluated relative to 0.001 mg/L, the percent of population exposed was equal to 1.23% (over 697,000 people).

Table 3.13-4: Stage 1 Simazine Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Ground Water	0.004	0.000%	0
	0.002	0.0150%	6,200
	0.001	0.823%	341,900

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Surface Water	0.004	0.0817%	46,300
	0.002	0.189%	106,800
	0.001	1.23%	697,100
Combined Ground & Surface Water	0.004	0.0471%	46,300
	0.002	0.115%	113,100
	0.001	1.06%	1,039,000

3.13.4.2 Stage 2 Analysis Occurrence Findings

The Stage 2 occurrence findings, based on the cross-section data, are presented in Tables 3.13-5 and 3.13-6. The statistically generated best estimate values, as well as the ranges around the best estimate value, are presented. (For a review of the Stage 2 analytical approach, please refer to Section 1.4 of this report. For complete details regarding the Stage 2 analyses, please refer to *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations* (USEPA, 2002)).

The percentages of ground water and surface water PWSs with estimated mean concentrations of simazine exceeding 0.004 mg/L, 0.002 mg/L, and 0.001 mg/L are 0.0000413%, 0.000509%, and 0.00992%, respectively.

Only 1 ground water PWS in the 16 States was estimated to have a mean concentration greater than 0.004 mg/L (0.0000305%), 0.002 mg/L (0.00289%) and 0.001 mg/L (0.00382%). The percentage of surface water systems with estimated mean concentration values greater than 0.004 mg/L was equal to 0.000143%. One surface water system in the 16 States was estimated to have a mean concentration value of simazine greater than 0.002 mg/L (0.00258%) and 0.001 mg/L (0.0673%).

Table 3.13-5: Stage 2 Estimated Simazine Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.004	0.0000305%	0.000% - 0.000%	1	0 - 0
	0.002	0.00289%	0.000% - 0.00761%	1	0 - 1
	0.001	0.00382%	0.000% - 0.0152%	1	0 - 2
Surface Water	0.004	0.000143%	0.000% - 0.000%	0	0 - 0
	0.002	0.00258%	0.000% - 0.0716%	1	0 - 1
	0.001	0.0673%	0.000% - 0.215%	1	0 - 3

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Combined Ground & Surface Water	0.004	0.0000413%	0.000% - 0.000%	1	0 - 0
	0.002	0.000509%	0.000% - 0.00688%	1	0 - 1
	0.001	0.00992%	0.000% - 0.0275%	1	0 - 4

Reviewing simazine occurrence by PWS population served (Table 3.13-6) shows that approximately 0.000107% of population served by all PWSs in the 16 States (an estimate of approximately 100 people) were potentially exposed to simazine levels above 0.004 mg/L. When evaluated relative to a threshold of 0.002 mg/L, the percent of population exposed was equal to 0.000897% (approximately 900 people). The percent of potential population exposed equaled 0.0197% (over 19,000 people in the 16 States) when evaluated relative to 0.001 mg/L.

The percentage of population served by ground water systems in the 16 States with estimated mean concentration values greater than 0.004 mg/L was equal to 0.000238% (an estimate of approximately 100 people) and the percentage served by surface water systems in the 16 States was equal to 0.0000106%. Approximately 700 (0.00178% of) people in the 16 cross-section States were served by ground water systems with estimated mean concentration values greater than 0.002 mg/L. The number of people in the 16 cross-section States served by surface water systems with estimated mean concentration values greater than 0.002 mg/L was equal to about 100 (0.000253% of) people. An estimated 4,100 (0.00991% of) people served by ground water systems in the in the 16 States were exposed to simazine at concentrations greater than 0.001 mg/L. Approximately 15,200 (0.0268% of) people were served by surface water systems with mean concentrations of simazine greater than 0.001 mg/L.

Table 3.13-6: Stage 2 Estimated Simazine Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.004	0.000238%	0.000% - 0.000%	100	0 - 0
	0.002	0.00178%	0.000% - 00733%	700	0 - 3,000
	0.001	0.00991%	0.000% - 0.0668%	4,100	0 - 27,700
Surface Water	0.004	0.0000106%	0.000% - 0.000%	0	0 - 0
	0.002	0.000253%	0.000% - 0.00382%	100	0 - 2,200
	0.001	0.0268%	0.000% - 0.147%	15,200	0 - 83,300

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Combined Ground & Surface Water	0.004	0.000107%	0.000% - 0.000%	100	0 - 0
	0.002	0.000897%	0.000% - 0.00310%	900	0 - 2,200
	0.001	0.0197%	0.000% - 0.105%	19,300	0 - 68,000

3.13.4.3 Estimated National Occurrence

Based on the Stage 2 estimated percent of systems (and population served by systems) exceeding each threshold, 1 system serving approximately 200 people nationally was estimated to have a mean concentration value of simazine greater than 0.004 mg/L. Approximately 1,900 people served by an estimated 1 system were potentially exposed to simazine concentrations greater than 0.002 mg/L. About 6 systems serving about 41,900 people nationally were estimated to have mean simazine concentrations greater than 0.001 mg/L. (See Section 1.4 for a description of how Stage 2 16-State estimates are extrapolated to national values.)

For ground water systems, approximately 1 PWSs serving about 200 people nationally was estimated to have a mean concentration greater than 0.004 mg/L. One ground water system serving approximately 1,500 people was estimated to have mean concentration value of simazine greater than 0.002 mg/L. An estimated 2 systems serving about 8,500 people nationally had estimated mean concentration values that exceeded 0.001 mg/L.

Zero surface water systems had estimated mean concentration values of simazine greater than 0.004 mg/L. Only 1 surface water systems serving about 300 people was estimated to have a mean concentration of simazine above 0.002 mg/L. Approximately 4 surface water systems serving 34,200 people had estimated mean concentrations greater than 0.001 mg/L.

Table 3.13-7: Estimated National Simazine Occurrence - Systems and Population Served

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.004	1	0 - 0	200	0 - 0
	0.002	1	0 - 5	1,500	0 - 6,300
	0.001	2	0 - 9	8,500	0 - 57,200
Surface Water	0.004	0	0 - 0	0	0 - 0
	0.002	1	0 - 4	300	0 - 4,900
	0.001	4	0 - 12	34,200	0 - 187,300

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Combined Ground & Surface Water	0.004	1	0 - 0	200	0 - 0
	0.002	1	0 - 4	1,900	0 - 6,600
	0.001	6	0 - 18	41,900	0 - 223,900

3.13.5 Additional Drinking Water Occurrence Data

Several additional data sources regarding the occurrence of fluoride in drinking water are also reviewed. Previously compiled occurrence information, from an OGWDW summary document entitled Occurrence and Exposure Assessment of Simazine in Public Drinking Water Supplies" (Wade Miller, 1989), is presented in the following section. This variety of studies and information are presented regarding levels of simazine in drinking water, with the scope of the reviewed studies ranging from national to regional. Note that none of the studies presented in the following section provide the quantitative analytical results or comprehensive coverage that would enable direct comparison to the occurrence findings estimated with the cross-section occurrence data presented in Section 3.13.4. All the following information in Section 3.13.5 is taken directly from "Occurrence and Exposure Assessment of Simazine in Public Drinking Water Supplies" (Wade Miller, 1989).

3.13.5.1 Groundwater Sources – National Studies

The National Screening Program for Organics in Drinking Water (NSP) (Boland, 1981, as cited in Wade Miller, 1989) was conducted by Stanford Research Institute (SRI) from June 1977 to March 1981. Finished drinking water samples, collected from 12 groundwater systems throughout the United States, were analyzed for simazine. The 12 systems analyzed included 1 small system (serving 501-3,300 individuals), 1 medium system (serving 3,301-10,000 individuals), 1 large system (serving 10,001-100,000 individuals), and 9 very large systems (serving greater than 100,000 individuals). Only 1 out of the 12 systems sampled, a very large system, had a concentration of simazine in excess of the quantification limit of 0.1 µg/L. The value of the positive sample was 1.0 µg/L.

3.13.5.2 Groundwater Sources – Regional Studies

The State of California conducted a monitoring program for organic chemical contamination of wells used by large public water systems (California Department of Health Services, 1986, as cited in Wade Miller, 1989). A total of 819 water systems were required to be monitored. Of the 5,650 wells that are used as part of these systems, 2,947 (over 50%) were sampled. Simazine was found in only 26 wells, at a mean concentration of 0.8 µg/L. The highest value found was 2.0 µg/L. The detection limit and other sampling information were not reported.

In addition, the California Department of Health Services provided unpublished data on results of sampling from small water systems (i.e., systems with fewer than 200 service connections) (California Department of Health Services, Unpublished, as cited in Wade Miller, 1989). A total of 304 systems and 608 samples were collected from 21 counties. Simazine was only found in two samples from one well in Merced County, at levels of 0.4 and 0.8 µg/L. The detection limit was not reported.

From July 1985 to June 1987, the Minnesota Departments of Health (MDH) and Agriculture (MDA) conducted cooperative surveys of observation, irrigation, and drinking water wells for selected pesticides (MDH and MDA, 1988, as cited in Wade Miller, 1989). These studies were designed to provide information on the extent of agricultural pesticide contamination in Minnesota's ground water and drinking water. In the first survey (MDA), simazine was detected in four samples from one well, out of 100 wells sampled, at a median concentration of 1.4 µg/L (range = 0.49 - 2.58 µg/L). The detection limit was 0.08 µg/L. In the second survey (MDH), simazine was not detected in any of the 400 samples taken. The detection limit for the MDH survey was 0.3 µg/L. The summary report did not distinguish between observation, irrigation, and drinking water wells.

3.13.5.3 Surface Water Sources – National Studies

The National Screening Program for Organics in Drinking Water (NSP) (Boland, 1981, as cited in Wade Miller, 1989) also presented data on levels of simazine in drinking water obtained from surface water systems. Finished drinking water samples, collected from 104 surface water systems throughout the United States, were analyzed for the presence of simazine. Of the 104 systems sampled, 13 systems (or 12%) contained simazine in excess of the quantification limit of 0.1 µg/L (Table 3.13-8). The range of positive values of simazine was 0.1 to 4.4 µg/L.

Table 3.13-8: Frequency of Surface Water Contamination by Simazine - National Screening Program for Organics in Drinking Water

System Size (Population Served)	Number of Systems in U.S.	Number of Systems Samples	Number of Positive Systems[1]	Percent of Positive Systems	Range of Values for Positive Systems
Unspecified	--	3	0	0	--
25-500	3,937	0	0	--	--
501-3,300	3,817	0	0	--	--
3,301-10,000	1,679	1	0	0	--
10,001-100,000	1,552	25	5	20	0.0001 - 0.0044
> 100,000	217	75	8	11	0.0001 - 0.0023
Total	11,202	104	13	12	0.0001 - 0.0044

1. Quantification limit = 0.0001 mg/L.
Source: Wade Miller 1989

3.13.5.4 Surface Water Sources – Regional Studies

Baker (1985, as cited in Wade Miller, 1989) reported on sampling conducted between 1980 and 1983 proximal to the Maumee River, Sundusky River, and Honey Creek. Finished tap water samples were analyzed for the presence of simazine in Tiffin, Fremont, and Bowling Green, Ohio. The range of peak concentrations reported was 0.13 - 1.9 µg/L. The highest value was from a sample in Tiffin, Ohio. No other sampling information was reported.

Baker et al. (1981, as cited in Wade Miller, 1989) analyzed finished drinking water samples collected from a water supply in Ohio between June 1980 and September 1981. Of five finished drinking water samples analyzed, all were found to contain simazine in the range of 0.026 to 0.883 µg/L. The detection limit was not reported.

Baker (1983a, as cited in Wade Miller, 1989) analyzed samples collected from three water supplies in Ohio in 1983 for simazine. The supplies obtained their raw water from two rivers that drained agricultural areas. Average concentrations of simazine in the samples collected at each of the supplies between May 28 and July 27, 1983, were 0.30 µg/L (18 samples), 0.077 µg/L (15 samples), and 0.19 µg/L (16 samples). Peak concentrations of simazine observed in 1983 were 0.63, 0.13, and 0.35 µg/L, respectively. The detection limit and the number of positive samples were not reported.

Pellizzari (1978, as cited in Wade Miller, 1989) summarized the results of the USEPA Region VI New Orleans Water Supply Study. For the three samples analyzed for residues of simazine, a sample mean of less than 0.1 µg/L was determined. The detection limit was not reported.

3.13.5.5 Groundwater and Surface Water Sources – STORET

The USEPA computerized water quality data base known as STORET was devised to assist Federal and State institutions in meeting objectives of Public Law 92-500 to maintain and enhance the physical, chemical, and biological quality of the nation's ambient waterways by providing for the collection and dissemination of basic water quality data (Staples et al., 1985, as cited in Wade Miller, 1989). Data are collected by States, EPA regional offices, and other government agencies and are maintained in the STORET system. STORET now contains approximately 80 million pieces of data, including data for drinking water from ground water and surface water sources.

Before presenting a summary of the drinking water data in STORET, it is important to note that there are significant limitations in using the data base to estimate representative concentrations of a contaminant such as simazine. Data entered into STORET are gathered from an array of studies conducted for various purposes. Analyses are conducted in a number of different laboratories employing different methodologies with a range of detection limits. In many cases, detection limits are not reported, making the reliability of the data highly questionable. Where detection limits have been reported, STORET assigns the detection limit value to those observations reported as not detected. This could lead to errors in interpretation and overestimation of concentrations in cases in which most values are nondetectable. Additionally, a few high values can inflate mean values and result in large standard deviations relative to the means (Staples et al., 1985, as cited in Wade Miller, 1989). Very high values may not be correct, as they may reflect sample contamination or analytical error and can significantly distort assessment of average concentrations. Staples et al. (1985, as cited in Wade Miller, 1989) also notes that the use of data collected prior to the 1980s is not recommended, since such data were obtained using less sensitive laboratory techniques and quality assurance procedures were not yet mandated for the data entered into the system.

With these limitations in mind, a summary of data for simazine is presented for drinking water from groundwater sources (USEPA, 1988, as cited in Wade Miller, 1989). According to STORET, there were 68 positive observations for simazine in groundwater from June 1984 to June 1987, with an overall mean value of 0.75 µg/L, and a range of 0.06 to 2.0 µg/L. The standard deviation for these observations was 0.42 µg/L. There were 112 samples reported as undetected, and assigned a detection limit value giving a calculated mean value of 1.07 µg/L, a range of 0.5 to 1.0 µg/L, and a standard deviation of 0.32 µg/L. Forty-seven samples were reported as having the presence of simazine verified, but not quantified, although a value of 0.5 µg/L was given as a mean. Including these samples, the undetected samples, and the detections known to be below the reported value, there were 1,677 observations for simazine in groundwater from February 1984 to November 1987, with an overall mean value of 0.58 and a range of

0.03 to 10.0 µg/L. The standard deviation for all observations was 0.94 µg/L. Detection limits and other sampling information were not given.

The USEPA's STORET data base similarly contains data on the occurrence of simazine in drinking water from surface water sources (USEPA, 1988 , as cited in Wade Miller, 1989). There were three positive observations for simazine in surface water during August 1986, with an overall mean value of 0.027 µg/L and a range of 0.02 to 0.04 µg/L. The standard deviation for these observations was 0.012 µg/L. One sample was reported as undetected, with a value of 0.001 µg/L. Including the undetected sample and the detections known to be below the reported value, there were seven observations for simazine in surface water from August 1986 to July 1987, with an overall mean value of 0.037 µg/L and a range of 0.001 to 0.06 µg/L. The standard deviation for all observations was 0.024 µg/L. Detection limits and other sampling information were not given.

3.13.6 Conclusion

Simazine is a triazine herbicide used to control deeply rooted herbaceous weeds. Its major use is on corn. Approximately 4.8 million pounds of simazine were used in 1992 on corn and several other crops. The greatest concentrations of simazine use are in the Midwest, Mid-Atlantic, California, and Florida. Industrial releases of simazine have been reported to TRI from eight States since 1995. Simazine was also an analyte for the NAWQA occurrence studies. In the NAWQA study, simazine was detected in ground and surface water. The median concentration for simazine in surface water was 0.012 µg/L, and for ground water, none of the median values exceeded the detection limit. The Stage 2 analysis, based on the 16-State cross-section, estimated that approximately 0.0000413% of combined ground water and surface water systems serving 0.000107% of the population exceeded the MCL of 0.004 mg/L. Based on this estimate, zero PWSs nationally are estimated to have simazine levels greater than the MCL.

The 16-State cross-section was designed to be nationally representative based upon VOC, SOC, and IOC pollution potentials as suggested by considerations of manufacturing, agriculture, and geographic diversity factors. Nationally, according to information from USGS, 44 States use simazine agriculturally, including 14 of the 16 cross-section States. Most agricultural use is concentrated in the Midwest, Mid-Atlantic, California, and Florida. The areas of high use are represented by six cross-section States with extensive use of simazine. TRI releases have been reported for simazine from 8 States nationally, including 2 of 16 cross-section States. The cross-section should adequately represent the occurrence of simazine on a national scale based upon the use, production, and release patterns of the 16-State cross-section in relation to the patterns observed for all 50 States.

3.13.7 References

Baker, D.B., K.A. Krieger, and J.V. Setzler. 1981. *The Concentrations and Transport of Pesticides in Northwestern Ohio Rivers.* Prepared by Water Quality Laboratory, Heidelberg College, Tiffin, OH, for Lake Erie Wastewater Management Study, U.S. Army Corps of Engineers, Buffalo, NY.

Baker, D.B. 1983a. *Herbicide Contamination in Municipal Water Supplies of Northwestern Ohio. Draft Final Report.* Prepared by Water Quality Laboratory, Heidelberg College, Tiffin, OH, for Great Lakes National Program Office, U.S. Environmental Protection Agency, Chicago, IL.

Baker, D.B. 1983b. *Studies of Sediment, Nutrient, and Pesticide Loading in Selected Lake Erie and Lake Ontario Tributaries.* Prepared by Water Quality Laboratory, Heidelberg College, Tiffin, OH, for U.S. Environmental Protection Agency, Region V, Chicago, IL.

Baker, D.B. 1985. Regional Water Quality Impacts of Intensive Row-Crop Agriculture: A Lake Erie Basin Case Study. Reprinted from the *Journal of Soil and Water Conservation.* v. 40, no. 1, pp. 125-132.

Baker, D.B. 1986. *Sediment, Nutrient and Pesticide Transport in Selected Lower Great Lakes Tributaries.* Prepared for Great Lakes National Program Office, U.S. Environmental Protection Agency, Chicago, IL. Grant Nos. R005727 and R005817.

Baker, D.B. 1987. Overview of Rural Nonpoint Pollution in the Lake Erie Basin. In: *Effects of Conservation Tillage on Groundwater Quality: Nitrates and Pesticides.* T.J. Logan et al. (eds.). Chelsea, MI: Lewis Publishers, Inc. pp. 65-91.

Blomquist, J.D., J.M. Denis, J.L. Cowles, J.A. Hetrick, R.D. Jones, and N.B. Birchfield. 2001. *Pesticides in Selected Water-Supply Reservoirs and Finished Drinking Water, 1999-2000: Summary of Results from a Pilot Monitoring Survey*. U.S. Geological Survey Open-File Report 01-456. 65 pp.

Boland, P.A. 1981. *National Screening Program for Organics in Drinking Water. Part II. Data.* Prepared by SRI International, Menlo Park, CA, for U.S. Environmental Protection Agency, Office of Drinking Water, Washington, DC. EPA Contract. No. 68-01-4666.

California Department of Health Services. 1986. *Final Report on a Monitoring Program for Organic Chemical Contamination of Large Public Water Systems in California.* Summary Version. Sacramento, CA: Department of Health Services. April, 1986.

California Department of Health Services. Unpublished. *Final Report on a Monitoring Program for Organic Chemical Contamination of Small Public Water Systems in California.* Summary Version (tables). Sacramento, CA: Department of Health Services.

Carey, A.E., and F.W. Kutz. 1983. *Trends in Ambient Concentrations of Agrochemicals in Humans and the Environment of the United States.* Presented at the International Conference on Environmental Hazards of Agrochemicals in Developing Countries, Alexandria, Egypt, November 8-12, 1983.

Cohen, S.Z., S.M. Creeger, R.F. Carsel, and C.G. Enfield. 1984. Potential for Pesticide Contamination in Groundwater Resulting from Agricultural Uses. In: *Treatment and Disposal of Pesticide Wastes.* R.F. Kruger and J.W. Seiber (eds.). Washington, DC: American Chemical Society. ACS Symposium Series No. 259: pp. 247-325.

EXTOXNET. 1996. *Pesticide Information Profile: Simazine*. Ithaca, NY: Extension Toxicology Network, Pesticide Management Education Program. Available on the Internet at http://ace.ace.orst.edu/info/extoxnet/pips/simazine.htm, revised June, 1996.

Gilliom, R.J., D.K. Mueller, and L.H. Nowell. 1998. *Methods for comparing water-quality conditions among National Water-Quality Assessment Study Units, 1992-95*. U.S. Geological Survey Open-File Report 97-589. Available on the Internet at: http://ca.water.usgs.gov/pnsp/rep/ofr97589, last updated October 9, 1998.

Hazardous Substances Data Bank (HSDB). 2001. *Hazardous Substances Data Bank: Simazine.* Available on the Internet at: http://toxnet.nlm.nih.gov/, last updated May 15, 2001.

Minnesota Department of Health (MDH) and Minnesota Department of Agriculture (MDA). 1988. *Pesticides and Groundwater: Surveys of Selected Minnesota Wells.* Prepared by Thomas G. Klaseus (MDH), Greg C. Buzicky (MDA), and Edward C. Schneider (MDH) for Legislative Commission on Minnesota Resources. February, 1988.

Pellizzari, E.D. 1978. *Preliminary Assessment of Halogenated Organic Compounds in Man and Environment Media.* Monthly Technical Progress Report No. 5, April 1-30, 1978. Prepared by Research Triangle Institute, Research Triangle Park, NC, for Office of Toxic Substances, U.S. Environmental Protection Agency, Washington, DC. EPA Contract No. 68-01-4731.

Schlachter, J. 1988. Memorandum on Program Improvement Subcommittee, FSTRAC, Preparation for April Meeting. Sent by: Jacquelyn D. Schlachter, Chairman - Program Improvement Subcommittee, U.S. Environmental Protection Agency, Region VII, Kansas City, KS. Sent to: Dennis Alt, IA; Pam Bonrud, SD; Bill Lee, NE; Kathy Miller, MT; Jennifer Orme, HQ; Sheila Sullivan, EPA Region V; and Dan Wilson, WI.

Staples, C.A., A.F. Werner, and T.J. Hoogheem. 1985. Assessment of Priority Pollutant Concentrations in the United States Using STORET Data Base. In: *Environmental Toxicology and Chemistry*. v. 4, pp. 131-142. New York, New York: Pergamon Press, Ltd.

USEPA. 1987. *Health Advisory for Simazine.* Washington, D.C: Office of Drinking Water, USEPA. August, 1987.

USEPA. 1988. Computer Printout of STORET Water Quality Data Base Retrieval Conducted March 23, 1988 by Science Applications International Corporation. Data available through the Office of Water Regulations and Standards.

USEPA. 2000. *TRI Explorer: Trends*. Available on the Internet at: http://www.epa.gov/triexplorer/trends.htm, last updated May 5, 2000.

USEPA. 2001. *National Primary Drinking Water Regulations - Consumer Factsheet on: SIMAZINE*. Available on the Internet at: http://www.epa.gov/safewater/dwh/c-soc/simazine.html, last updated April 12, 2001.

USEPA. 2002. *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT*. EPA Report/815-D-02-005, Office of Water, 55 pp.

USGS. 1998a. *Annual Use Maps*. Available on the Internet at: http://water.wr.usgs.gov/pnsp/use92/, last updated March 20, 1998.

USGS. 1998b. *Sources & Limitations of Data Used to Produce Maps of Annual Pesticide Use*. Available on the Internet at: http://water.wr.usgs.gov/pnsp/use92/mapex.html, last updated March 20, 1998.

USGS. 1998c. *Pesticides in Surface and Ground Water of the United States: Summary of Results of the National Water Quality Assessment Program (NAWQA). PROVISIONAL DATA -- SUBJECT TO REVISION*. Available on the Internet at: http://water.wr.usgs.gov/pnsp/allsum/, last updated July 22, 1998.

Wade Miller Associates, Inc. 1989. *Occurrence and Exposure Assessment of Simazine in Public Drinking Water Supplies - DRAFT*. Draft report submitted to EPA for review April 12, 1989.

Williams, W.M., P.W. Holden, D.W. Parsons, and M.N. Lorber. 1988. *Pesticides in Groundwater Data Base. 1988 Interim report.* Washington, DC: Office of Pesticide Programs, USEPA.

3.14 Toxaphene

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Tables and Figures

3.14.1 Introduction, Use and Production

Toxaphene is a manufactured insecticide containing over 670 chemicals. It does not occur naturally and is usually found as a solid or gas. In its original form, toxaphene is a yellow to amber waxy solid that smells like turpentine. It does not burn and evaporates when in solid form or when mixed with liquids. Toxaphene was one of the most heavily used insecticides in the United States until 1982, when it was canceled for most uses; all uses were banned in 1990. It was used primarily in the southern United States to control insect pests on cotton and other crops. It was also used to control insect pests on livestock and to kill unwanted fish in lakes. Toxaphene is also known as camphechlor, chlorocamphene, polychlorocamphene, and chlorinated camphene (ATSDR, 1996).

Toxaphene was formerly used as a nonsystemic stomach and contact insecticide. It was used to control many insects that thrived on cotton, corn, fruit, vegetables, and small grains and to control the *Cussia obtusifola* soybean pest. The principal use was for pest control on cotton crops. Toxaphene was also used to control livestock ectoparasites such as lice, flies, ticks, mange, and scab mites. Its relatively low toxicity to bees and its long-persisting insecticidal effect made it especially useful in the treatment of flowering plants. At one time toxaphene was also used in the United States to eradicate fish. In 1974, an estimated 44.1 million pounds was used in the United States, and was distributed as follows: 85% on cotton; 7% on livestock and poultry; 5% on other field crops; 3% on soybeans; and less than 1% on sorghum (ATSDR, 1996).

Through the early 1970s toxaphene or mixtures of toxaphene with rotenone were used widely in lakes and streams by fish and game agencies to eliminate biologic communities that were considered undesirable for sport fishing. Such uses of toxaphene by fish and game agencies have been discontinued in the United States and Canada. Toxaphene use in this country has declined drastically since 1975, at which time it was reported to be the most heavily used pesticide. The total amount consumed was estimated to be 18.7 million pounds in 1980 and 10.8 million pounds in 1982 (ATSDR, 1996).

In November 1982, EPA canceled the registrations of toxaphene for most of its uses as a pesticide or pesticide ingredient. In the period following November 1982, its use was restricted to controlling scabies on sheep and cattle; controlling grasshopper and army worm infestations on cotton, corn, and small grains; controlling specific insects on banana and pineapple crops in Puerto Rico and the U.S. Virgin Islands; and for emergency use only (to be determined on a case-by-case basis by EPA). Formulations suitable for other purposes were to be sold or distributed until December 31, 1983, for use only on registered sites. The distribution or sale of remaining stocks of toxaphene formulations was permitted until December 31, 1986, for use on no-till corn, soybeans, and peanuts (to control sicklepod), and dry and southern peas, and to control emergency infestations. All registered uses of toxaphene mixtures in the United States and any of its territories were canceled in 1990 (ATSDR, 1996).

In 1976, toxaphene was produced primarily by Hercules Incorporated, Wilmington, Delaware. Production during 1976 by three U.S. companies (Hercules Incorporated, Tenneco, and Vicksburg Chemical Co., a division of Vertac) totaled 41.9 million pounds, which was a 29% decline from the production level of 59.5 million pounds in 1975 (ATSDR, 1996).

Total U.S. production in 1977 was estimated to be 39.9 million pounds. The most recent production volumes are from 1982, when it was estimated that 3.7 million pounds were produced in the United States. This represents a decline of more than 90% from 1972, when toxaphene was the most heavily manufactured insecticide in the United States with a production volume of 46.0 million pounds (ATSDR, 1996). By 1982, when EPA canceled most of its uses, consumption was reported at 12 million pounds (USEPA, 2001).

3.14.2 Environmental Release

Toxaphene is released directly to the environment primarily in its use as an insecticide. Total U.S. production in 1982 was estimated to be 3.7 million pounds (ATSDR, 1996). Toxaphene is not listed as a Toxics Release Inventory (TRI) contaminant, so no TRI release records are maintained. Therefore, the use of toxaphene (described in the previous section) may provide the primary indication of where releases are most likely.

3.14.3 Ambient Occurrence

To understand the presence of a chemical in the environment, an examination of ambient occurrence is useful. In a drinking water context, ambient water is untreated source water residing in surface waters and aquifers. There are few available data on the occurrence of toxaphene in ambient waters of the United States. The most comprehensive and nationally consistent data describing ambient water quality in the United States are being produced through the United States Geological Survey's (USGS) National Water Quality Assessment (NAWQA) program. However, national NAWQA data are currently unavailable for toxaphene.

3.14.3.1 Additional Ambient Occurrence Data

Additional studies of ambient data are summarized below. A summary document entitled "Occurrence and Human Exposure to Pesticides in Drinking Water, Food and Air in the United States of America" (USEPA, 1989), was previously prepared for past USEPA assessments of various pesticides. In that review, one national and several regional studies were included on the occurrence of toxaphene in surface water non-drinking water sources. Barbash and Resek (1996) also conducted reviews of pesticides in ground water non-drinking water sources, including a national review and a compilation of various monitoring studies on the occurrence of toxaphene. The following information for the surface water studies only is taken directly from "Occurrence and Human Exposure to Pesticides in Drinking Water, Food and Air in the United States of America" (USEPA, 1989).

3.14.3.1.1 Surface Water Sources – National Studies

The National Surface Water Monitoring Program presented data on levels of toxaphene in surface water samples collected throughout the U.S. during the period 1975 to 1979 (USEPA, 1989). During this time, 2,479 samples were collected and analyzed for toxaphene. Although no detection limit was given for toxaphene, 11 positive samples (or 0.4%) were found during testing. The range of positive values was 0.0 to 1.65 µg/L.

3.14.3.1.2 Surface Water Sources – Regional Studies

Mattraw (1975, as cited in USEPA, 1989) did not detect toxaphene in any surface water samples collected and analyzed during an organochlorine residue survey in Florida. The number of samples analyzed and the detection limit were not reported.

Toxaphene was detected in 11 (or 55%) of 20 Mississippi Delta lakes sampled by Herring and Cotton (1970, as cited in USEPA, 1989). The maximum reported concentration was 1.92 µg/L (the detection limit was not reported).

3.14.3.1.3 Ground Water Sources – National Studies

The Pesticides in Ground Water Data Base (PGWDB), developed by EPA's Offices of Pesticide Programs (OPP), contains information derived from monitoring studies conducted by pesticide registrants, universities, and government agencies. The data are presented in several categories, including all information collected to date (excluding data known to be of poor quality and data that is from point source contamination); data derived from scientifically confirmed agricultural use; and confirmed information attributed to known point sources and documented misuse. While extreme care was taken to confirm detections of pesticides in ground water, the authors caution that the studies investigated have not been limited to drinking water supplies and some studies included samples from many types of wells including observation and irrigation wells. In addition, many studies have focused on shallow ground water which may not be representative of drinking water sources in the area. As such, the results cannot be used to estimate human exposure to pesticides in drinking water, but do provide an additional assessment of possible toxaphene occurrence. The PGWDB is the most comprehensive summary available on pesticide occurrence in ground water, including data from a total of 68,824 wells sampled for pesticide analytes from 45 States (Barbash and Resek, 1996).

Results of the review of the PGWDB indicate that toxaphene was detected in 9 of the 4,273 wells sampled. The maximum concentration reported was 0.0180 µg/L. The minimum concentration reported was 0.00115 µg/L. The frequency of exceedances of the MCL (or Health Advisory Level [HAL], if the MCL unavailable) among sampled wells is 0.070% (Barbash and Resek, 1996).

3.14.3.1.4 Ground Water Sources – Regional Studies

Several monitoring studies, including results from various multistate, State and local monitoring studies of pesticides, are reviewed in Barbash and Resek (1996). Results from these studies indicate that toxaphene was detected in at least one study reviewed, although it was not possible to determine the exact number of studies for which toxaphene was an analyte, or exactly how many studies did detect toxaphene. In the summary information reviewed, details were provided regarding the geographic distribution and the total number of systems collected, although further detail is beyond the scope of this report.

3.14.3 Drinking Water Occurrence Based on the 16-State Cross-Section

The analysis of toxaphene occurrence presented in the following section is based on State compliance monitoring data from the 16 cross-section States. The 16-State cross-section is the largest and most comprehensive compliance monitoring data set compiled by EPA to date. These data were evaluated relative to several concentration thresholds of interest: 0.003 mg/L; 0.0015 mg/L; and 0.001 mg/L.

All sixteen cross-section State data sets, with the exception of Alabama, contained occurrence data for toxaphene. These data represent over 52,000 analytical results from approximately 14,000 PWSs during the period from 1984 to 1998 (with most analytical results from 1992 to 1997). The number of sample results and PWSs vary by State, although the State data sets have been reviewed and checked to ensure adequacy of coverage and completeness. The overall modal detection limit for toxaphene in the 16 cross-section States is equal to 0.001 mg/L. (For details regarding the 16-State cross-section, please refer to Section 1.3.5 of this report.)

3.14.3.1 Stage 1 Analysis Occurrence Findings

Table 3.14-1 illustrates the low occurrence of toxaphene in drinking water for the public water systems in the 16-State cross-section relative to three thresholds: 0.003 mg/L (the current MCL), 0.0015 mg/L, and 0.001 mg/L (the modal MRL). Only 1 PWS (approximately 0.00724%) had analytical results exceeding the MCL; 0.0290% of systems (4 systems) had results exceeding 0.0015 mg/L; and 0.0362% of systems (5 systems) had results exceeding 0.001 mg/L.

No ground water systems had any analytical results greater than the MCL. Only 1 ground water system (0.00806%) had results above 0.0015 mg/L or 0.001 mg/L.

One (0.0716% of) surface water systems had results greater than the MCL. Approximately 3 (0.215% of) surface water systems had at least one analytical result greater than 0.0015 mg/L. Four (0.286% of) surface water systems had results exceeding 0.001 mg/L.

Table 3.14-1: Stage 1 Toxaphene Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Ground Water	0.003	0.000%	0
	0.0015	0.00806%	1
	0.001	0.00806%	1
Surface Water	0.003	0.0716%	1
	0.0015	0.215%	3
	0.001	0.286%	4
Combined Ground & Surface Water	0.003	0.00724%	1
	0.0015	0.0290%	4
	0.001	0.0362%	5

Reviewing toxaphene occurrence in the 16 cross-section States by PWS population served (Table 3.14-2) shows that approximately 0.131% of the population (125,000 people) was served by PWSs with at least one analytical result of toxaphene greater than the MCL (0.003 mg/L). Approximately 150,900 (0.159% of) people were served by systems with an exceedance of 0.0015 mg/L. Almost 206,000 (0.216% of) people were served by systems with at least one analytical result greater than 0.001 mg/L.

The percentage of population served by ground water systems with analytical results greater than the MCL was equal to 0%. When evaluated relative to 0.0015 mg/L and 0.001 mg/L, the percent of population exposed was equal to 0.0436% (approximately 17,500 people).

The percentage of population served by surface water systems with exceedances of the MCL (0.003 mg/L) was equal to 0.227% (125,000 people). When evaluated relative to 0.0015 mg/L and 0.001 mg/L, the percent of population exposed was equal to 0.243% (about 133,400 people) and 0.343% (about 188,400 people), respectively.

Table 3.14-2: Stage 1 Toxaphene Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Ground Water	0.003	0.000%	0
	0.0015	0.0436%	17,500
	0.001	0.0436%	17,500
Surface Water	0.003	0.227%	125,000
	0.0015	0.243%	133,400
	0.001	0.343%	188,400
Combined Ground & Surface Water	0.003	0.131%	125,000
	0.0015	0.159%	150,900
	0.001	0.216%	205,900

3.14.3.2 Stage 2 Analysis Occurrence Findings

The Stage 2 occurrence findings, based on the cross-section data, are presented in Tables 3.14-3 and 3.14-4. The statistically generated best estimate values, as well as the ranges around the best estimate value, are presented. (For a review of the Stage 2 analytical approach, please refer to Section 1.4 of this report. For complete details regarding the Stage 2 analyses, please refer to *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations* (USEPA, 2002)).

No ground water or surface water PWSs had an estimated mean concentration of toxaphene exceeding 0.003 mg/L, or 0.0015 mg/L. Approximately 0.000145% of PWSs (approximately 1 system in the 16-State cross-section) were estimated to have a mean concentration greater than 0.001 mg/L. The percentage of ground water PWSs with estimated mean concentration exceeding 0.001 mg/L was equal to 0.0000967% (less than 1 system in the 16 States). Approximately 0.000573% of surface water systems (about 1 system in the 16 States) had estimated mean concentration values of toxaphene greater than 0.001 mg/L.

Table 3.14-3: Stage 2 Estimated Toxaphene Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.003	0.000%	0.000% - 0.000%	0	0 - 0
	0.0015	0.000%	0.000% - 0.000%	0	0 - 0
	0.001	0.0000967%	0.000% - 0.000%	0	0 - 0
Surface Water	0.003	0.000%	0.000% - 0.000%	0	0 - 0
	0.0015	0.000%	0.000% - 0.000%	0	0 - 0
	0.001	0.000573%	0.000% - 0.000%	1	0 - 0
Combined Ground & Surface Water	0.003	0.000%	0.000% - 0.000%	0	0 - 0
	0.0015	0.000%	0.000% - 0.000%	0	0 - 0
	0.001	0.000145%	0.000% - 0.000%	1	0 - 0

Reviewing toxaphene occurrence by PWS population served (Table 3.14-4) shows that approximately 0.000833% of population served by all PWSs in the 16 States (an estimated 800 people in the 16 States) were potentially exposed to toxaphene levels above 0.001 mg/L. The percentage of population served by ground water systems relative to 0.001 mg/L was equal to 0.0000376%. Approximately 0.00141% of the population served by surface water systems (about 800 people) were exposed to toxaphene at levels greater than 0.001 mg/L. When evaluated relative to a threshold of 0.003 mg/L and 0.0015 mg/L, the percent of population exposed was equal to 0% for all system types.

Table 3.14-4: Stage 2 Estimated Toxaphene Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.003	0.000%	0.000% - 0.000%	0	0 - 0
	0.0015	0.000%	0.000% - 0.000%	0	0 - 0
	0.001	0.0000376%	0.000% - 0.000%	0	0 - 0
Surface Water	0.003	0.000%	0.000% - 0.000%	0	0 - 0
	0.0015	0.000%	0.000% - 0.000%	0	0 - 0
	0.001	0.00141%	0.000% - 0.000%	800	0 - 0

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Combined Ground & Surface Water	0.003	0.000%	0.000% - 0.000%	0	0 - 0
	0.0015	0.000%	0.000% - 0.000%	0	0 - 0
	0.001	0.000833%	0.000% - 0.000%	800	0 - 0

3.14.3.3 Estimated National Occurrence

As illustrated in Table 3.14-5, the Stage 2 analysis estimates zero systems serving zero people nationally have estimated mean concentration values of toxaphene greater than 0.003 mg/L or 0.0015 mg/L. Only 1 surface water system serving approximately 1,800 people nationally had an estimated mean concentration value of toxaphene greater than 0.001 mg/L. (See Section 1.4 for a description of how Stage 2 16-State estimates are extrapolated to national values.)

Table 3.14-5: Estimated National Toxaphene Occurrence - Systems and Population Served

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.003	0	0 - 0	0	0 - 0
	0.0015	0	0 - 0	0	0 - 0
	0.001	0	0 - 0	0	0 - 0
Surface Water	0.003	0	0 - 0	0	0 - 0
	0.0015	0	0 - 0	0	0 - 0
	0.001	1	0 - 0	1,800	0 - 0
Combined Ground & Surface Water	0.003	0	0 - 0	0	0 - 0
	0.0015	0	0 - 0	0	0 - 0
	0.001	1	0 - 0	1,800	0 - 0

3.14.4 Additional Drinking Water Occurrence Data

Several additional data sources regarding the occurrence of toxaphene in drinking water are also reviewed. Previously compiled occurrence information, from an OGWDW summary document entitled "Occurrence and Human Exposure to Pesticides in Drinking Water, Food and Air in the United States of America" (USEPA, 1989), is presented in the following section. This variety of studies and information are presented regarding levels of toxaphene in drinking water, with the scope of the reviewed studies ranging from national to regional. Note that none of the studies presented in the following section provide the quantitative analytical results or comprehensive coverage that would enable direct comparison to the occurrence findings estimated with the cross-section occurrence data presented in Section 3.14.4. These additional studies, however, do enable a broader assessment of the Stage 2 occurrence estimates presented for this Six-Year Review. All the following information in Section 3.14.5 is taken directly from "Occurrence and Human Exposure to Pesticides in Drinking Water, Food and Air in the United States of America" (USEPA, 1989).

3.14.4.1 Ground Water Sources – National Studies

The Federal Reporting Data System (FRDS, 1984, as cited in USEPA, 1989) provides information on public water supplies found to be in violation of current Maximum Contaminant Levels (MCLs). Data are not available on the number of ground water systems in the U.S. that have monitoring requirements for toxaphene; however, no violations of the current MCL of 5 µg/L were reported for toxaphene during the years 1979-1983.

The 1978 Rural Water Survey (USEPA, 1984, as cited in USEPA, 1989) involved the collection of samples from 267 households (the majority using private water supplies) in rural locations throughout the U.S. and analyses for toxaphene. A total of 71 public drinking water systems of varying sizes using ground water were covered by the survey. None of the samples from the 71 ground water systems studied exceeded the minimum quantification limit of 0.17 µg/L for toxaphene.

3.14.4.2 Ground Water Sources – Regional Studies

Irwin and Healy (1978, as cited in USEPA, 1989) summarized a study of data collected in 1976 during a water quality reconnaissance of public water supplies in Florida. None of the 100 water supplies sampled utilizing the five aquifers in Florida contained toxaphene in excess of the detection limit (the detection limit was not reported).

Tucker and Burke (1978, as cited in USEPA 1989) presented the results of analyses of samples collected from wells in nine New Jersey counties. None of the samples tested contained concentrations of toxaphene in excess of the minimum reportable concentration of 0.06 µg/L for this study.

3.14.4.3 Surface Water Sources – National Studies

Data were obtained from the Federal Reporting Data System (FRDS, 1984, as cited in USEPA, 1989) on violations of the current MCL of 5 µg/L for toxaphene. The data were obtained for the years 1979 to 1983 and include information for all surface water systems in the United States. The analysis indicated that none of the samples from the surface water systems studied contained toxaphene in excess of the current MCL.

The 1978 Rural Water Survey (USEPA, 1984, as cited in USEPA, 1989) also presented data on drinking water samples obtained from surface water systems of varying sizes. None of the samples from the 21 public drinking water systems contained concentrations of toxaphene in excess of the minimum quantification limit of 0.17 µg/L.

3.14.4.4 Surface Water Sources – Regional Studies

Irwin and Healy (1978, as cited in USEPA, 1989), summarizing data collected during a water quality reconnaissance of public water supplies in Florida, reported that none of the samples from the 16 surface water supplies studied contained concentrations of toxaphene in excess of the detection limit. The detection limit was not reported.

In a study on the effects of forest runoff on the quality of a public water supply in Oregon, Elliot (1979, as cited in USEPA, 1989) observed a concentration of toxaphene of 3 µg/L.

To assemble a database which would reflect the status of Great Lakes drinking water quality, the Canadian Public Health Association gathered data from October 1984 through August 1985 (Canadian Public Health Association, 1986, as cited in USEPA, 1989). The data collected covered the period from the mid 1970s to early 1985. The study was funded by the Health Protection Branch of Health and Welfare Canada and the Ontario Ministry of the Environment. A research team, appointed by the Association, reviewed data on the quality of water at 31 representative Canadian and United States communities and 24 offshore sites to evaluate the human health implications.

For each of the 31 communities, data consisted of: 1) background information on the community; 2) treatment plant schematics and associated treatment process information; and 3) water quality data. Water sample types included raw water (treatment plant intake), distribution water (treated water), and tap water. Water quality data collected included general parameters (e.g., alkalinity, turbidity), microbiological and radiological parameters, inorganic parameters, and organic parameters (including volatiles, base/neutrals, pesticides and PCBs, and phenols and acids). For each parameter, the water type, time period, concentration (mean, range), number of samples and detection limit are presented.

For most of the volatile organics, including toxaphene, the available data indicate that there were very low levels of these contaminants in the raw, treated, or tap water. Most of the values found were “not detected” or near the detection limit (Canadian Public Health Association, 1986, as cited in USEPA, 1989).

3.14.4.5 Unspecified Sources – National Study

In an EPA survey (USEPA, 1977, as cited in USEPA, 1989) of pesticide contamination in commercial drinking water sampled during 1975 and 1976, 27 of 58 samples analyzed were found to be positive for toxaphene. The levels of toxaphene were at or below 0.05 µg/L. The detection limit was not reported.

3.14.4.6 Unspecified Sources – Regional Study

In a report on source identification of pollutants entering a sewage treatment plant, Levins et al. (1979, as cited in USEPA 1989) two drinking water sources in a drainage basin were tested in Georgia. Although the detection limits were not reported, toxaphene was not detected in either of the samples tested.

3.14.5 Conclusion

Toxaphene was formerly used as a nonsystemic stomach and contact insecticide. The principal use was for pest control on cotton crops. In the U.S., toxaphene use has declined drastically since 1975, at which time it was reported to be the most heavily used pesticide. In November 1982, EPA canceled the registrations of toxaphene for most of its uses as a pesticide or pesticide ingredient. All registered uses of toxaphene mixtures in the United States and any of its territories were canceled in 1990. Toxaphene is not a TRI chemical, so there is no information available on releases of toxaphene. There are also no ambient data available. The Stage 2 analysis, based on the 16-State cross-section, estimated that zero percent of combined ground water and surface water systems serving zero percent of the population exceeded the MCL of 0.003 mg/L. Based on this estimate, zero PWSs nationally are estimated to have levels greater than the MCL.

The 16-State cross-section was designed to be nationally representative based upon VOC, SOC, and IOC pollution potentials as suggested by considerations of manufacturing, agriculture, and geographic diversity factors. The cross-section should adequately represent the occurrence of toxaphene on a national scale based upon the fact that toxaphene is no longer produced or used in any state and that there are no documented releases for toxaphene.

3.14.6 References

Agency for Toxic Substances and Disease Registry (ATSDR). 1996. *Toxicological Profile for Toxaphene*. U.S. Department of Health and Human Services, Public Health Service. 215 pp. + Appendices. Available on the Internet at: http://www.atsdr.cdc.gov/toxprofiles/tp94.pdf

Barbash, J. E., and E. A. Resek. 1996. *Pesticides in Ground Water: Distribution, Trends, and Governing Factors*. Volume two of *Pesticides in the Hydrologic System*. Chelsea, MI: Ann Arbor Press, Inc. 588 pp.

Canadian Public Health Association. 1986. *Comprehensive Survey of the Status of Great Lakes Drinking Water.* Prepared in cooperation with Health and Welfare Canada and the Ministry of the Environment. Ottawa, Canada: Canadian Public Health Association. August 1986.

Elliot, W.M. 1979. Portland's Public Water Supply -- Pure and Simple. Proceedings of the National Conference on Environmental Engineering. New York, NY: American Society of Civil Engineers.

Federal Reporting Data System (FRDS). 1984. Computer printout containing data on organic chemical MCL violations, FY 1979-1983. Washington, DC: USEPA. April 4, 1984.

Herring, J., and D. Cotton. 1970. Pesticide residues of 20 Mississippi delta lakes. Proceedings of the. 4th Annual Conference of S.E. Assoc. *Game Fish Comm*. 482.

Irwin, G.A., and H.G. Healy. 1978. *Chemical and Physical Quality of Selected Public Water Supplies in Florida, August-September 1976.* Tallahassee, FL: Water Resources Division, U.S. Geological Survey. USGS/WRI 78-21.

Levins, P., J. Adams, P. Brenner, S. Coons, K. Thrun, and J. Varone. 1979. *Sources of Toxic Pollutants Found in Influents to Sewage Treatment Plants. IV.* R.M. Clayton Drainage Basin, Atlanta report. Prepared by Arthur D. Little, Inc., for Office of Water Planning and Standards, U.S. Environmental Protection Agency, Washington, DC. EPA Contract No. 68-01-3857.

Mattraw, H.C. 1975. Occurrence of chlorinated hydrocarbon insecticides, southern Florida, 1968-1972. *Pestic. Monit. J.* v. 9, p. 106.

Tucker, R.K., and T.A. Burke. 1978. *A Second Preliminary Report on the Findings of the State Groundwater Monitoring Project.* New Jersey: Department of Environmental Protection.

USEPA. 1977. *Toxaphene: Position document 1*. Washington, DC: Special Pesticide Review Division, USEPA. EPA/SPRD-80/55.

USEPA. 1984. Rural Water Survey. Computer data provided by Department of Sociology, Cornell University, Ithaca, New York.

USEPA. 1989. *Draft Final Report on the Occurrence and Human Exposure to Pesticides in Drinking Water, Food, and Air in the United States of America*. Office of Drinking Water, USEPA. September, 1989. 202 pp.

USEPA. 2001. *National Primary Drinking Water Regulations - Consumer Factsheet on: TOXAPHENE*. Available on the Internet at: http://www.epa.gov/OGWDW/dwh/c-soc/toxaphen.html, last updated April 12, 2001.

USEPA. 2002. *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT*. EPA Report/815-D-02-005, Office of Water, 55 pp.

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4.0 VOLATILE ORGANIC CONTAMINANTS

4.1 Benzene

Table of Contents

Tables and Figures

4.1.1 Introduction, Use and Production

Benzene, also known as benzol, has the chemical formula C_6H_6 and is a colorless liquid with a sweet odor. Benzene evaporates into air very quickly and dissolves slightly in water. It is also highly flammable. Benzene is found in the environment as a result of both anthropogenic and natural processes. It is also a part of crude oil and gasoline and cigarette smoke. Benzene was first discovered and isolated from coal tar in the 1800s. Today, benzene is made mostly from petroleum sources. Because of its wide use, benzene ranks in the top 20 in production volume for chemicals produced in the United States (ATSDR, 1997).

Benzene is produced naturally by volcanoes and forest fires and is present in many plants and animals. It is also a major industrial chemical made from coal and oil (NSC, 2001).

The greatest use of benzene is as a building block for making plastics, rubber, resins and synthetic fabrics like nylon and polyester (USEPA, 2001). Benzene is also used in the following manufacturing processes: medicines, dyes, artificial leather, linoleum, oil cloth, pesticides, plastics and resins, PCB, aviation fuel, detergents, flavors and perfumes, paints and coatings, airplane dope, varnishes, lacquers, explosives and other organics. It is used in photogravure printing and as a component of high octane gasoline. In organic synthesis, it is used to make ethylbenzene, isopropyl-benzene, cyclohexane, aniline, maleic anhydride and alkylbenzenes (NTP, 2001).

Benzene is also a component of gasoline since it occurs naturally in crude oil and it is a byproduct of oil refining processes. The percentage by volume of benzene in unleaded gasoline is approximately 1-2%. In the past, certain consumer products, such as some types of paint strippers and carpet glue, carburetor cleaners, denatured alcohol, textured carpet liquid detergent, furniture wax, and rubber cement used in tire patch kits and arts and crafts supplies contained small amounts of benzene (ATSDR, 1997).

The use of benzene in certain pesticides has been canceled. Under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), the USEPA has established a voluntary cancellation of registered products containing benzene as an active ingredient. Benzene was once used alone or in formulations to control screwworms on animals and as an early fumigant for grain. Under the Food, Drug, and Cosmetics Act, benzene is regulated as an indirect food additive and restricted for use only as a component of adhesives used on articles intended for packaging, transport, or holding foods (ATSDR, 1997).

More than 98% of the benzene produced in the U.S. is derived from the petrochemical and petroleum refining industries. Catalytic reformat is the major source of benzene; between 1978 and 1981, catalytic reformats accounted for approximately 44-50% of the total U.S. benzene production. In 1994, benzene was the 17th highest volume chemical produced in the US, with 14.7 billion pounds produced. Other production data are as follows: 12.3 billion pounds in 1993, 12.0 billion pounds in 1992, and 11.5 billion pounds in 1991 (ATSDR, 1997).

Table 4.1-1 shows the number of facilities in each State that manufacture and process benzene, the intended uses of the product, and the range of maximum amounts derived from the Toxics Release Inventory (TRI) of EPA (ATSDR, 1997).

Table 4.1-1: Benzene Manufacturers and Processors by State

State[a]	Number of facilities	Range of maximum amounts on site in thousands of pounds[b]	Activities and uses[c]
AK	4	0-10,000	1,3,4,8,10
AL	18	0-50,000	1,2,3,4,5,6,7,8,9,11,13
AR	4	1-10,000	1,3,4,7,13
AZ	2	10-1,000	1,6,10,13
CA	35	0-50,000	1,2,3,4,5,6,7,8,9,10,13
CO	2	1,000-10,000	1,3,4,6,7
DE	4	1-50,000	1,6,7,9,12,13
GA	6	0-10,000	1,2,4,8,9,10,11
HI	2	1,000-10,000	1,2,6
IA	1	1,000-10,000	1,4
IL	26	1-100,000	1,2,3,4,5,6,7,8,9,10,11,12,13
IN	18	1-100,000	1,2,3,4,5,6,8,9,10,11,13
KS	10	0-50,000	1,3,4,5,6,7,8,9,10,13
KY	12	1-50,000	1,3,4,5,6,7,8,9,10,11,13
LA	40	0-500,000	1,2,3,4,5,6,7,8,9,10,11,13
MD	3	1-10,000	7,8,9
MI	28	0-10,000	1,2,3,4,5,6,7,8,9,10,11,13
MN	3	1-100,000	1,3,4,6,8,9
MO	7	0-100	8,9,13
MS	6	10-50,000	1,3,4,6,7,8
MT	4	100-500,000	1,2,3,4,6,7,8,9
NC	3	0-1,000	1,5,11
ND	1	10,000-50,000	1,2,3,4,7
NE	1	0-1	11
NJ	12	1-50,000	1,2,3,4,6,7,8,9,10,11,13
NM	4	1-10,000	1,3,4,6,8,13
NY	5	1-1,000	1,2,4,5,9,11,13
OH	25	0-100,000	1,2,3,4,5,6,8,9,10,11,13
OK	6	1-50,000	1,2,3,4,5,6,7,8,9,13
OR	1	1,000-10,000	10
PA	21	0-50,000	1,2,3,4,5,6,7,8,10,11,13
PR	5	100-50,000	1,2,3,5,6,7,8
SC	3	0-1,000	1,5,7,12
TN	9	0-10,000	1,3,5,6,7,8,9,12,13
TX	94	0-500,000	1,2,3,4,5,6,7,8,9,10,11,12,13
UT	8	10-50,000	1,2,3,4,6,7,8,9,10,13
VA	5	1-1,000	1,2,3,5,6,7,9,11
VT	1	100,000-500,000	1,2,3,4,7
WA	6	100-100,000	1,2,3,4,6,7,8
WI	4	1-10,000	1,6,9,12,13
WV	8	1-10,000	1,4,5,6,7,8,9,13
WY	5	0-10,000	1,3,4,5,6,7,8,10

[a] Post office State abbreviations used
[b] Data in TRI are maximum amounts on site at each facility
[c] Activities/Uses:

1. Produce
2. Import
3. For on-site use/processing
4. For sale/distribution
5. As a byproduct
6. As an impurity
7. As a reactant
8. As a formulation component
9. As a product component
10. For repackaging only
11. As a chemical processing aid
12. As a manufacturing aid
13. Ancillary or other uses

Source: ATSDR, 1997 compilation of TRI93 1995 data

4.1.2 Environmental Release

Benzene is listed as a Toxics Release Inventory (TRI) chemical. Table 4.1-2 illustrates the environmental releases for benzene from 1988 to 1999. (Benzene data are only available for these years.) Air emissions constitute most of the on-site releases, with a steady decrease over the years, except for small increases in 1997 and 1999. The decrease in air emissions has been the major contributor to decreases in benzene total on- and off-site releases, as the release total declined every year but 1997. Surface water discharges have also generally decreased, and averaged around 15,000 pounds for 1997-1999. Underground injection declined until 1994, and has been rising ever since. Releases to land (such as spills or leaks within the boundaries of the reporting facility) have varied between levels of 717,000 pounds and 18,000 pounds between 1988 and 1999, with no discernable trend. Off-site releases (including metals or metal compounds transferred off-site) also span a wide range of values, although releases between 1988 and 1990 were greater than any releases since. These TRI data for benzene were reported from 49 States (except Vermont), Puerto Rico, Washington D.C., the Virgin Islands, Guam, American Samoa, and the Northern Mariana Islands (USEPA, 2000). Fifteen of the 16 cross-section States (used for analyses of benzene occurrence in drinking water; see Section 4.1.4) reported releases of benzene, the exception being Vermont. (For a map of the 16-State cross-section, see Figure 1.3-1.)

Table 4.1-2: Environmental Releases (in pounds) for Benzene in the United States, 1988-1999

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1999	7,287,778	13,647	617,825	18,732	147,994	8,085,976
1998	7,239,578	15,070	504,109	237,544	185,440	8,181,741
1997	8,777,297	12,226	363,100	62,474	83,476	9,298,573
1996	8,219,965	27,357	312,766	51,178	66,246	8,677,512
1995	9,410,086	21,290	282,642	18,583	71,391	9,803,992
1994	9,853,271	22,294	223,103	25,555	203,685	10,327,908
1993	11,362,776	19,450	356,660	31,220	94,171	11,864,277
1992	13,236,803	24,347	355,683	342,241	93,486	14,052,560
1991	19,032,803	27,238	824,342	113,153	140,989	20,138,525
1990	25,846,649	25,303	689,066	717,008	264,685	27,542,711
1989	27,422,786	169,170	668,610	114,132	241,518	28,616,216
1988	32,341,184	46,732	825,035	126,728	396,880	33,736,559

Source: USEPA, 2000

4.1.3 Ambient Occurrence

Benzene was detected in 14 out of 398 wells (3.5%) in urban areas of the local, State, and federal data set compiled by NAWQA. The minimum and maximum concentrations detected were 0.2 µg/L and 290 µg/L, respectively. The median value of detection concentrations was 1.0 µg/L. Benzene was also detected in 24 of the 2,504 wells (0.96%) with analysis in rural areas. The minimum and maximum concentrations detected were 0.2 µg/L and 73 µg/L, respectively. The median value of detection concentrations was 0.7 µg/L. These data (urban and rural) represent untreated ambient ground water of the conterminous United States for the years 1985-1995 (Squillace et al., 1999).

Benzene was also an analyte in both the NURP and NPDES data. The NURP study found benzene in urban runoff. The minimum and maximum concentrations detected were 3.5 µg/L and 13 µg/L, respectively, with no mean value reported. The use of the land from which the samples were taken was unspecified. The NPDES related investigations analyzing urban and highway runoff detected benzene.

The maximum concentration of benzene in NPDES samples of stormwater was 0.8 µg/L, and the drinking water standard (MCL) is 5 µg/L (Lopes and Dionne, 1998).

4.1.3.1 Additional Ambient Occurrence Data

A summary document entitled "Benzene: Occurrence in Drinking Water, Food, and Air" (JRB Associates, 1983), was previously prepared for past USEPA assessments of benzene. However, no information on the ambient occurrence of benzene was included in that document. (The document did include information regarding benzene occurrence in drinking water, which is discussed in Section 4.1.5 of this report.)

4.1.4 Drinking Water Occurrence Based on the 16-State Cross-Section

The analysis of benzene occurrence presented in the following section is based on State compliance monitoring data from the 16 cross-section States. The 16-State cross-section is the largest and most comprehensive compliance monitoring data set compiled by EPA to date. These data were evaluated relative to several concentration thresholds of interest: 0.005 mg/L; 0.0005 mg/L; and 0.0004 mg/L.

All sixteen cross-section State data sets contained occurrence data for benzene. These data represent more than 194,000 analytical results from approximately 23,000 PWSs during the period from 1984 to 1998 (with most analytical results from 1992 to 1997). The number of sample results and PWSs vary by State, although the State data sets have been reviewed and checked to ensure adequacy of coverage and completeness. The overall modal detection limit for benzene in the 16 cross-section States is equal to 0.0005 mg/L. (For details regarding the 16-State cross-section, please refer to Section 1.3.5 of this report.)

4.1.4.1 Stage 1 Analysis Occurrence Findings

Table 4.1-3 illustrates the occurrence of benzene in drinking water for the public water systems in the 16-State cross-section relative to three thresholds: 0.005 mg/L (the current MCL), 0.0005 mg/L (the modal MRL), and 0.0004 mg/L. Based on the 16-State cross-section data, a total of 44 (approximately 0.189% of) ground water and surface water PWSs had analytical results exceeding the MCL; 1.02% of systems (237 systems) had results exceeding 0.0005 mg/L; and 1.24% of systems (288 systems) had results exceeding 0.0004 mg/L.

Approximately 0.185% of ground water systems (40 systems) had any analytical results greater than the MCL. About 0.941% of ground water systems (204 systems) had results above 0.0005 mg/L. The percentage of ground water systems with at least one result greater than 0.0004 mg/L was equal to 1.10% (239 systems).

Only 4 (0.251% of) surface water systems had results greater than the MCL. A total of 33 (2.07% of) surface water systems had at least one analytical result greater than 0.0005 mg/L. Forty-nine (3.07% of) surface water systems had results exceeding 0.0004 mg/L.

Table 4.1-3: Stage 1 Benzene Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Ground Water	0.005	0.185%	40
	0.0005	0.941%	204
	0.0004	1.10%	239
Surface Water	0.005	0.251%	4
	0.0005	2.07%	33
	0.0004	3.07%	49
Combined Ground & Surface Water	0.005	0.189%	44
	0.0005	1.02%	237
	0.0004	1.24%	288

Reviewing benzene occurrence by PWS population served (Table 4.1-4) shows that approximately 0.581% (almost 575,000 people) of the 16-State population was served by PWSs with at least one analytical result of benzene greater than the MCL (0.005 mg/L). The percentage of population exposed dramatically increased when evaluated relative to 0.0005 mg/L and 0.0004 mg/L. Approximately 12.4 million (11.2% of) people were served by systems with an exceedance of 0.0005 mg/L. A total of about 13.2 million (11.9% of) people were served by systems with at least one analytical result greater than 0.0004 mg/L.

The percentage of population served by ground water systems with analytical results greater than the MCL was equal to 0.980% (about 486,300 people). When evaluated relative to 0.0005 mg/L or 0.0004 mg/L, the percent of population exposed was equal to 6.20% (3,074,800 people) and 6.74% (approximately 3.3 million people), respectively.

The percentage of population served by surface water systems with exceedances of 0.005 mg/L was equal to 0.144% (88,300 people). Approximately 15.2% of the population served by surface water systems (about 9.3 million people) was exposed to benzene concentrations greater than 0.0005 mg/L. When evaluated relative to 0.0004 mg/L, the percent of population exposed was equal to 16.0% (over 9.8 million people).

Table 4.1-4: Stage 1 Benzene Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Ground Water	0.005	0.980%	486,300
	0.0005	6.20%	3,074,800
	0.0004	6.74%	3,346,200
Surface Water	0.005	0.144%	88,300
	0.0005	15.2%	9,289,900
	0.0004	16.0%	9,823,500
Combined Ground & Surface Water	0.005	0.518%	574,700
	0.0005	11.2%	12,364,700
	0.0004	11.9%	13,169,800

4.1.4.2 Stage 2 Analysis Occurrence Findings

The Stage 2 occurrence findings, based on the cross-section data, are presented in Tables 4.1-5 and 4.1-6. The statistically generated best estimate values, as well as the ranges around the best estimate value, are presented. (For a review of the Stage 2 analytical approach, please refer to Section 1.4 of this report. For complete details regarding the Stage 2 analyses, please refer to *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT* (USEPA, 2002)).

A total of 7 (0.0312% of) ground water and surface water PWSs in the 16 States had an estimated mean concentration of benzene exceeding 0.005 mg/L. Approximately 65 (0.279% of) PWSs in the 16 States had an estimated mean concentration exceeding 0.0005 mg/L, and 80 (0.343%) had an estimated mean concentration exceeding 0.0004 mg/L.

An estimated 7 (0.0332% of) ground water PWSs in the 16 cross-section States had a mean concentration greater than 0.005 mg/L, 61 (0.282%) had a mean concentration greater than 0.0005 mg/L, and 75 (0.344%) had a mean concentration greater than 0.0004 mg/L. Approximately 1 (0.00363% of), 4 (0.237% of), and 5 (0.323% of) surface water PWSs in the 16 States had estimated mean concentrations exceeding 0.005 mg/L, 0.0005 mg/L, and 0.0004 mg/L, respectively.

Table 4.1-5: Stage 2 Estimated Benzene Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.005	0.0332%	0.0138% - 0.0554%	7	3 - 11
	0.0005	0.282%	0.198% - 0.369%	61	43 - 80
	0.0004	0.344%	0.249% - 0.452%	75	54 - 98
Surface Water	0.005	0.00363%	0.000% - 0.0627%	1	0 - 1
	0.0005	0.237%	0.0627% - 0.501%	4	1 - 8
	0.0004	0.323%	0.125% - 0.627%	5	2 - 10
Combined Ground & Surface Water	0.005	0.0312%	0.0172% - 0.0516%	7	4 - 12
	0.0005	0.279%	0.198% - 0.370%	65	46 - 86
	0.0004	0.343%	0.245% - 0.456%	80	57 - 106

Reviewing benzene occurrence by PWS population served (Table 4.1-6) shows that approximately 0.00947% of population served by all PWSs in the 16 cross-section States (an estimate of about 10,500 people) was potentially exposed to benzene levels above 0.005 mg/L. The percentage of population served by PWSs in the 16 States with levels of benzene above 0.0005 mg/L and 0.0004 mg/L were 0.260% (about 288,000 people) and 0.309% (over 342,000 people), respectively.

When the percent of population served by ground water systems was evaluated relative to a threshold of 0.005 mg/L, 0.0005 mg/L, and 0.0004 mg/L, the percentage of population exposed in the 16 cross-section States was equal to 0.0204% (an estimated 10,100 people), 0.481% (an estimated 238,700 people) and 0.546% (an estimated 271,100 people), respectively.

The percentage of population served by surface water systems with levels above 0.005 mg/L was equal to 0.000625% (an estimated 400 people in the 16 States), and the percentage of population served with levels above 0.0005 mg/L was 0.0805% (over 49,000 people). The percentage of the population served by surface water systems with levels above 0.0004 mg/L was 0.117% (about 71,400 people in the 16 States).

Table 4.1-6: Stage 2 Estimated Benzene Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.005	0.0204%	0.00407% - 0.0629%	10,100	2,000 - 31,200
	0.0005	0.481%	0.340% - 0.632%	238,700	168,900 - 313,500
	0.0004	0.546%	0.399% - 0.758%	271,100	197,900 - 376,000
Surface Water	0.005	0.000625%	0.000% - 0.0220%	400	0 - 13,500
	0.0005	0.0805%	0.0194% - 0.283%	49,300	11,900 - 173,100
	0.0004	0.117%	0.0244% - 0.451%	71,400	15,000 - 276,200
Combined Ground & Surface Water	0.005	0.00947%	0.00188% - 0.0300%	10,500	2,100 - 33,200
	0.0005	0.260%	0.176% - 0.389%	288,000	194,700 - 431,400
	0.0004	0.309%	0.211% - 0.514%	342,500	234,200 - 570,100

4.1.4.3 Estimated National Occurrence

Based on the Stage 2 estimated percent of systems (and population served by systems) exceeding each threshold, an estimated 20 PWSs nationally serving approximately 20,200 people could be exposed to benzene concentrations above 0.005 mg/L. About 181 systems serving 553,400 people nationally had estimated mean concentrations greater than 0.0005 mg/L. Approximately 223 systems serving about 658,000 people nationally were estimated to have mean benzene concentrations greater than 0.0004 mg/L. (See Section 1.4 for a description of how Stage 2 16-State estimates are extrapolated to national values.)

For ground water systems, an estimated 20 PWSs serving about 17,500 people nationally had mean concentrations greater than 0.005 mg/L. Approximately 168 systems serving about 412,100 people nationally had estimated mean concentration values that exceeded 0.0005 mg/L. About 204 ground water systems serving almost 468,200 people had estimated mean concentrations greater than 0.0004 mg/L.

Approximately 1 surface water systems serving 800 people was estimated to have mean concentration of benzene above 0.005 mg/L. About 13 surface water systems serving 102,500 people had estimated mean concentrations greater than 0.0005 mg/L. An estimated 18 surface water systems serving approximately 148,500 people had mean concentrations greater than 0.0004 mg/L.

Table 4.1-7: Estimated National Benzene Occurrence - Systems and Population Served

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.005	20	8 - 33	17,500	3,500 - 53,900
	0.0005	168	118 - 219	412,100	291,700 - 541,300
	0.0004	204	148 - 269	479,900	341,800 - 649,200
Surface Water	0.005	1	0 - 4	800	0 - 28,000
	0.0005	13	4 - 28	102,500	24,700 - 359,800
	0.0004	18	7 - 35	151,400	31,100 - 574,200
Combined Ground & Surface Water	0.005	20	11 - 34	20,200	4,000 - 63,800
	0.0005	181	129 - 240	553,400	374,000 - 828,800
	0.0004	223	159 - 296	658,000	449,900 - 1,095,300

4.1.5 Additional Drinking Water Occurrence Data

Several additional data sources regarding the occurrence of benzene in drinking water are also reviewed. Previously compiled occurrence information, from an OGWDW summary document entitled "Occurrence of Benzene in Drinking Water, Food, and Air" (JRB Associates, 1983), is presented in this section. This variety of studies and information are presented regarding levels of benzene in drinking water, with the scope of the reviewed studies ranging from national to regional. Note that none of the studies presented in the following section provide the quantitative analytical results or comprehensive coverage that would enable direct comparison to the occurrence findings estimated with the cross-section occurrence data presented in Section 4.1.4. These additional studies, however, do enable a broader assessment of the Stage 2 occurrence estimates presented for this Six-Year Review. All the following information in Section 4.1.5 is taken directly from "Occurrence of Benzene in Drinking Water, Food, and Air" (JRB Associates, 1983).

4.1.5.1 Overview and Quality Assurance Assessment of Federal Drinking Water Surveys

Four national drinking water surveys provide data on benzene: the National Organic Monitoring Survey (NOMS), the National Screening Program for Organics in Drinking Water (NSP), the 1978 Community Water Supply Survey (CWSS), and the Groundwater Supply Survey (GWSS). The terms used in this report are those used in the individual surveys, recognizing that they may not always correspond to strict technical definitions.

The National Organic Monitoring Survey (NOMS) was conducted to identify contaminant sources, to determine the frequency of occurrence of specific drinking water contaminants, and to provide data for the establishment of maximum contaminant levels (MCL's) for various organic compounds in drinking water (Brass et al., 1977, as cited in JRB Associates, 1983). The NOMS was conducted in three phases: March-April 1976, May-July 1976, and November 1976-January 1977. Finished drinking water samples from 113 communities were analyzed for 21 different compounds. Of the 113 community supplies sampled, 18 had groundwater sources, 91 had surface water sources, and 4 had a mixed groundwater/surface water source.

The analytical results of the NOMS were made available in printed form by EPA's Technical Support Division, Office of Drinking Water. Additional information on the locations and source of the supplies, and on the populations served by the supplies in the NOMS were provided by Wayne Mello (1983) at EPA's Technical Support Division, Office of Drinking Water. A single value for benzene was reported for each supply studied in the NOMS.

The National Screening Program for Organics in Drinking Water (NSP), conducted by SRI International from June 1977 to March 1981, examined both raw and finished drinking water samples from 166 water systems in 33 States for 51 organic chemical contaminants. Data are available for benzene on finished water samples from 12 groundwater and 100 surface water supplies. However, the data for three of the groundwater supplies and 27 of the surface water supplies were indicated by Boland (1981, as cited in JRB Associates, 1983) to be suspect due to potential interference by chlorodibromomethane and trichloroethylene.

In the Community Water Supply Survey (CWSS), carried out in 1978, 106 surface water supplies, 330 groundwater supplies, and 16 supplies with mixed sources were examined for volatile organic chemical contamination. Fourteen purgeable organic compounds were analyzed and total organic carbon levels were determined. Samples were taken of raw, finished, and distribution water. Only the latter two types of water are considered here. Data for benzene in finished and/or distribution samples were obtained from a total of 289 groundwater and 97 surface water supplies.

The Groundwater Supply Survey (GWSS) was conducted from December 1980 to December 1981 to develop additional data on the occurrence of volatile organic chemicals in the nation's groundwater supplies (Westrick et al., 1983, as cited in JRB Associates, 1983). It was hoped that this study would stimulate State efforts toward the detection and control of groundwater contamination and the identification of potential chemical "hot spots." A total of 945 systems were sampled, of which 466 were chosen at random. The remaining 479 systems were chosen nonrandomly based on information from States encouraged to identify locations believed to have a higher than normal probability of VOC contamination (e.g., locations near landfills or industrial activity). The file provided a single analytical result for each supply sampled. One sample of finished water was collected from each supply at a point near the entrance to the distribution system.

Each of the drinking water surveys was evaluated with respect to the validity of the reported occurrence data for a number of organic chemicals, including benzene. The evaluations were carried out by analyzing information about the procedures used for collection and analysis of samples as well as the quality control protocols used. The reported results for the compounds studied in each survey were judged with respect to their qualitative acceptability (i.e., was the substance correctly identified as benzene), and their quantitative acceptability (i.e., are the reported measurements reliable). In the case of benzene, a qualitatively acceptable but quantitatively unacceptable rating was given for data from the NOMS, NSP and CWSS due to suspected biodegradation of the samples, which were held unrefrigerated for prolonged periods before analysis (particularly the CWSS). Benzene values in excess of the quantitation limit reported for some samples in these studies are qualitatively valid and can be taken as minimum values, representative of samples which probably originally contained benzene at higher concentrations. In the case of the GWSS, all data were rated both quantitatively and qualitatively acceptable.

4.1.5.2 Groundwater – Federal Surveys

The National Organic Monitoring Survey (NOMS), the National Screening Program for Organics in Drinking Water (NSP), the Community Water Supply Survey (CWSS), and the Groundwater Supply Survey (GWSS) all contain data concerning the levels of benzene in groundwater supplies from across the country.

Eighteen groundwater systems were analyzed for benzene during Phase I of NOMS (March to April 1976); the Phase I data are not reported here because of sample contamination invalidating the results. Eighteen groundwater systems were sampled during Phase II of the study (May to July 1976) with one containing benzene at a concentration of 0.1 µg/L. Only one supply was analyzed during Phase III of the study (November 1976 to January 1977) for benzene; none was observed. The minimum quantifiable limits for benzene were 0.1-0.2 µg/L in Phase II and 0.2 µg/L in Phase III.

Twelve groundwater supplies were tested for benzene contamination in the NSP. Data for three of these were indicated by Boland (1981, as cited in JRB Associates, 1983) to be suspect because of a potential analytical interference. Of the remaining 9 systems, none were found to be contaminated with benzene above the quantification limit of 0.1 µg/L.

The 1978 CWSS provided information on benzene levels in 289 groundwater systems. Of these systems, 5 contained detectable levels of benzene, with values ranging from 0.51-21.8 µg/L. The mean value was 5.0 µg/L with a standard deviation of 9.3 µg/L; the median value was 0.95 µg/L. The minimum quantitation limits for benzene in the CWSS ranged from 0.50-1 µg/L.

In the GWSS, 3 of the 456 randomly chosen water systems serving 25 or more individuals were contaminated with benzene, at concentrations of 0.61, 3, and 15 µg/L. Of the 473 nonrandom locations sampled serving 25 or more individuals, 8 were contaminated with benzene, at concentrations between 0.5-12 µg/L, the highest values being 1.6, 2.7, and 12 µg/L. The average benzene level for the nonrandom systems was 4.1 µg/L with a standard deviation of 4.9 µg/L; the median value was 2.2 µg/L. The minimum quantitation limit for benzene was 0.5 µg/L.

4.1.5.3 Groundwater – State Data

Data supplied to the U.S. Environmental Protection Agency by Connecticut and Delaware, showed relatively small amounts of benzene in the groundwater supplying one of four cities examined. Six samples from this site had benzene concentrations ranging from nondetectable to 4.0 µg/L, with an average of 1.8 µg/L. In Elkhart, Indiana, five samples had benzene concentrations ranging from 0.3-3,500 µg/L, with an average of 2,200 µg/L. Benzene was detected in drinking water samples from Lunenberg, Massachusetts, where 10 samples had benzene levels from undetectable to 145 µg/L (average of 70 µg/L). Finally, in Nassau County, New York, eight of 165 wells tested for benzene showed positive results, but were not quantified.

4.1.5.4 Surface Water – Federal Surveys

The National Organic Monitoring Survey (NOMS), the National Screening Program for Organics in Drinking Water (NSP), and the Community Water Supply Survey (CWSS) all contain data concerning the levels of benzene in surface water supplies from across the country.

In Phase I of the National Organic Monitoring Survey (March to April 1976), water samples from 89 surface water systems were analyzed for benzene; the Phase I data are not reported here because of sample contamination invalidating the results. Ninety-one systems were sampled during the second phase of the survey and 5 were found to be contaminated, at levels ranging from 0.1-1.8 µg/L. The average benzene concentration among the positive Phase II samples was 0.5 µg/L with a standard deviation of 0.7 µg/L; the median concentration was 0.3 µg/L. During the third phase of the NOMS (November 1976 to January 1977), analyses revealed benzene contamination in 4 out of a total of 14 systems sampled. The contamination levels for these systems ranged from 0.1-1.5 µg/L. The mean concentration was 0.9 µg/L with a standard deviation of 0.6 µg/L; the median level was 1.0 µg/L. The minimum quantifiable limits for benzene ranged from 0.1-0.4 µg/L in Phase II and 0.1-0.2 µg/L in Phase III.

Surface water samples from 100 drinking water systems were analyzed for benzene during the National Screening Program (NSP) between June 1977 and March 1981. Data for 27 of these were indicated by Boland (1981, as cited in JRB Associates, 1983) to be suspect because of a potential analytical interference. Of the remaining 73 systems, 23 contained detectable levels of benzene, ranging from 0.1-1.8 µg/L. The average concentration among the 23 positive systems was 0.2 µg/L with a standard deviation of 0.4 µg/L; the median level was 0.1 µg/L. The quantification limit for the NSP was 0.1 µg/L.

One of the 97 surface water systems sampled during the Community Water Supply Survey (CWSS) contained benzene, at a concentration of 0.56 µg/L. The minimum quantitation limit for benzene in the CWSS was 0.5 µg/L.

4.1.5.5 Surface Water – State Data

Three States provided data to the EPA on levels of benzene in drinking water supplies derived from surface water. Connecticut and Delaware reported data for a total of four cities, none of which had any positive samples. In New York, one of two cities supplying surface water data had detectable benzene concentrations. Of five samples from Waterford, New York, four were positive for benzene, with levels of 1.0-4.7 µg/L (average of 2.2 µg/L).

4.1.5.6 Projected National Occurrence of Benzene in Public Water Supplies

As reported in the JRB Associates (1983) report, public water systems in the United States fall into two major categories with respect to water source (surface water and groundwater) and into five size categories and twelve subcategories according to the number of individuals served. The JRB 1983 report presented estimates of both the number of drinking water supplies nationally within each of the source/size categories expected to have benzene present, and of the concentration of benzene expected to be present in those supplies.

The key features of the methodology used and assumptions made to develop the national estimates are summarized here. The estimates are based on the data from the Federal surveys only. The State data were not included for several reasons. Generally, these data are from a few States and were not considered to be geographically representative. There was also a general lack of data on the population served by systems measured, the type of water sampled, and the methodologies used to sample, identify, and measure benzene.

The Federal survey data from the NOMS, NSP, CWSS, and GWSS were pooled together for developing the national projections. It was assumed in combining these surveys that the resulting data base would be representative of the nation's water supplies. In the case of the GWSS data, both the random and nonrandom samples were included in the projections because a statistical test of the GWSS data showed no statistically significant difference in the frequency of occurrence of positive values or the mean of the positive values between the random and nonrandom samples.

Ideally, adequate data would be available to develop the national projections separately for each of the twelve system size categories within the groundwater and surface water groups; however, the available data were too limited for this. JRB (1983) consolidated some of the size categories to have sufficient data for developing the projections. In consolidating data from various size categories, consideration was given to the potential for there being statistically significant differences in the frequency of occurrence of benzene as a function of system size. The consolidation of size categories therefore involved a balancing of the need to group size categories together to have an adequate data base for developing the national projections against the need to treat size categories separately in order to preserve the influence of system size as a determinant of contamination potential. The consolidation of size categories also took into account EPA's classification of systems into the five major groups as very small (25-500), small (501-3,300), medium (3,301-10,000), large (10,001-100,000), and very large (> 100,000) (Kuzmack, 1983, as cited in JRB Associates, 1983).

Once the data were consolidated, statistical models for extrapolating to the national level were tested and an appropriate model selected. In the case of benzene, the delta distribution was used for groundwater and the multinominal method was used for surface water. The frequency of contamination of groundwater and surface water systems at various concentrations was determined for each consolidated size category. For completing the national estimates, it was assumed that the frequency of contamination observed for each consolidated category was directly applicable to each of the system sizes comprising it.

In the JRB Associates (1983) report, it is noted that some of the data used in computing the national estimates are from samples held for a prolonged period of time prior to analysis, with possible biodegradation of benzene. Therefore, they concluded that these projections of national occurrence may underestimate actual contaminant levels.

4.1.5.6.1 Groundwater Supplies

The combined benzene groundwater data from the NOMS, NSP, CWSS, and GWSS surveys are available. JRB Associates (1983) also reported that data were available for a total of 1,223 supplies from the combined surveys. Of these, 17 supplies were reported to have benzene present, at concentrations ranging from 0.13 µg/L to 15 µg/L. Based on the overall distribution of positive values and maximum possible values for those supplies in which benzene was not found, 0.5 µg/L was selected as the common minimum quantifiable concentration for the combined survey data. That is, quantitative projections are made of supplies at several concentration ranges > 0.5 µg/L, while only a total number for supplies expected to have either no benzene or levels below 0.5 µg/L can be determined. Although some data indicate the presence of benzene in groundwater supplies at levels < 0.5 µg/L, it is not possible to determine the proportion of supplies that have benzene present and the proportion that are actually free of benzene contamination.

Of the 1,206 supplies reporting no benzene to be present, 1,202 were assumed to have maximum possible levels of < 0.5 µg/L based on the minimum quantifiable concentrations reported for the various surveys. The other 4 supplies reporting no benzene to be present had maximum possible levels ranging from 0.6 µg/L to 1.0 µg/L. It is assumed, based on the overall distribution of values, that benzene if present in these 4 supplies is so at a concentration of < 0.5 µg/L, although a rigorous, conservative argument could be made for assuming a level equal to the maximum possible value.

Sixteen of the 1,223 supplies examined had measured values of benzene > 0.5 µg/L. When the twelve size categories were consolidated into the five major EPA groupings, there was no apparent trend in the frequency of values > 0.5 µg/L as a function of size:

Very small	0.3%	(1/362)
Small	1.4%	(4/293)
Medium	1.6%	(3/186)
Large	2.4%	(8/338)
Very large	0%	(0/44)
Overall	1.3%	(16/1,223)

A test for statistical significance revealed that at the 0.05 level, the difference among the five categories was not significant; therefore, all supplies were grouped together for the analysis. As noted previously, the frequency of occurrence of benzene at various concentrations was determined for the consolidated group and then applied to the number of supplies nationally within each of the individual size categories comprising the group.

No groundwater supplies are estimated to have benzene present in any of the 10 µg/L ranges above 50 µg/L, but it can be estimated that there are two supplies with benzene present at levels exceeding 50 µg/L. This apparent discrepancy is due to the rounding of fractional numbers of supplies resulting from the delta distribution to the nearest integer. That is, the fractional numbers of supplies estimated to have benzene above 50 µg/L were rounded to 0 within each individual 10 µg/L range, while the sum of all the fractional numbers above 50 µg/L was rounded to 2. The cumulative estimates are probably more descriptive of the national occurrence than are the estimates within each 10 µg/L range. An estimated 635 groundwater supplies (range of 330-939), approximately 1.3% of the total groundwater supplies in the United States, are expected to have benzene at levels of > 0.5 µg/L; the remaining 47,823 supplies have either no benzene or levels < 0.5 µg/L.

It is estimated that 60 supplies (range of 0-154) are expected to have benzene levels > 10 µg/L; while 2 supplies (range of 0-23) are expected to have levels > 50 µg/L. Most of the supplies with high benzene levels are expected to be in the smaller size categories. Although, as noted previously, the frequency of benzene occurrence appears to be independent of system size, the number of systems affected nationally is greater for the small sizes because there are many more small systems in existence.

4.1.5.6.2 Surface Water Systems

Data are available for a total of 223 surface water supplies. Of these, 29 supplies were reported by JRB Associates (1983) to have benzene present at concentrations ranging from 0.1 µg/L to 1.4 µg/L.

Based on the overall distribution of positive values and maximum possible values for those supplies in which benzene was not found, 0.5 µg/L was selected as the common minimum quantifiable concentration for the combined survey data. That is, quantitative projections are made of supplies at several concentration ranges > 0.5 µg/L, while only a total number for supplies expected to have either no benzene or levels below 0.5 µg/L can be determined. Although some data indicate the presence of benzene in surface water supplies at levels < 0.5 µg/L, it is not possible to determine the proportion that have benzene present and the proportion that are free of benzene contamination.

Only 6 of the 223 supplies examined had measured values of benzene > 0.5 µg/L. The twelve size categories were consolidated into the five major EPA groupings, showing the following frequency of occurrence of values > 0.5 µg/L as a function of size:

Very small	0%	(0/18)
Small	2.9%	(1/34)
Medium	4.2%	(1/24)
Large	1.9%	(1/52)
Very large	3.2%	(3/95)
Overall	2.7%	(6/223)

A test for statistical significance revealed that at the 0.05 level, there was no difference in the frequency of occurrence of benzene at levels > 0.5 µg/L among these groups. Therefore, the data from all sizes were consolidated to develop the national estimates. As noted previously, the frequency of occurrence of benzene at various concentrations was determined for the consolidated group and then applied to the number of supplies nationally within each of the individual size categories comprising it.

An estimated 301 surface water supplies (range of 64-537), approximately 2.7% of the total surface water systems in the United States, are expected to have benzene at levels > 0.5 µg/L; the remaining 10,901 supplies have either no benzene or levels < 0.5 µg/L. It is estimated that no surface water supplies will have levels > 5 µg/L.

4.1.6 Conclusion

Benzene is a manufactured organic chemical that is used heavily in several industries and (in 1994) was the 17th highest volume chemical produced in the U.S. Most benzene is used as a building block for making plastics, rubber, resins and synthetic fabrics like nylon and polyester. It is also used in the manufacture of medicines, dyes, artificial leather, linoleum, oil cloth, pesticides, plastics and resins, PCB, aviation fuel, other organics, and in organic synthesis. Recent statistics regarding production and use indicate that benzene is a very abundant chemical. Industrial releases of benzene have been reported to TRI since 1988 in 49 States, Puerto Rico, Washington D.C., the Virgin Islands, Guam, American Samoa, and the Northern Mariana Islands. Benzene was also an analyte for the NAWQA, NURP, and NPDES ambient occurrence studies. In the NAWQA study, benzene was detected in 3.5% of urban wells and 0.96% of rural wells, with median detection values of 1.0 µg/L and 0.7 µg/L, respectively. The Stage 2 analysis, based on the 16-State cross-section, estimated that approximately 0.0313% of combined ground water and surface water systems serving 0.0105% of the population had estimated mean concentrations of benzene greater than the MCL of 0.005 mg/L. Based on this estimate, approximately 20 PWSs nationally serving approximately 22,500 people are expected to have estimated mean concentrations of benzene greater than the MCL.

The 16-State cross-section was designed to be nationally representative based upon VOC, SOC, and IOC pollution potentials as suggested by considerations of manufacturing, agriculture, and geographic diversity factors. Nationally, benzene is manufactured and/or processed in over 40 States and has TRI releases in every state except for Vermont. Benzene is manufactured and/or processed in 14 out of the 16 cross-section States and has TRI releases in 15 of the 16 cross-section States. The cross-section should adequately represent the occurrence of benzene on a national scale based upon the use, production, and release patterns of the 16-State cross-section in relation to the patterns observed for all 50 States.

4.1.7 References

Agency for Toxic Substances and Disease Registry (ATSDR). 1997. *Toxicological Profile for Benzene.* U.S. Department of Health and Human Services, Public Health Service. 423 pp. + Appendices. Available on the Internet at http://www.atsdr.cdc.gov/toxprofiles/tp3.pdf

Boland, P.A. 1981. *National Screening Program for Organics in Drinking Water.* Prepared by SRI International, Menlo Park, California, for Office of Drinking Water, U.S. Environmental Protection Agency, Washington, DC. EPA Contract No. 68-01-4666.

Brass, H.J., M.A. Feige, T. Halloran, J.W. Mello, D. Munch, and R.F. Thomas. 1977. The National Organic Monitoring Survey: A sampling and analysis for purgeable organic compounds. *Drinking water quality enhancement through source protection.* R.B. Pojasek (ed.). Ann Arbor, MI: Ann Arbor Science, pp. 393-416.

JRB Associates. 1983. *Benzene: Occurrence in Drinking Water, Food, and Air.* Draft report submitted to EPA for review November 23, 1983.

Kuzmack, A.M. 1983. Memorandum: Characterization of the water supply industry (FY82). Washington, D.C.: Office of Water, U.S. Environmental Protection Agency. May 16, 1983.

Lopes, T.J. and S.G. Dionne. 1998. *A Review of Semivolatile and Volatile Organic Compounds in Highway Runoff and Urban Stormwater*. U.S. Geological Survey Open-File Report 98-409. 67 pp.

Mello, Wayne. 1983. Personal communication between Wayne Mello, Technical Support Division, Office of Drinking Water, U.S. Environmental Protection Agency, and author of JRB Associates, 1983, March 10, 1983.

National Safety Council (NSC). 2001. *Benzene Chemical Backgrounder*. Itasca, IL: National Safety Council. Available on the Internet at: http://www.crossroads.nsc.org/ChemicalTemplate.cfm?id=83&chempath=chemicals, accessed July 23, 2001.

National Toxicology Program (NTP). 2001. *National Toxicology Program Health and Safety Information Sheet - Benzene.* Available on the Internet at http://ntp-server.niehs.nih.gov/htdocs/CHEM_H&S/NTP_Chem7/Radian71-43-2.html, last updated August 13, 2001.

Squillace, P.J., M.J. Moran, W.W. Lapham, C.V. Price, R.M. Clawges, and J.S. Zogorski. 1999. Volatile organic compounds in untreated ambient groundwater of the United States, 1985-1995. *Env. Sci. and Tech*. 33(23):4176-4187.

USEPA. 2000. *TRI Explorer: Trends*. Available on the Internet at: http://www.epa.gov/triexplorer/trends.htm, last updated May 5, 2000.

USEPA. 2001. *National Primary Drinking Water Regulations - Consumer Factsheet on: Benzene.* Office of Ground Water and Drinking Water, USEPA. Available on the Internet at http://www.epa.gov/safewater/dwh/c-voc/benzene.html, last updated April 12, 2001.

USEPA. 2002. *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT*. EPA Report/815-D-02-005, Office of Water, 55 pp.

Westrick, J.J., J.W. Mello, and R.F. Thomas. 1983. *The Ground Water Supply Survey summary of volatile organic contaminant occurrence data.* EPA Technical Support Division, Office of Drinking Water, Cincinnati, Ohio.

4.2 Carbon Tetrachloride

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Tables and Figures

4.2.1 Introduction, Use and Production

Carbon tetrachloride (CCl_4) is a clear liquid that evaporates very easily. It has a sweet odor and does not easily burn. Most carbon tetrachloride that escapes to the environment is, therefore, found as a gas. Carbon tetrachloride does not occur naturally but has been produced in large quantities to make refrigeration fluid and propellants for aerosol cans (ATSDR, 1994). Its major routes of entry to drinking water are a consequence of its industrial production and use (JRB Associates, 1983). It is expected that discharges to surface water during production and use, and leaching into groundwater from wastes deposited in landfills are primary causes of carbon tetrachloride contamination of drinking water (JRB Associates, 1983). Carbon tetrachloride is also known as carbona, carbon chloride, carbon tet, methane tetrachloride, perchloromethane, tetrachloromethane, and benzinoform (ATSDR, 1994).

With few exceptions, production of carbon tetrachloride has been eliminated in developed nations, including the U.S. As an ozone-depleting substance (ODS), carbon tetrachloride falls under the auspices of the Montreal Protocol, which mandated the cessation of production of carbon tetrachloride as of January 1, 2000. The only exceptions to this rule are for “transformation” and “destruction”.

Under the transformation exemption, the Protocol excludes from phase-out those ODSs that are used as feedstocks during the manufacturing process. The rationale for this exemption is that no ODS is released into the atmosphere after transformation, and thus it is unnecessary for the Protocol to prohibit such use. To qualify for the exemption under international law, an ODS must be nearly 100% transformed into a non-ODS product and any residual must be destroyed as provided under the destruction exemption (McKenna and Cuneo, 2001).

Under the destruction exemption, controlled substances that are destroyed rather than emitted to the atmosphere are not subject to the ban. This exemption is based on the Protocol's definition of “production” which is “the amount of controlled substances produced, minus the amount destroyed by technologies approved by the Parties” (McKenna and Cuneo, 2001).

Prior to the enactment of the Montreal Protocol, use of carbon tetrachloride was already heavily restricted. All consumer uses, such as use in the production of refrigeration fluid and propellants for aerosols, as a pesticide, as a cleaning fluid, and in fire extinguishers, were prohibited, and its application was limited to some industrial applications. The major use of carbon tetrachloride in the early 1990s was in the production of chlorofluorocarbons, such as dichlorodifluoromethane and trichlorofluoroemthane (ATSDR, 1994).

The decrease in use of carbon tetrachloride has led to a similar decrease in the amount produced. According to the latest figures available before the ban on production, the U.S. produced between 573 and 761 million pounds each year from 1981-1988. Production was 413 million pounds in 1990 and 315 million pounds in 1991. Because of the continual phasing out of most uses of carbon tetrachloride, production was expected to lessen to an even greater extent in the 1990s, although no data is available to corroborate that assumption (ATSDR, 1994).

Table 4.2-1 shows the number of facilities in each State that manufactured and processed carbon tetrachloride as of 1992, the intended uses of the product, and the range of maximum amounts derived from the Toxics Release Inventory (TRI) of EPA (ATSDR, 1994).

Table 4.2-1: Carbon Tetrachloride Manufacturers and Processors by State[a]

State[b]	Number of facilities	Range of maximum amounts on site in thousands of pounds[c]	Activities and uses[d]
AL	4	10-49,999	1,4,5,11
AR	2	10-99	7,11
CA	8	0-49,999	1,3,4,5,7,8,11,12,13
CO	1	1-9	1,5,11
DE	1	100-999	7
GA	2	0-0.09	8,9,12
IL	3	10-9,999	7,11
IN	2	10-99	1,5,6,11
KS	5	10-9,999	1,3,4,7,11
KY	6 (1)[e]	10-9,999	1,3,5,7,10,11,13
LA	16	0-49,999	1,3,4,5,6,7,11,12,13
MD	1	10-99	7
MI	2	10-999	7,11
MN	2	1-99	11,13
MO	2	10-99	13
MS	2	0.1-99	11,13
MT	1	0.1-0.9	11
ND	1	10-99	11
NJ	4	0-9,999	3,7,8,9,11
NY	1 (1)[e]	No Data	11
OH	6	1-999	1,5,10,11,12,13
OK	2	10-99	11
PA	2	10-99	11
TN	2	1-999	11
TX	14	1-49,999	1,4,5,6,7,8,10,11,12,13
VA	1	10-99	13
VI	1	10-99	11
WV	2	0.1-999	1,4,6
WY	1	1-9	11

[a] Derived from TRI90 (1992)
[b] Post office State abbreviations used
[c] Data in TRI are maximum amounts on site at each facility
[d] Activities/Uses include:

1. Produce
2. Import
3. For on-site use/processing
4. For sale/distribution
5. As a byproduct
6. As an impurity
7. As a reactant
8. As a formulation component
9. As an article component
10. For repackaging only
11. As a chemical processing aid
12. As a manufacturing aid
13. Ancillary or other uses

[e] Number of facilities reporting “no data” regarding maximum amount of the substance on site

Source: ATSDR, 1994 compilation of TRI90 1992 data

4.2.2 Environmental Release

Carbon tetrachloride is listed as a Toxics Release Inventory (TRI) chemical. Table 4.2-2 illustrates the environmental releases for carbon tetrachloride from 1988 to 1999. (Carbon tetrachloride data are only available for these years.) Air emissions constitute the vast majority of the on-site releases, with a steady decrease over the years. Surface water discharges have generally decreased from 1988 to 1999, with the exception of an increase in 1998. Releases to land (such as spills or leaks within the boundaries of the reporting facility) decreased from 1988 to 1993, remained at zero for three years, and then began increasing in 1997. Off-site releases (including metals or metal compounds transferred off-site) have generally decreased from 1988 to 1999. The decrease in air emissions, as well as underground injection, have predominantly contributed to decreases in carbon tetrachloride total on- and off-site releases in recent years. These TRI data for carbon tetrachloride were reported from 38 States, Puerto Rico, and the Virgin Islands (USEPA, 2000). Sixteen of the 38 States reported every year. Twelve of the cross-section

States (used for analyses of carbon tetrachloride occurrence in drinking water; see Section 4.2.4) reported releases. (For a map of the 16-State cross-section, see Figure 1.3-1.)

Table 4.2-2: Environmental Releases (in pounds) for Carbon Tetrachloride in the United States, 1988-1999

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1999	237,235	84	27,548	938	7,307	273,112
1998	274,291	2,586	23,163	1,679	9,956	311,675
1997	357,902	315	32,958	135	18,697	410,007
1996	363,681	215	44,515	0	9,245	417,656
1995	420,754	717	53,966	0	7,735	483,172
1994	651,098	1,223	12,654	0	50,791	715,766
1993	2,243,590	1,453	34,332	79	121,363	2,400,817
1992	1,399,490	2,444	45,984	333	11,955	1,460,206
1991	1,549,782	2,849	42,475	2,157	39,111	1,636,374
1990	1,753,340	4,718	31,557	1,005	10,163	1,800,783
1989	3,465,179	15,656	122,030	1,616	24,996	3,629,477
1988	3,795,248	15,627	98,050	14,759	49,703	3,973,387

Source: USEPA, 2000

4.2.3 Ambient Occurrence

National NAWQA data, as well as NURP and NPDES data, are currently unavailable for carbon tetrachloride. Additional studies of ambient data are also unavailable. A summary document entitled “Occurrence of Carbon Tetrachloride in Drinking Water, Food and Air” (JRB Associates, 1983), was previously prepared for past USEPA assessments of carbon tetrachloride. However, no information on the ambient occurrence of carbon tetrachloride was included in that document. (The document did include information regarding carbon tetrachloride occurrence in drinking water, which is discussed in Section 4.2.5 of this report.)

4.2.4 Drinking Water Occurrence Based on the 16-State Cross-Section

The analysis of carbon tetrachloride occurrence presented in the following section is based on State compliance monitoring data from the 16 cross-section States. The 16-State cross-section is the largest and most comprehensive compliance monitoring data set compiled by EPA to date. These data were evaluated relative to several concentration thresholds of interest: 0.005 mg/L; 0.0025 mg/L; and 0.0005 mg/L.

All sixteen cross-section State data sets contained occurrence data for carbon tetrachloride. These data represent more than 182,000 analytical results from approximately 23,000 PWSs during the period from 1984 to 1998 (with most analytical results from 1992 to 1997). The number of sample results and PWSs vary by State, although the State data sets have been reviewed and checked to ensure adequacy of coverage and completeness. The overall modal detection limit for carbon tetrachloride in the 16 cross-section States is equal to 0.0005 mg/L. (For details regarding the 16-State cross-section, please refer to Section 1.3.5 of this report.)

4.2.4.1 Stage 1 Analysis Occurrence Findings

Table 4.2-3 illustrates the occurrence of carbon tetrachloride in drinking water for the public water systems in the 16-State cross-section relative to three thresholds: 0.005 mg/L (the current MCL), 0.0025 mg/L, and 0.0005 mg/L (the modal MRL). Based on the 16-State cross-section data, a total of 47 (approximately 0.204% of) ground water and surface water PWSs had analytical results exceeding the MCL; 0.386% of systems (89 systems) had results exceeding 0.0025 mg/L; and 1.56% of systems (359 systems) had results exceeding 0.0005 mg/L.

Approximately 0.205% of ground water systems (44 systems) had any analytical results greater than the MCL. About 0.350% of ground water systems (75 systems) had results above 0.0025 mg/L. The percentage of ground water systems with at least one result greater than 0.0005 mg/L was equal to 1.32% (283 systems).

Only 3 (0.191% of) surface water systems had results greater than the MCL. A total of 14 (0.889% of) surface water systems had at least one analytical result greater than 0.0025 mg/L. Seventy-six (4.83% of) surface water systems had results exceeding 0.0005 mg/L.

Table 4.2-3: Stage 1 Carbon Tetrachloride Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Ground Water	0.005	0.205%	44
	0.0025	0.350%	75
	0.0005	1.32%	283
Surface Water	0.005	0.191%	3
	0.0025	0.889%	14
	0.0005	4.83%	76
Combined Ground & Surface Water	0.005	0.204%	47
	0.0025	0.386%	89
	0.0005	1.56%	359

Reviewing carbon tetrachloride occurrence in the 16 cross-section States by PWS population served (Table 4.2-4) shows that approximately 7.35% of the 16-State population (over 8 million people) was served by PWSs with at least one analytical result of carbon tetrachloride greater than the MCL (0.005 mg/L). Approximately 9.2 million (8.32% of) people were served by systems with an exceedance of 0.0025 mg/L. Over 13.6 million (12.3% of) people were served by systems with at least one analytical result greater than 0.0005 mg/L.

The percentage of population served by ground water systems with analytical results greater than the MCL was equal to 0.830% (about 411,200 people). When evaluated relative to 0.0025 mg/L and 0.0005 mg/L, the percent of population exposed was equal to 2.14% (1,060,200 people) and 7.64% (approximately 3.8 million people), respectively.

The percentage of population served by surface water systems with exceedances of 0.005 mg/L was equal to 12.6% (over 7.7 million people). Approximately 13.3% of the population served by surface water systems in the 16 States (almost 8.2 million people) was exposed to carbon tetrachloride concentrations greater than 0.0025 mg/L. When evaluated relative to 0.0005 mg/L, the percent of population exposed was equal to 16.1% (over 9.8 million people).

Table 4.2-4: Stage 1 Carbon Tetrachloride Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Ground Water	0.005	0.830%	411,200
	0.0025	2.14%	1,060,200
	0.0005	7.64%	3,783,200
Surface Water	0.005	12.6%	7,721,100
	0.0025	13.3%	8,147,200
	0.0005	16.1%	9,818,800
Combined Ground & Surface Water	0.005	7.35%	8,132,300
	0.0025	8.32%	9,207,300
	0.0005	12.3%	13,602,000

4.2.4.2 Stage 2 Analysis Occurrence Findings

The Stage 2 occurrence findings, based on the cross-section data, are presented in Tables 4.2-5 and 4.2-6. The statistically generated best estimate values, as well as the ranges around the best estimate value, are presented. (For a review of the Stage 2 analytical approach, please refer to Section 1.4 of this report. For complete details regarding the Stage 2 analyses, please refer to *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT* (USEPA, 2002)).

A total of 4 (0.0159% of) ground water and surface water PWSs in the 16 States had an estimated mean concentration of carbon tetrachloride exceeding 0.005 mg/L. Approximately 6 (0.0256% of) PWSs in the 16 States had an estimated mean concentration exceeding 0.0025 mg/L, and 48 (0.210%) had an estimated mean concentration exceeding 0.0005 mg/L.

An estimated 4 (0.0171% of) ground water PWSs in the 16 cross-section States had a mean concentration greater than 0.005 mg/L, 6 (0.0273%) had a mean concentration greater than 0.0025 mg/L, and 41 (0.193%) had a mean concentration greater than 0.0005 mg/L. Approximately 0.000381% (less than 1), 0.00267% (about 1), and 0.441% of (approximately 7) surface water PWSs in the 16 States had estimated mean concentrations exceeding 0.005 mg/L, 0.0025 mg/L, and 0.0005 mg/L, respectively.

Table 4.2-5: Stage 2 Estimated Carbon Tetrachloride Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.005	0.0171%	0.00932% - 0.0233%	4	2 - 5
	0.0025	0.0273%	0.0186% - 0.0373%	6	4 - 8
	0.0005	0.193%	0.140% - 0.242%	41	30 - 52
Surface Water	0.005	0.000381%	0.000% - 0.000%	0	0 - 0
	0.0025	0.00267%	0.000% - 0.0635%	1	0 - 1
	0.0005	0.441%	0.254% - 0.699%	7	4 - 11
Combined Ground & Surface Water	0.005	0.0159%	0.00869% - 0.0217%	4	2 - 5
	0.0025	0.0256%	0.0174% - 0.0347%	6	4 - 8
	0.0005	0.210%	0.161% - 0.265%	48	37 - 61

Reviewing carbon tetrachloride occurrence by PWS population served (Table 4.2-6) shows that approximately 0.0316% of population served by all PWSs in the 16 cross-section States (an estimate of approximately 35,000 people) was potentially exposed to carbon tetrachloride levels above 0.005 mg/L. The percentage of population served by PWSs in the 16 States with levels of carbon tetrachloride above 0.0025 mg/L was 0.0474% (approximately 52,500 people). Approximately 7.37% of the population served in the 16 States (over 8.1 million people) was exposed to carbon tetrachloride concentrations above 0.0005 mg/L.

When the percent of population served by ground water systems was evaluated relative to a threshold of 0.005 mg/L, 0.0025 mg/L, and 0.0005 mg/L, the percentage of population exposed in the 16 cross-section States was equal to 0.0705% (an estimated 34,900 people), 0.104% (an estimated 51,600 people) and 0.764% (an estimated 378,500 people), respectively.

The percentage of population served by surface water systems with levels above 0.005 mg/L was equal to 0.0000713%, and the percentage of population served with levels above 0.0025 mg/L was 0.00139% (about 800 people). The percentage of the population served by surface water systems dramatically increased to about 12.7% (about 7.8 million people in the 16 States) when evaluated relative to 0.0005 mg/L.

Table 4.2-6: Stage 2 Estimated Carbon Tetrachloride Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.005	0.0705%	0.00158% - 0.0950%	34,900	800 - 47,000
	0.0025	0.104%	0.0938% - 0.191%	51,600	46,500 - 94,400
	0.0005	0.764%	0.627% - 1.05%	378,500	310,600 - 521,700
Surface Water	0.005	0.0000713%	0.000% - 0.000%	0	0 - 0
	0.0025	0.00139%	0.000% - 0.00104%	800	0 - 600
	0.0005	12.7%	12.4% - 13.9%	7,779,500	7,571,900 - 8,487,800
Combined Ground & Surface Water	0.005	0.0316%	0.000707% - 0.0429%	35,000	800 - 47,500
	0.0025	0.0474%	0.0420% - 0.0865%	52,500	46,500 - 95,700
	0.0005	7.37%	7.16% - 8.00%	8,154,900	7,916,000 - 8,849,500

4.2.4.3 Estimated National Occurrence

Based on the Stage 2 estimated percent of systems (and population served by systems) exceeding each threshold, an estimated 10 PWSs serving approximately 67,400 people nationally could be exposed to carbon tetrachloride concentrations above 0.005 mg/L. About 17 systems serving 101,100 people had estimated mean concentrations greater than 0.0025 mg/L. Approximately 137 systems serving about 15.7 million people nationally were estimated to have mean carbon tetrachloride concentrations greater than 0.0005 mg/L. (See Section 1.4 for a description of how Stage 2 16-State estimates are extrapolated to national values.)

For ground water systems, an estimated 10 PWSs serving about 60,400 people nationally had mean concentrations greater than 0.005 mg/L. Approximately 16 systems serving about 89,300 people nationally had estimated mean concentration values that exceeded 0.0025 mg/L. About 115 ground water systems serving almost 654,600 people had estimated mean concentrations greater than 0.0005 mg/L.

Approximately 1 surface water system serving less than 100 people was estimated to have a mean concentration of carbon tetrachloride above 0.005 mg/L. One surface water system serving about 1,800 people nationally had an estimated mean concentration greater than 0.0025 mg/L. An estimated 25 surface water systems serving over 16 million people had mean concentrations greater than 0.0005 mg/L.

Table 4.2-7: Estimated National Carbon Tetrachloride Occurrence - Systems and Population Served

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.005	10	6 - 14	60,400	1,400 - 81,400
	0.0025	16	11 - 22	89,300	80,400 - 163,300
	0.0005	115	83 - 144	654,600	537,200 - 902,200
Surface Water	0.005	1	0 - 0	< 100	0 - 0
	0.0025	1	0 - 4	1,800	0 - 1,300
	0.0005	25	14 - 39	16,221,400	15,788,500 - 17,698,400
Combined Ground & Surface Water	0.005	10	6 - 14	67,400	1,500 - 91,400
	0.0025	17	11 - 23	101,100	89,500 - 184,300
	0.0005	137	105 - 172	15,705,100	15,245,000 - 17,042,800

4.2.5 Additional Drinking Water Occurrence Data

Several additional data sources regarding the occurrence of carbon tetrachloride in drinking water are also reviewed. Previously compiled occurrence information, from an OGWDW summary document entitled "Occurrence of Carbon Tetrachloride in Drinking Water, Food, and Air" (JRB Associates, 1983), is presented in the following section. This variety of studies and information are presented regarding levels of carbon tetrachloride in drinking water, with the scope of the reviewed studies ranging from national to regional. Note that none of the studies presented in the following section provide the quantitative analytical results or comprehensive coverage that would enable direct comparison to the occurrence findings estimated with the cross-section occurrence data presented in Section 4.2.4. These additional studies, however, do enable a broader assessment of the Stage 2 occurrence estimates presented for this Six-Year Review. All the following information in Section 4.2.5 is taken directly from "Occurrence of Carbon Tetrachloride in Drinking Water, Food, and Air" (JRB Associates, 1983).

JRB Associates (1983) found three major types of data available that were potentially useful for describing the occurrence of carbon tetrachloride in the nation's public drinking water supplies. First, there are several Federal surveys in which a number of public water supplies from throughout the U.S. were selected for analysis of chemical contamination, including carbon tetrachloride. Second, data are available from State surveys and from State investigations of specific incidents of known or suspected contamination of a supply. Third, there are miscellaneous published data which, like some of the State data, tend to be from studies in response to suspected contamination of specific sites. For accomplishing the basic objectives of this study, namely to estimate the number of public water supplies nationally within the various source and size categories contaminated with carbon tetrachloride, the distribution of carbon tetrachloride concentrations in those supplies, and the number of individuals exposed to those concentrations, it was determined that the Federal survey data provides the most suitable data base. The State and miscellaneous data tend to be poorly described with respect to the source and size categories of the supplies examined and the sampling and analysis methods used for determining contaminant levels.

The lack of source and system size information precludes using the data for estimating levels in public water supplies of similar characteristics. The absence of details on sampling and analysis methods precludes evaluating those data for their qualitative and quantitative reliability. Also, because much of the State and miscellaneous data are from investigations in response to incidents of known or suspected contamination (e.g., spills), they were judged to be not representative of contaminant levels in the nation's water supplies in general. Although they are not used with the Federal data for the purpose of estimating contamination levels nationally, the available State and miscellaneous data are presented here to provide some additional perspective on carbon tetrachloride occurrence in drinking water.

Data are presented only on drinking water samples taken from a consumer's tap (i.e., distribution water samples) or on treated water samples taken at the water supply (i.e., finished water samples) because these are considered to be most representative of the water consumed by the public. No data on raw (i.e., untreated) water are presented. It is recognized that for some groundwater supplies where no treatment of the water occurs, samples identified as raw may be representative of water consumed by the users of the supply. However, it was generally not possible to differentiate between those groundwater supplies that do and those that do not treat raw water from the available survey data.

4.2.5.1 Overview and Quality Assurance Assessment of Federal Drinking Water Surveys

Six Federal drinking water surveys provide data on carbon tetrachloride: the National Organics Reconnaissance Survey (NORS), the National Organic Monitoring Survey (NOMS), the National Screening Program for Organics in Drinking Water (NSP), the 1978 Community Water Supply Survey (CWSS), the Rural Water Survey (RWS), and the Groundwater Supply Survey (GWSS). The terms used in this report are those used in the individual surveys, recognizing that they may not always correspond to strict technical definitions.

The National Organics Reconnaissance Survey (NORS) was conducted in 1975 to determine the extent of the presence of carbon tetrachloride, 1,2-dichloroethane, and four trihalomethanes in drinking water supplies from 80 cities across the country (Symons et al., 1975, as cited in JRB Associates, 1983). The effect of the water sources and treatment practices on the formation of these compounds were also examined in NORS. Of the 80 supplies studied, 16 were indicated as having a groundwater source and 64 as having a surface water source. Symons et al. (1975, as cited in JRB Associates, 1983) did not provide data on the population served by the supplies studied in the NORS; the populations served were estimated by JRB based on information available from other sources for the supplies studied and from census data for the locations of the supplies.

The National Organic Monitoring Survey (NOMS) was conducted to identify contaminant sources, to determine the frequency of occurrence of specific drinking water contaminants, and to provide data for the establishment of maximum contaminant levels (MCLs) for various organic compounds in drinking water (Brass et al. 1977, as cited in JRB Associates, 1983). The NOMS was conducted in three phases: March to April 1976, May to July 1976, and November 1976 to January 1977. Finished drinking water samples from 113 communities were analyzed for 21 different compounds. Of the 113 community supplies sampled, 18 had groundwater sources, 91 had surface water sources, and 4 had a mixed groundwater/surface water source. For carbon tetrachloride, data are available for 18 groundwater sources and 89 surface water sources.

The analytical results of the NOMS were made available in printed form by EPA's Technical Support Division, Office of Drinking Water. Additional information on the locations and source of the supplies, and on the populations served by the supplies in the NOMS were provided by Wayne Mello (1983, as cited in JRB Associates, 1983) at EPA's Technical Support Division, Office of Drinking Water. A single value for carbon tetrachloride was reported for each supply studied in the NOMS.

The National Screening Program for Organics in Drinking Water (NSP), conducted by SRI International from June 1977 to March 1981, examined both raw and finished drinking water samples from 166 water systems in 33 States for 51 organic chemical contaminants. Data are available for carbon tetrachloride on finished water samples from 12 groundwater and 106 surface water supplies.

In the Community Water Supply Survey (CWSS), carried out in 1978, 106 surface water supplies, 330 groundwater supplies, and 16 supplies with mixed sources were examined for volatile organic chemical contamination. Fourteen purgeable organic compounds were analyzed and total organic carbon levels were determined. Samples were taken of raw, finished, and distribution water. Only the latter two types of water are considered here. Data for carbon tetrachloride in finished and/or distribution samples were obtained from a total of 316 groundwater and 105 surface water supplies.

The Rural Water Survey (RWS), conducted in 1978, was carried out in response to Section 3 of the Safe Drinking Water Act, which mandated that EPA "conduct a survey of the quantity, quality, and availability of rural drinking water supplies." Drinking water samples were collected for analysis of inorganic chemicals, pesticides, and VOCs from 2,655 households throughout the United States located in areas defined in the survey as rural. Of these, a total of 855 household samples were examined for VOCs. The majority of these samples were obtained from households receiving water from private wells or small supplies serving fewer than 25 people. For carbon tetrachloride, data are available in the RWS for 207 groundwater and 45 surface water supplies serving 25 or more people.

The RWS did not obtain data on the number of persons in each household served by the supplies. However, data were obtained on the number of service connections at each supply. With the input of Dr. Bruce Brower at Cornell University, who participated in the statistical analysis of the RWS for parameters other than VOCs, the population served by each supply was estimated from the average number of persons per household (3.034) observed in the survey. A single value was reported for each household; in some cases it was necessary to average two or three households obtaining water from the same supply. Brass (1981, as cited in JRB Associates, 1983) cautions that the RWS water samples were analyzed 6 to 27 months after collection and that degradation of some VOCs may have occurred during this holding period.

The Groundwater Supply Survey (GWSS) was conducted from December 1980 to December 1981 to develop additional data on the occurrence of volatile organic chemicals in the nation's groundwater supplies (Westrick et al., 1983, as cited in JRB Associates, 1983). It was hoped that this study would stimulate State efforts toward the detection and control of groundwater contamination and the identification of potential chemical "hot spots." A total of 945 systems were sampled, of which 466 were chosen at random. The remaining 479 systems were chosen nonrandomly based on information from States encouraged to identify locations believed to have a higher than normal probability of VOC contamination (e.g., locations near landfills or industrial activity). One sample of finished water was collected from each supply at a point near the entrance to the distribution system.

Each of the drinking water surveys was evaluated with respect to the validity of the reported occurrence data for a number of organic chemicals, including carbon tetrachloride. The evaluations were carried out by analyzing information about the procedures used for collection and analysis of samples as well as the quality control protocols used. The analyzed compounds dealt with in each study were assigned one of three possible ratings: quantitatively acceptable, qualitatively acceptable (i.e., the substance measured was carbon tetrachloride), and totally unacceptable. In the case of carbon tetrachloride, a qualitatively acceptable rating was given for data from the CWSS and RWS because of suspected biodegradation of the samples, which were held unrefrigerated for prolonged periods before analysis, although it is recognized that biodegradation of carbon tetrachloride is less likely to occur than it is for unsaturated and aromatic VOCs. Carbon tetrachloride values in excess of the quantitation limit reported for some samples in these studies are qualitatively valid and can be taken as minimum values, representative of samples which probably originally contained carbon tetrachloride at higher concentrations. In the case of the NORS, NOMS, NSP, and GWSS, all data were rated both quantitatively and qualitatively acceptable.

4.2.5.2 Groundwater – Federal Surveys

The National Organics Reconnaissance Survey (NORS), the National Organic Monitoring Survey (NOMS), the National Screening Program for Organics in Drinking Water (NSP), the Community Water Supply Survey (CWSS), the Rural Water Survey (RWS), and the Groundwater Supply Survey (GWSS) all contain data concerning the levels of carbon tetrachloride in groundwater supplies from across the country.

In the NORS, finished water samples were analyzed for 16 groundwater systems. Only one system was reported to have carbon tetrachloride present, although the level of contamination was below the minimum quantifiable concentration of 2 µg/L for that analysis. All other groundwater supplies were indicated as having "none found," with the minimum quantifiable concentration ranging from 1-2 µg/L.

Eighteen groundwater systems were analyzed for carbon tetrachloride during Phase I of NOMS (March to April 1976); only one system contained detectable carbon tetrachloride, at a concentration of 4.0 µg/L. None of the 18 systems resampled during Phase II of the study (May to July 1976) contained quantifiable levels of carbon tetrachloride. Samples analyzed during Phase III of the study (November 1976 to January 1977) were negative for all 14 systems examined. The minimum quantifiable limits for carbon tetrachloride ranged from 1.0-2.0 µg/L in Phase 1, 0.2-0.4 µg/L in Phase II, and 0.2-0.4 µg/L in Phase III.

Twelve groundwater supplies were tested for carbon tetrachloride contamination in the NSP. Of these 12 systems, two were found to be contaminated with carbon tetrachloride at levels of 0.2 and 0.5 µg/L. The quantification limit for carbon tetrachloride was 0.1 µg/L.

The 1978 CWSS provided information on carbon tetrachloride levels in 316 groundwater systems. Of these systems, 6 contained detectable levels of carbon tetrachloride, with values ranging from 0.67-2.15 µg/L. The mean value was 1.4 µg/L with a standard deviation of 0.50 µg/L; the median value was 1.4 µg/L. The minimum quantitation limit for carbon tetrachloride in the CWSS was 0.50 µg/L.

The RWS examined 207 groundwater supplies for carbon tetrachloride and found 2 to have levels above the minimum quantification limit of 0.5 µg/L. The two positive values were 0.8 to 0.88 µg/L.

In the GWSS, 15 of the 456 randomly chosen water systems serving 25 or more individuals were contaminated with carbon tetrachloride, at concentrations ranging from 0.21-16 µg/L. The three systems with the highest values were contaminated at 1.7, 2.8, and 16 µg/L. Ten of the 15 systems with detections of carbon tetrachloride served populations in excess of 10,000 people. The average for all randomly chosen systems was 1.7 µg/L with a standard deviation of 4.0 µg/L; the median was 0.37 µg/L. Of the 473 nonrandom locations sampled serving 25 or more individuals, 15 were contaminated with carbon tetrachloride, at concentrations between 0.21-15 µg/L, the highest values being 1.8, 9.4, and 15 µg/L. Six of the 15 systems with detections of carbon tetrachloride served populations in excess of 10,000 people. The average carbon tetrachloride level for the nonrandom systems was 2.2 µg/L with a standard deviation of 4.2 µg/L; the median value was 0.45 µg/L. The minimum quantitation limit for carbon tetrachloride was 0.2 µg/L.

4.2.5.3 Groundwater – State Data

Eight States (California, Connecticut, Delaware, Indiana, Maine, Massachusetts, New Jersey, and New York) provided the U.S. Environmental Protection Agency with information concerning carbon tetrachloride contamination in groundwater supplies. Analytical results for carbon tetrachloride in samples from four locations in California ranged from undetectable to greater than 20 µg/L. Of 33 locations sampled in Connecticut, carbon tetrachloride levels ranged from undetectable to 66 µg/L; 70 of the 85 samples contained less than 5.0 µg/L. Indiana provided data on eight samples from one location, all with undetectable carbon tetrachloride. A total of 84 groundwater samples from 57 locations in Maine and four samples from one location in Massachusetts proved to be free of detectable carbon tetrachloride. Data on 235 samples from 12 unidentified counties in New Jersey indicated that 190 had no detectable carbon tetrachloride; another 35 samples contained carbon tetrachloride at less than 1.0 µg/L. In another study, 18 locations in New Jersey reported carbon tetrachloride levels ranging from not detectable to 863 µg/L. Finally, 20 of 365 groundwater samples taken in New York contained detectable carbon tetrachloride.

4.2.5.4 Groundwater – Miscellaneous Data

Region V of the U.S. Environmental Protection Agency conducted a study in early 1975 in which drinking water samples from 50 cities were analyzed for carbon tetrachloride (USEPA, 1975, as cited in JRB Associates, 1983). Of 16 groundwater systems sampled, seven contained carbon tetrachloride, at levels ranging from 1.0-13.0 µg/L (averaging 4.6 µg/L). In a survey by Bush et al. (1977, as cited in JRB Associates, 1983) of New York State drinking water supplies, 7 of 11 groundwater samples from the Buffalo area and Long Island contained carbon tetrachloride, at levels of less than 0.2 µg/L.

4.2.5.5 Surface Water – Federal Surveys

The National Organics Reconnaissance Survey (NORS), the National Organic Monitoring Survey (NOMS), the National Screening Program for Organics in Drinking Water (NSP), the Community Water Supply Survey (CWSS), and the Rural Water Survey (RWS) all contain data concerning the levels of carbon tetrachloride in surface water supplies from across the country.

In the NORS, finished water from 64 surface water systems were studied, of which nine were found to have carbon tetrachloride present. Five of the nine positive systems reported carbon tetrachloride to be present but below the minimum quantifiable concentration of 2 µg/L. Of those with quantifiable levels, two were reported as 2 µg/L and two as 3 µg/L. The 55 negative surface water supplies were indicated as having "none found," with the minimum quantifiable concentration from 1-2 µg/L. It should be noted that confirmatory quantitative analyses were performed for 8 surface water supplies in NORS, using a method able to quantify carbon tetrachloride at 0.05 µg/L. Three of these eight supplies were originally reported as having carbon tetrachloride present, but below the minimum quantifiable concentration of 2 µg/L; the presence of carbon tetrachloride was confirmed in all three cases at concentrations ranging from 0.4 to 0.8 µg/L. Of the five supplies originally reported as having none found, four were observed in the confirmatory analysis to have carbon tetrachloride present at levels ranging from 0.2 to 0.3 µg/L.

In Phase I of the National Organic Monitoring Survey (March to April 1976), water samples from 89 surface water systems were analyzed for carbon tetrachloride. Of these 89 systems, only two were found to contain carbon tetrachloride, at levels of 1.8 and 2.9 µg/L. Eighty-eight systems were sampled during the second phase of the survey (May to July 1976) and 10 were found to be contaminated, at levels ranging from 0.19-10 µg/L, including the two systems identified as positive in the first phase of the study. The average carbon tetrachloride concentration among the positive Phase II samples was 2.4 µg/L with a standard deviation of 2.9 µg/L; the median concentration was 1.4 µg/L. During the third phase of the NOMS (November 1976 to January 1977), analyses revealed carbon tetrachloride contamination in 11 out of a total of 87 systems. The contamination levels for these systems ranged from 0.2-29 µg/L. The mean concentration averaged 4.3 µg/L with a standard deviation of 8.4 µg/L; the median level was 1.3 µg/L. Only two systems had concentrations above 4.9 µg/L. The minimum quantifiable limits for carbon tetrachloride ranged from 1.0-3.0 µg/L in Phase I, 0.2-0.4 µg/L in Phase II, and 0.2-0.4 µg/L in Phase III.

Surface water samples from 106 drinking water systems were analyzed for carbon tetrachloride during the National Screening Program (NSP) between June 1977 and March 1981. Of these, 36 systems contained detectable levels of carbon tetrachloride, ranging from 0.1-30 µg/L. Only two of these systems were contaminated at levels greater than 1.8 µg/L (8.4 and 30 µg/L). The average concentration among the 36 positive systems was 1.6 µg/L with a standard deviation of 5.1 µg/L; the median level was 0.4 µg/L. The quantification limit for the NSP was 0.1 µg/L.

Of the 105 surface water systems sampled during the Community Water Supply Survey (CWSS), three contained quantifiable levels of carbon tetrachloride. These three positive values were 0.52, 0.64, and 0.925. The mean concentration averaged 0.70 with a standard deviation of 0.21 µg/L and a median of 0.64 µg/L. The minimum quantitation limit for carbon tetrachloride in the CWSS was 0.50 µg/L.

The RWS examined drinking water from 45 surface water supplies; only 1 supply was found to have carbon tetrachloride present above the minimum quantification limit of 0.5 µg/L (0.8 µg/L).

4.2.5.6 Surface Water – State Data

Only two States, Connecticut and New York, provided carbon tetrachloride data from surface water sources. In 11 samples from 9 locations in Connecticut, carbon tetrachloride concentrations ranged from undetectable to 1.5 µg/L. Of 23 samples from three locations in New York, only one was found to contain detectable carbon tetrachloride (0.1 µg/L).

4.2.5.7 Surface Water – Miscellaneous Data

In 34 surface water systems analyzed during the EPA Region V study, carbon tetrachloride levels ranged from 0.9-26.0 µg/L (averaging 4.8 µg/L) (USEPA, 1975, as cited in JRB Associates, 1983). In the Bush et al. (1977, as cited in JRB Associates, 1983) study, 16 drinking water samples from surface water were analyzed, 13 from Lake Erie and 3 from Niagara Falls, New York. Seven of the samples from Lake Erie were contaminated with carbon tetrachloride, at 0.2-4.8 µg/L (averaging 2.4 µg/L). Two of the samples from Niagara Falls were contaminated, with levels of 0.3 and 1.1 µg/L.

4.2.5.8 Projected National Occurrence of Carbon Tetrachloride in Public Water Supplies

As reported in the JRB Associates (1983) report, public water systems fall into two major categories with respect to water source (surface water and groundwater) and into five size categories and twelve subcategories according to the number of individuals served. The JRB (1983) report presented estimates of both the number of drinking water supplies nationally within each of the source/size categories expected to have carbon tetrachloride present, and of the concentration of carbon tetrachloride expected to be present in those supplies.

The key features of the methodology used and assumptions made to develop the national estimates are summarized here. The estimates are based on the data from the Federal surveys only. The State data and miscellaneous information were not included for several reasons. Generally, these data are from a few States and were not considered to be geographically representative. There was also a general lack of data on the population served by systems measured, the type of water sampled, and the methodologies used to sample, identify, and measure carbon tetrachloride. Furthermore, since much of these data were apparently obtained in response to incidents of recognized contamination problems, they may not be representative of typical conditions existing nationally. However, while these data were not used for computing the national projections, they do provide a valuable and necessary perspective for evaluating those projections, especially with respect to the projected high levels of contamination of carbon tetrachloride.

The Federal survey data from the NORS, NOMS, NSP, CWSS, RWS, and GWSS were pooled together for developing the national projections. It was assumed in combining these surveys that the resulting data base would be representative of the nation's water supplies. In the case of the GWSS data, both the random and nonrandom samples were included in the projections because a test of the GWSS data showed no statistically significant difference in the frequency of occurrence of positive values or the mean of the positive values of carbon tetrachloride.

Ideally, adequate data would be available to develop the national projections separately for each of the twelve system size categories within the groundwater and surface water groups; however, the available data were too limited for this. JRB (1983) consolidated some of the size categories to have sufficient data for developing the projections. In consolidating data from various size categories, consideration was given to the potential for there being statistically significant differences in the frequency of occurrence of carbon tetrachloride as a function of system size. The consolidation of size categories therefore involved a balancing of the need to group size categories together to have an adequate data base for developing the national projections against the need to treat size categories separately in order to preserve the influence of system size as a determinant of contamination potential. The consolidation of size categories also took into account EPA's classification of systems into the five major groups as very small (25-500), small (501-3,300), medium (3,301-10,000), large (10,001-100,000), and very large (> 100,000) (Kuzmack, 1983, as cited in JRB Associates, 1983).

Once the data were consolidated, statistical models for extrapolating to the national level were tested and an appropriate model selected. In the case of carbon tetrachloride, the multinominal method was used. The frequency of contamination of groundwater and surface water systems at various concentrations was determined for each consolidated size category. For completing the national estimates, it was assumed that the frequency of contamination observed for each consolidated category was directly applicable to each of the system sizes comprising it.

4.2.5.8.1 Groundwater Systems

Data are available for a total of 1,466 supplies from the combined surveys (NORS, NOMS, NSP, CWSS, RWS, and GWSS). Of these, 42 supplies were reported to have carbon tetrachloride present, at concentrations ranging from 0.2 µg/L to 16 µg/L.

Based on the overall distribution of positive values and maximum possible values for those supplies in which carbon tetrachloride was not found, 0.5 µg/L was selected as the common minimum quantifiable concentration for the combined survey data. That is, quantitative projections are made of supplies at several concentration ranges > 0.5 µg/L, while only a total number for supplies expected to have either no carbon tetrachloride or levels below 0.5 µg/L can be determined. Although some data indicate the presence of carbon tetrachloride in groundwater supplies at levels < 0.5 µg/L, it is not possible to determine the proportion of supplies that have carbon tetrachloride present and the proportion that are actually free of carbon tetrachloride contamination.

Of the 1,424 supplies reporting no carbon tetrachloride to be present, 1,402 were assumed to have maximum possible levels of < 0.5 µg/L based on the minimum quantifiable concentrations reported for the various surveys (885 of these had maximum levels of < 0.2 µg/L). The other 22 supplies reporting no carbon tetrachloride to be present had maximum possible levels ranging from approximately 0.6 µg/L to 2 µg/L. It is assumed, based on overall distribution of values, that carbon tetrachloride if present in the 22 supplies is so at a concentration of < 0.5 µg/L, although a rigorous conservative argument could be made for assuming a level equal to the maximum possible value. The impact of this assumption is notable both in terms of the national projection of groundwater systems above 0.5 µg/L and in terms of the population exposed.

Twenty-three of the 1,466 supplies examined had measured values of carbon tetrachloride ≥ 0.5 µg/L. When the twelve size categories were consolidated into the five major EPA groupings, there was an apparent relationship between the frequency of values ≥ 0.5 µg/L and system size:

Very small	0.2%	(1/423)
Small	1.9%	(8/417)
Medium	1.4%	(3/214)
Large	1.9%	(7/363)
Very large	8.2%	(4/49)
Overall	1.6%	(23/1,466)

A test for statistical significance revealed that at the $\alpha = 0.05$ level, a statistically significant difference was found between the very small and small categories, as well as between the large and very large categories. No further consolidation of these five categories was done. As noted previously, the frequency of occurrence of carbon tetrachloride at various concentrations was determined for the consolidated groups and then applied to the number of supplies nationally within each of the size categories comprising each group.

About 335 groundwater supplies (range of 124-545), approximately 0.7% of the total groundwater supplies in the United States, are expected to have carbon tetrachloride at levels of ≥ 0.5 µg/L; the remaining 48,123 supplies have either no carbon tetrachloride or levels < 0.5 µg/L.

It is estimated that 110 supplies (range of 0-277) are expected to have carbon tetrachloride levels > 5 µg/L, while 107 supplies (range of 0-273) are expected to have levels > 10 µg/L. Most of the supplies with high carbon tetrachloride levels are expected to be in the smaller size categories. Although, as noted previously, the frequency of carbon tetrachloride occurrence is greater in the very large system size, the number of systems affected nationally is greater for the small sizes because there are many more small systems in existence.

It is interesting to note the impact on the national projections of the assumption made that the 22 supplies with undetected but maximum potential values of 0.6-2 µg/L had < 0.5 µg/L. Had it been assumed that carbon tetrachloride was present in those supplies at their maximum possible values, the national projection of supplies with carbon tetrachloride levels ≥ 0.5 µg/L would have increased to 417 (200-633) with no differences in levels > 5 µg/L. These differences in the 0.5-5 µg/L range would be found in systems serving > 500 people.

4.2.5.8.2 Surface Water Systems

Data are available for a total of 312 surface water supplies. Of these, 51 supplies were reported by JRB Associates (1983) to have carbon tetrachloride present at concentrations ranging from 0.1 µg/L to 30 µg/L, although this high value is the only one reported above 10 µg/L.

Based on the overall distribution of positive values and maximum possible values for those supplies in which carbon tetrachloride was not found, 0.5 µg/L was selected as the common minimum quantifiable concentration for the combined survey data. That is, quantitative projections are made of supplies at several concentration ranges > 0.5 µg/L, while only a total number for supplies expected to have either no carbon tetrachloride or levels below 0.5 µg/L can be determined. Although some data indicate the presence of carbon tetrachloride in surface water supplies at levels < 0.5 µg/L, it is not possible to determine the proportion that have carbon tetrachloride present and the proportion that are free of carbon tetrachloride contamination.

Of the 261 supplies reporting no carbon tetrachloride to be present, 186 had maximum possible levels of < 0.5 µg/L based on the minimum quantifiable concentrations reported for the various surveys. The other 75 supplies reporting no carbon tetrachloride to be present had maximum possible levels ranging from 0.53 µg/L to 2 µg/L. It is assumed, based on the overall distribution of values, that carbon tetrachloride if present in these 75 supplies is so at a concentration of < 0.5 µg/L, although a rigorous conservative argument could be made for assuming a level equal to the maximum possible value. As will be noted further below, the difference between these alternatives is considerable for the estimate of the number of surface water supplies with carbon tetrachloride > 0.5 µg/L; also the impact on the estimated population exposed to carbon tetrachloride at levels > 0.5 µg/L in surface water supplies is very large.

Forty of the 312 supplies examined had measured values of carbon tetrachloride > 0.5 µg/L. When the twelve size categories were consolidated into the five major EPA groupings, there was a general trend in the frequency of values > 0.5 µg/L as a function of size:

Very small	0%	(0/20)
Small	3.3%	(2/60)
Medium	2.4%	(1/42)
Large	12.2%	(9/74)
Very large	24.1%	(28/116)
Overall	12.8%	(40/312)

A test for statistical significance revealed that at the $\alpha = 0.05$ level, the very small, small, and medium groups were not different from one another and that the large and very large groups are not different; however, the combined very small, small, and medium groups and the combined large and very large groups are different. These two consolidated categories were selected for developing the national estimates:

Very small/small/medium (25-10,000)
Large/very large (> 10,000)

As noted previously, the frequency of occurrence of carbon tetrachloride at various concentrations was determined for the consolidated groups and then applied to the number of supplies nationally within each of the size categories comprising each group.

About 575 surface water supplies (range of 299-850), approximately 5.10% of the total surface water systems in the United States, are expected to have carbon tetrachloride at levels > 0.5 µg/L; the remaining 10,627 supplies have either no carbon tetrachloride or levels < 0.5 µg/L. It is estimated that 26 surface water supplies (range of 0-55) will have levels > 5 µg/L and 9 (range of 0-26) will have levels > 2 µg/L. None are projected to have levels above 30 µg/L.

JRB Associates (1983) reported that a notable impact on the national projections by the assumption made that the 75 supplies with undetected but maximum potential values of 0.53-2 µg/L had < 0.5 µg/L. Had it been assumed that carbon tetrachloride was present in these supplies at their maximum possible values, the national projections of supplies with carbon tetrachloride levels > 0.5 µg/L would be 1,819 (range of 1,326-2,311) supplies. However, there would be no difference in the projected number of surface water supplies with levels > 5 µg/L.

4.2.6 Conclusion

With few exceptions, production of carbon tetrachloride has been eliminated in developed nations, including the U.S. The major use of carbon tetrachloride in the early 1990s was in the production of chlorofluorocarbons, such as dichlorodifluoromethane and trichlorofluoromethane. According to the latest figures available before the production ban, the U.S. produced between 573 and 761 million pounds each year from 1981 to 1988. Industrial releases of carbon tetrachloride have been reported to TRI since 1988 in 38 States, Puerto Rico, and the Virgin Islands. The Stage 2 analysis, based on the 16-State cross-section, estimated that approximately 0.0159% of combined ground water and surface water systems serving 0.0316% of the population had estimated mean concentrations of carbon tetrachloride greater than the MCL of 0.005 mg/L. Based on this estimate, approximately 10 PWSs nationally serving about 67,400 people are expected to have estimated mean concentrations of carbon tetrachloride greater than the MCL.

The 16-State cross-section was designed to be nationally representative based upon VOC, SOC, and IOC pollution potentials as suggested by considerations of manufacturing, agriculture, and geographic diversity factors. Nationally, TRI releases have been reported for carbon tetrachloride from 38 States, including 12 of 16 cross-section States. Except for certain exemptions, carbon tetrachloride is no longer produced or used in any State, including the cross-section States. The cross-section should adequately represent the occurrence of carbon tetrachloride on a national scale based upon the use, production, and release patterns of the 16-State cross-section in relation to the patterns observed for all 50 States.

4.2.7 References

Agency for Toxic Substances and Disease Registry (ATSDR). 1994. *Toxicological Profile for Carbon Tetrachloride*. U.S. Department of Health and Human Services, Public Health Service. 229 pp. + Appendices. Available on the Internet at: http://www.atsdr.cdc.gov/toxprofiles/tp30.pdf.

Brass, H.J., M.A. Feige, T. Halloran, J.W. Mello, D. Munch, and R.F. Thomas. 1977. The National Organic Monitoring Survey: A sampling and analysis for purgeable organic compounds. *Drinking water quality enhancement through source protection.* R.B. Pojasek (ed.). Ann Arbor, MI: Ann Arbor Science, pp. 393-416.

Brass, H.J. 1981. Rural Water Survey organics data. Memorandum of March 17, 1981 to Hugh Hanson, Chief, Science and Technology Branch, Office of Drinking Water, and David Schnare, Office of Drinking Water, U.S. Environmental Protection Agency, Washington, DC.

Bush, B., R.S. Narang, and S. Syrotynski. 1977. Screening for halo organics in New York State drinking water. *Bull. Envir. Contam. Toxicol.* 18(4): October 1977.

JRB Associates. 1983. *Occurrence of Carbon Tetrachloride in Drinking Water, Food and Air - DRAFT.* Draft report submitted to EPA for review November 17, 1983.

Kuzmack, A.M. 1983. Memorandum: Characterization of the water supply industry (FY82). Washington, DC: Office of Water, U.S. Environmental Protection Agency. May 16, 1983.

McKenna and Cuneo, L.L.P. 2001. Montreal Protocol to limit the use of the ‘transformation’ exemption from the ODS Ban. *McKenna and Cuneo, L.L.P. Client Bulletin*. Available on the Internet at: http://www.mckennacuneo.com/articles/archive/ENV04019970620.html

Mello, Wayne. 1983. Personal communication between Wayne Mello, Technical Support Division, Office of Drinking Water, U.S. Environmental Protection Agency, and author of JRB Associates, 1983, March 10, 1983.

Symons, J.M., T.A. Bellar, and J.K. Carswell et al. 1975. National Organics Reconnaissance Survey for Halogenated Organics. *J. Amer. Water Works Assoc.* 667(11): 634-647.

USEPA. 1975. *Sources of organic, metal, and other inorganic parameter concentrations in selected Region V drinking water supplies.* Chicago IL: Water Division and Surveillance and Analyses Division, USEPA.

USEPA. 2000. *TRI Explorer: Trends*. Available on the Internet at: http://www.epa.gov/triexplorer/trends.htm, last updated May 5, 2000.

USEPA. 2002. *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT.* EPA Report/815-D-02-005, Office of Water, 55 pp.

Westrick, J.J., J.W. Mello, and R.F. Thomas. 1983. *The Ground Water Supply Survey summary of volatile organic contaminant occurrence data.* EPA Technical Support Division, Office of Drinking Water, Cincinnati, Ohio.

4.3 1,4-Dichlorobenzene

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Tables and Figures

4.3.1 Introduction, Use and Production

1,4-Dichlorobenzene (chemical formula $C_6H_4Cl_2$) is usually called para-DCB or p-DCB; however, there are about 20 additional names for it, including para crystals and paracide. It is also called paramoth because it is one of two chemicals commonly used to make mothballs. At room temperature, 1,4-dichlorobenzene is a white solid with a strong odor that one would probably recognize as the smell of mothballs. Most of the 1,4-dichlorobenzene that is released to the general environment is present as a vapor. 1,4-Dichlorobenzene does not occur naturally, but is produced by chemical companies to make products for home use and other chemicals such as resins (ATSDR, 1998). 1,4-Dichlorobenzene can burn, but not easily. Its major routes of entry to drinking water are a consequence of industrial activity. It is expected that discharges to the environment during production of the dichlorobenzenes and the use of a variety of solvents, pesticides, and deodorants containing dichlorobenzene are primary causes of dichlorobenzene contamination of drinking water (JRB Associates, 1983).

For over 20 years, 1,4-dichlorobenzene has been primarily used as a space deodorant for toilets and refuse containers, and as a fumigant for control of moths, molds, and mildews. When exposed to air, it slowly changes from a solid to a vapor. It is the vapor that acts as a deodorizer or insect killer. Most people recognize the odor as the smell of mothballs, and can smell 1,4-dichlorobenzene in the air at very low levels (ATSDR, 1998).

About half to a third of the 1,4-dichlorobenzene produced is used as a deodorant and fumigant, 37% is exported, 27% is used to produce polyphenylene sulfide resin, and another 10% is used as an intermediate in the production of other chemicals, such as 1,2,4-trichlorobenzene (ATSDR, 1998) and 2,5-dichloroaniline (NTP, 1991). 1,4-Dichlorobenzene is also used in the control of certain tree-boring insects and ants; in the control of blue mold in tobacco seed beds (ATSDR, 1998); as a disintegrating paste for molding concrete and stoneware; as a lubricant (NTP, 1991); and in the manufacture of plastics, dyes, and pharmaceuticals (USEPA, 2001).

Estimates for the production of 1,4-dichlorobenzene in the U.S. are as follows: 1972, 77.2 million pounds; 1975, 45.9 million pounds; 1977, 16-116 million pounds; 1981, 15 million pounds (ATSDR, 1998). (More recent data is unavailable.) The three primary manufacturers of 1,4-dichlorobenzene are Monsanto Company in Sauget, Illinois; PPG Industries, Inc., in Natrium, West Virginia; and Standard Chlorine of Delaware, Inc., in Delaware City, Delaware; with annual production capacities of 33, 36, and 75 million pounds, respectively (ATSDR, 1998).

Table 4.3-1 lists the facilities in each State that manufacture and process 1,4-dichlorobenzene, the intended uses of the product, and the range of maximum amounts that are stored on site. The data were derived from the Toxics Release Inventory (TRI) of EPA (ATSDR, 1998).

Table 4.3-1: Facilities that Manufacture or Process 1,4-Dichlorobenzene

Facility	Location [a]	Range of maximum amount on site in pounds	Activities and uses
Bay State Sterling	North Manchester, IN	1,000-9,999	Manufacturing Aid
Bay State Sterling	Westborough, MA	1,000-9,999	Manufacturing Aid
Caroline Solite Corp.	Norwood, NC	1,000-9,999	Ancillary/Other Use
Coughlan Prods. Corp.	Clifton, NJ	10,000-99,999	Formulation Component
Coughlan Prods. Corp.	Wayne, NJ	10,000-99,999	Formulation Component
Coughlan Prods. Corp.	Paterson, NJ	10,000-99,999	Formulation Component
Crest Prods. Inc.	Oldsmar, FL	10,000-99,999	Formulation Component
Dow Chemical Co.	Plaquemine, LA	1,000-9,999	Produce, Impurity
Fortron Ind.	Wilmington, NC	100,000-999,999	Reactant

Facility	Location [a]	Range of maximum amount on site in pounds	Activities and uses
Fresh Prods. Inc.	Toledo, OH	10,000-99,999	Import, Sale/Dist., Repackaging, Ancillary/Other
Fuller Brush Co.	Great Bend, KS	100,000-999,999	Reactant
Heartland Cement Co.	Independence, KS	100-999	Ancillary/Other Use
Hospital Specialty Co.	Cleveland, OH	100,000-999,999	Article Component
I. Schneid Inc.	Atlanta, GA	10,000-99,999	Article Component, Repackaging
Monsanto	Sauget, IL	1,000,000-9,999,999	Produce, Sale/Distribution
Nipa Hardwicke Inc.	Elgin, SC	10,000-99,999	Reactant
Phillips Chemical Co.	Borger, TX	100,000-999,999	Reactant
Phillips Research Center	Bartlesville, OK	1,000-9,999	Reactant
PPG Ind. Inc.	New Martinsville, WV	1,000,000-9,999,999	Produce, Sale/Distribution
Standard Chlorine of	Delaware City, DE	10,000,000-49,999,999	Produce, On-site Use/Processing, Sale/Dist.,
Willert Home Prods.	Saint Louis, MO	100,000-999,999	Article Component

[a] Post office State abbreviations used

Source: ATSDR, 1998 compilation of TRI96 1998 data

4.3.2 Environmental Release

1,4-Dichlorobenzene is listed as a Toxics Release Inventory (TRI) chemical. Table 4.3-2 illustrates the environmental releases for 1,4-dichlorobenzene from 1988 to 1999. (1,4-Dichlorobenzene data are only available for these years.) Air emissions constitute most of the on-site releases, with a steady decrease that has moderated in recent years. The decrease in air emissions has been the primary contributor to decreasing levels of total on- and off-site releases. Surface water discharges have slightly decreased from the high in 1989, although levels have been rising since 1995. Underground injection has remained relatively constant, except for a considerable increase from 1997 to 1999. Releases to land (such as spills or leaks within the boundaries of the reporting facility) and off-site releases (including metals or metal compounds transferred off-site) have no discernable trend in the amounts released, as they range from almost zero to a few thousand pounds in any given year. These TRI data for 1,4-dichlorobenzene were reported from 22 States, with six States reporting every year (USEPA, 2000). Nine of the 22 States are in the 16-State cross-section (used for analyses of 1,4-dichlorobenzene occurrence in drinking water; see Section 4.3.4). (For a map of the 16-State cross-section, see Figure 1.3-1.)

Table 4.3-2: Environmental Releases (in pounds) for 1,4-Dichlorobenzene in the United States, 1988-1999

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1999	178,210	1,880	7,300	1,370	0	188,760
1998	181,899	1,706	3,100	460	--	187,165
1997	262,266	1,728	2,000	1,960	289	268,243
1996	236,502	1,881	2,000	480	--	240,863
1995	242,372	1,287	--	3,100	3,328	250,087
1994	257,211	1,595	2,000	1,100	--	261,906
1993	357,891	1,265	2,000	1,112	213	362,481
1992	337,946	2,021	2,000	622	751	343,340
1991	344,254	2,146	2,000	420	770	349,590

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1990	818,133	3,912	255	38	4,006	826,344
1989	1,592,229	6,621	250	250	1	1,599,351
1988	1,891,419	6,153	4,000	1,300	750	1,903,622

Source: USEPA, 2000

4.3.3 Ambient Occurrence

1,4-Dichlorobenzene was detected in 6 out of 330 wells (1.8%) in urban areas of the local, State, and federal data set compiled by NAWQA. The minimum and maximum concentrations detected were 0.3 µg/L and 56 µg/L, respectively. The median value of detection concentrations was 1 µg/L. 1,4-Dichlorobenzene was also detected in 4 of the 2,434 wells (0.16%) with analysis in rural areas. The minimum and maximum concentrations detected were 0.8 µg/L and 6.7 µg/L, respectively. The median value of detection concentrations was 1.3 µg/L. These data (urban and rural) represent untreated ambient ground water of the conterminous United States for the years 1985-1995 (Squillace et al., 1999).

4.3.3.1 Additional Ambient Occurrence Data

A summary document entitled "Dichlorobenzenes: Occurrence in Drinking Water, Food, and Air" (JRB Associates, 1983), was previously prepared for past USEPA assessments of 1,4-dichlorobenzene. However, no information on the ambient occurrence of 1,4-dichlorobenzene was included in that document. (The document did include information regarding 1,4-dichlorobenzene occurrence in drinking water, which is discussed in Section 4.3.5 of this report.)

4.3.4 Drinking Water Occurrence Based on the 16-State Cross-Section Data

The analysis of 1,4-dichlorobenzene occurrence presented in the following section is based on State compliance monitoring data from the 16 cross-section States. The 16-State cross-section is the largest and most comprehensive compliance monitoring data set compiled by EPA to date. These data were evaluated relative to several concentration thresholds of interest: 0.075 mg/L; 0.005 mg/L; and 0.0005 mg/L.

Fourteen of the sixteen cross-section State data sets contained occurrence data for 1,4-dichlorobenzene. (There were no 1,4-dichlorobenzene data from California or Montana.) These data represent more than 123,000 analytical results from approximately 19,000 PWSs during the period from 1984 to 1998 (with most analytical results from 1992 to 1997). The number of sample results and PWSs vary by State, although the State data sets have been reviewed and checked to ensure adequacy of coverage and completeness. The overall modal detection limit for 1,4-dichlorobenzene in the 16 cross-section States is equal to 0.0005 mg/L. (For details regarding the 16-State cross-section, please refer to Section 1.3.5 of this report.)

4.3.4.1 Stage 1 Analysis Occurrence Findings

Table 4.3-3 illustrates the Stage 1 analysis of 1,4-dichlorobenzene in drinking water for the public water systems in the 16-State cross-section. Based on the 16-State cross-section data, no ground water or surface water PWSs had any analytical results exceeding the MCL (0.075 mg/L). Only 0.0844% of all PWSs in the 16 States (a total of 16 systems) had any analytical results greater than 0.005 mg/L. Approximately 1.32% of PWSs (250 systems) had analytical detections of 1,4-dichlorobenzene greater than 0.0005 mg/L.

Approximately 0.0908% of ground water PWSs (16 systems) had any analytical results exceeding the 0.005 mg/L, compared to 0% of surface water systems. Over 1.2% of ground water PWSs (217 systems) had at least one analytical result greater than 0.0005 mg/L. About 2.45% of surface water systems (33 systems) had any analytical results of 1,4-dichlorobenzene greater than 0.0005 mg/L.

Table 4.3-3: Stage 1 1,4-Dichlorobenzene Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Ground Water	0.075	0.000%	0
	0.005	0.0908%	16
	0.0005	1.23%	217
Surface Water	0.075	0.000%	0
	0.0050	0.000%	0
	0.0005	2.45%	33
Combined Ground & Surface Water	0.075	0.000%	0
	0.005	0.0844%	16
	0.0005	1.32%	250

Reviewing 1,4-dichlorobenzene occurrence in the 16 cross-section States by PWS population served (Table 4.3-4) shows that no ground water or surface water systems had any analytical detections greater than the MCL (0.075 mg/L). Approximately 0.230% of the population (almost 168,000 people) was served by systems with at least one analytical results greater than 0.005 mg/L. Approximately 2.53% of the population (over 1.8 million people) was served by PWSs with analytical detections of 1,4-dichlorobenzene greater than 0.0005 mg/L.

The percentage of population served by ground water systems in the 16 States with analytical results greater than 0.005 mg/L was equal to 0.464% (about 168,000 people). When evaluated relative to 0.0005 mg/L, the percent of population exposed by ground water systems was equal to 3.16% (over 1.1 million people). The percentage of population served by surface water systems with exceedances of 0.0005 mg/L was equal to 1.90% (700,400 people).

Table 4.3-4: Stage 1 1,4-Dichlorobenzene Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Ground Water	0.075	0.000%	0
	0.005	0.464%	167,800
	0.0005	3.16%	1,143,000
Surface Water	0.075	0.000%	0
	0.005	0.000%	0
	0.0005	1.90%	700,400
Combined Ground & Surface Water	0.075	0.000%	0
	0.005	0.230%	167,800
	0.0005	2.53%	1,843,400

4.3.4.2 Stage 2 Analysis Occurrence Findings

The Stage 2 occurrence findings, based on the cross-section data, are presented in Tables 4.3-5 and 4.3 - 6. The statistically generated best estimate values, as well as the ranges around the best estimate value, are presented. (For a review of the Stage 2 analytical approach, please refer to Section 1.4 of this report. For complete details regarding the Stage 2 analyses, please refer to *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT* (USEPA, 2002)).

No ground water or surface water PWSs in the 16 States had an estimated mean concentration of 1,4-dichlorobenzene exceeding 0.075 mg/L (the current MCL). The percentage of PWS in the 16 States with estimated mean concentration values of 1,4-dichlorobenzene greater than 0.005 mg/L was equal to 0.000253%. The percentage of PWSs with estimated mean concentrations exceeding 0.0005 mg/L (the modal detection limit) was about 0.114% PWSs (22 systems) in the 16 States.

A greater proportion of ground water systems, as compared to surface water systems, were estimated to exceed the modal detection limit. Approximately 0.000273% of ground water systems in the 16 States had estimated mean concentrations greater than 0.005 mg/L, as compared to 0% of surface water systems. About 0.117% of ground water systems (an estimated 21 systems in the 16 States) had estimated mean concentrations greater than 0.0005 mg/L. This compares with about 0.0746% of the surface water systems (about 1 system) with estimated mean concentrations greater than 0.0005.

Table 4.3-5: Stage 2 Estimated 1,4-Dichlorobenzene Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.075	0.000%	0.000% - 0.000%	0	0 - 0
	0.005	0.000273%	0.000% - 0.00568%	0	0 - 1
	0.0005	0.117%	0.0738% - 0.170%	21	13 - 30
Surface Water	0.075	0.000%	0.000% - 0.000%	0	0 - 0
	0.005	0.000%	0.000% - 0.000%	0	0 - 0
	0.0005	0.0746%	0.000% - 0.223%	1	0 - 3
Combined Ground & Surface Water	0.075	0.0000%	0.000% - 0.000%	0	0 - 0
	0.005	0.000253%	0.000% - 0.00527%	0	0 - 1
	0.0005	0.114%	0.0738% - 0.164%	22	14 - 31

Reviewing 1,4-dichlorobenzene occurrence by PWS population served (Table 4.3-6) shows that approximately 0.00000206% of the population in the 16 States was served by PWSs with mean concentrations greater than 0.005 mg/L. Approximately 0.0379% of population served by all PWSs in the 16 States (an estimate of approximately 27,700 people) was potentially exposed to 1,4-dichlorobenzene levels above 0.0005 mg/L. When evaluated relative to a threshold of 0.075 mg/L, the percent of population exposed was equal to 0%.

For ground water systems, about 0.00000416% of the population served by ground water systems in the 16 States was exposed to 1,4-dichlorobenzene levels above 0.005 mg/L. An estimated 0.0505% of the population (about 18,300 people) was served by systems in the 16 States whose mean concentration value exceeded 0.0005 mg/L.

No surface water systems had mean concentrations that exceeded 0.005 mg/L. Approximately 0.0255% of the 16-State population was served by surface water PWSs (about 9,400 people) with estimated mean concentrations of 1,4-dichlorobenzene above 0.0005 mg/L.

Table 4.3-6: Stage 2 Estimated 1,4-Dichlorobenzene Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.075	0.000%	0.000% - 0.000%	0	0 - 0
	0.005	0.00000416%	0.000% - 0.0000691%	0	0 - < 100

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
	0.0005	0.0505%	0.00580% - 0.187%	18,300	2,100 - 67,600
Surface Water	0.075	0.000%	0.000% - 0.000%	0	0 - 0
	0.005	0.000%	0.000% - 0.000%	0	0 - 0
	0.0005	0.0255%	0.000% - 0.193%	9,400	0 - 70,900
Combined Ground & Surface Water	0.075	0.000%	0.000% - 0.000%	0	0 - 0
	0.005	0.00000206%	0.000% - 0.0000343%	0	0 - < 100
	0.0005	0.0379%	0.00390% - 0.167%	27,700	2,800 - 121,800

4.3.4.3 Estimated National Occurrence

As illustrated in Table 4.3-7, the Stage 2 analysis estimated zero PWSs nationally were estimated to have mean concentration values of 1,4-dichlorobenzene greater than 0.075 mg/L or 0.005 mg/L. Approximately 74 systems serving about 80,700 people nationally were estimated to have mean 1,4-dichlorobenzene concentrations greater than 0.0005 mg/L. An estimated 69 ground water PWSs serving about 43,300 people nationally had mean concentrations greater than 0.0005 mg/L. Approximately 4 surface water systems serving 32,400 people was estimated to have mean concentrations of 1,4-dichlorobenzene above 0.0005 mg/L. (See Section 1.4 for a description of how Stage 2 16-State estimates are extrapolated to national values.)

Table 4.3-7: Estimated National 1,4-Dichlorobenzene Occurrence - Systems and Population Served

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.075	0	0 - 0	0	0 - 0
	0.005	0	0 - 3	0	0 - < 100
	0.0005	69	44 - 101	43,300	5,000 - 160,000
Surface Water	0.075	0	0 - 0	0	0 - 0
	0.005	0	0 - 0	0	0 - 0
	0.0005	4	0 - 12	32,400	0 - 245,400

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Combined Ground & Surface Water	0.075	0	0 - 0	0	0 - 0
	0.005	0	0 - 3	0	0 - < 100
	0.0005	74	48 - 106	80,700	8,300 - 355,500

4.3.5 Additional Drinking Water Occurrence Data

Several additional data sources regarding the occurrence of 1,4-dichlorobenzene in drinking water are also reviewed. Previously compiled occurrence information on one of the three isomers of dichlorobenzene, para-dichlorobenzene (1,4-dichlorobenzene), from an OGWDW summary document entitled "Dichlorobenzenes: Occurrence in Drinking Water, Food, and Air" (JRB Associates, 1983), is presented in the following section. This variety of studies and information are presented regarding levels of 1,4-dichlorobenzene in drinking water, with the scope of the reviewed studies ranging from national to regional. Note that none of the studies presented in the following section provide the quantitative analytical results or comprehensive coverage that would enable direct comparison to the occurrence findings estimated with the cross-section occurrence data presented in Section 4.3.4. These additional studies, however, do enable a broader assessment of the Stage 2 occurrence estimates presented for this Six-Year Review. All the following information in Section 4.3.5 is taken directly from "Dichlorobenzenes: Occurrence in Drinking Water, Food, and Air" (JRB Associates, 1983).

The JRB Associates (1983) report found three major types of data available that were potentially useful for describing the occurrence of dichlorobenzene in the nation's public drinking water supplies. First, there are several Federal surveys in which a number of public water supplies from throughout the U.S. were selected for analysis of chemical contamination, including dichlorobenzene. Second, data are available from State surveys and from State investigations of specific incidents of known or suspected contamination of a supply. Third, there are miscellaneous published data which, like some of the State data, tend to be from studies in response to suspected contamination of specific sites. For accomplishing the basic objectives of this study, namely to estimate the number of public water supplies nationally within the various source and size categories contaminated with dichlorobenzene, the distribution of dichlorobenzene concentrations in those supplies, and the number of individuals exposed to those concentrations, it was determined that the Federal survey data provides the most suitable data base. The State and miscellaneous data tend to be poorly described with respect to the source and size categories of the supplies examined and the sampling and analysis methods used for determining contaminant levels. The lack of source and system size information precludes using the data for estimating levels in public water supplies of similar characteristics. The absence of details on sampling and analysis methods precludes evaluating those data for their qualitative and quantitative reliability. Also, because much of the State and miscellaneous data are from investigations in response to incidents of known or suspected contamination (e.g., spills), they were judged to be not representative of contaminant levels in the nation's water supplies in general. Although they are not used with the Federal data for the purpose of estimating contamination levels nationally, the available State and miscellaneous data are presented here to provide some additional perspective on dichlorobenzene occurrence in drinking water.

Data are presented only on drinking water samples taken from a consumer's tap (i.e., distribution water samples) or on treated water samples taken at the water supply (i.e., finished water samples) because these are considered to be most representative of the water consumed by the public. No data on raw (i.e., untreated) water are presented. It is recognized that for some groundwater supplies where no treatment of the water occurs, samples identified as raw may be representative of water consumed by the users of the supply. However, it was generally not possible to differentiate between those groundwater supplies that do and do not treat raw water from the available survey data.

4.3.5.1 Overview and Quality Assurance Assessment of Federal Drinking Water Surveys

Three Federal drinking water surveys provide data on dichlorobenzene: the National Organic Monitoring Survey (NOMS), the National Screening Program for Organics in Drinking Water (NSP), and the Groundwater Supply Survey (GWSS). The terms used in this report are those used in the individual surveys, recognizing that they may not always correspond to strict technical definitions.

The National Organic Monitoring Survey (NOMS) was conducted to identify contaminant sources, to determine the frequency of occurrence of specific drinking water contaminants, and to provide data for the establishment of maximum contaminant levels (MCLs) for various-organic compounds in drinking water (Brass et al., 1977, as cited in JRB Associates, 1983). The NOMS was conducted in three phases: March-April 1976, May-July 1976, and November 1976-January 1977. Finished drinking water samples from 113 communities were analyzed for 21 different compounds. Of the 113 community supplies sampled, 18 had groundwater sources, 91 had surface water sources, and 4 had a mixed groundwater/surface water source.

The analytical results of the NOMS were made available in printed form by EPA's Technical Support Division, Office of Drinking Water. Additional information on the locations and source of the supplies, and on the populations served by the supplies in the NOMS were provided by Wayne Mello (1983) at EPA's Technical Support Division, Office of Drinking Water. A single value for dichlorobenzenes was reported for each supply studied in the NOMS.

The National Screening Program for Organics in Drinking Water (NSP), conducted by SRI International from June 1977 to March 1981, examined both raw and finished drinking water samples from 166 water systems in 33 States for 51 organic chemical contaminants. Data are available only for p-dichlorobenzene (1,4-dichlorobenzene) on finished water samples from 12 groundwater and 103 surface water supplies.

The Groundwater Supply Survey (GWSS) was conducted from December 1980 to December 1981 to develop additional data on the occurrence of volatile organic chemicals in the nation's groundwater supplies (Westrick et al., 1983, as cited in JRB Associates, 1983). It was hoped that this study would stimulate State efforts toward the detection and control of groundwater contamination and the identification of potential chemical “hot spots.” A total of 945 systems were sampled, of which 466 were chosen at random. The remaining 479 systems were chosen nonrandomly based on information from States encouraged to identify locations believed to have a higher than normal probability of VOC contamination (e.g., locations near landfills or industrial activity).

Each of the drinking water surveys was evaluated with respect to the validity of the reported occurrence data for a number of organic chemicals, including dichlorobenzene. The evaluations were carried out by analyzing information about the procedures used for collection and analysis of samples as well as the quality control protocols used. The analyzed compounds dealt with in each study were assigned one of three possible ratings: quantitatively acceptable, qualitatively acceptable (i.e., the substance measured was dichlorobenzene), and totally unacceptable. In the case of dichlorobenzene, a qualitatively acceptable rating was given for data from the NOMS (Phases II and III) because of suspected biodegradation of the samples, which were held unrefrigerated for prolonged periods before analysis. Dichlorobenzene values in excess of the quantitation limit reported for some samples in these studies are qualitatively valid and can be taken as minimum values, representative of samples which probably originally contained dichlorobenzene at higher concentrations. In the case of the NOMS (Phase I), NSP, and GWSS, all data were rated both quantitatively and qualitatively acceptable.

4.3.5.2 Groundwater – Federal Surveys

Three Federal surveys contain data concerning the levels of one or more of the three dichlorobenzene isomers in groundwater supplies from across the country. The National Organics Monitoring Survey (NOMS) and Groundwater Supply Survey (GWSS) contain data on all three isomers. The National Screening Program for Organics in Drinking Water (NSP) contains data on p-dichlorobenzene only.

Eighteen groundwater systems were analyzed for p-dichlorobenzene during Phase I of NOMS (March to April 1976), with none of the systems containing quantifiable levels. These 18 systems were sampled again during Phase II of the study (May to July 1976) for all three isomers of dichlorobenzene. Four systems contained p-dichlorobenzene at levels ranging from 0.006-0.41 µg/L. The average of the positive values was 0.13 µg/L with a standard deviation of 0.19 µg/L; the median value was 0.04 µg/L. Two of the 17 systems analyzed for p-dichlorobenzene proved positive, with levels of 0.09 and 0.1 µg/L. The minimum quantifiable limit for p-dichlorobenzene was1.0 µg/L in Phase I and 0.005 µg/L in Phases II and III.

Twelve groundwater supplies were tested for p-dichlorobenzene contamination in the NSP. Of these 12 systems, one was contaminated with p-dichlorobenzene at a level of 0.5 µg/L. The quantification limit for p-dichlorobenzene was 0.1 µg/L.

In the GWSS, 5 of the 456 randomly chosen water systems serving 25 or more individuals were positive for p-dichlorobenzene, at concentrations ranging from 0.52-1.3µg/L. The three systems with the highest values were contaminated at 0.66, 0.68, and 1.3 µg/L. Of the 5 positive p-dichlorobenzene systems, 3 were from systems serving populations in excess of 10,000 people. The average for all randomly chosen systems was 0.8 µg/L with a standard deviation of 0.3 µg/L; the median was 0.7 µg/L. Of the 473 nonrandom locations sampled serving 25 or more individuals, 4 were contaminated with p-dichlorobenzene at levels ranging from 0.7-0.9 µg/L. All 4 positive p-dichlorobenzene samples were from systems serving populations under 10,001 people. The average p-dichlorobenzene concentration for the nonrandom systems was 0.8 µg/L with a standard deviation of 0.09 µg/L; the median value was 0.7 µg/L. The minimum quantitation limit for dichlorobenzene was 0.5 µg/L.

4.3.5.3 Groundwater – State Data

Dichlorobenzene data (undifferentiated by isomer) on groundwater from 274 wells, supplied to the EPA by New Jersey, contained only one positive value (between 1-10 µg/L).

Data from California, Indiana, and New Jersey revealed a low incidence of p-dichlorobenzene contamination. Groundwater supplies from four locations in California (unspecified water type) were sampled with only one containing a quantifiable amount of p-dichlorobenzene (0.4 µg/L from Morada). Analytical results from seven groundwater samples from Elkhart, Indiana proved negative for p-dichlorobenzene. One hundred seventy-five groundwater samples were taken from New Jersey with only one positive value between the detection limit and 9.9 µg/L (unquantified).

4.3.5.4 Surface Water – Federal Surveys

Two Federal studies, the National Organic Monitoring Survey (NOMS) and the National Screening Program for Organics in Drinking Water (NSP), contain data concerning dichlorobenzene levels in surface water supplies from across the country. The NOMS contains information on all three isomers of dichlorobenzene, while the NSP provides data for p-dichlorobenzene only.

In Phase I of the National Organic Monitoring Survey (March to April 1976), water samples from 89 surface water systems were analyzed only for p-dichlorobenzene. Of these 89 systems, only two were found to contain p-dichlorobenzene, at levels of 1.0 and 3.0 µg/L. Ninety-one systems were sampled during the second phase of the survey (May to July 1976) and sixteen of the 91 systems were contaminated with p-dichlorobenzene, at levels ranging from 0.007-1.6 µg/L, including the three systems identified as positive in the first phase of the study. The average p-dichlorobenzene concentration among the positive Phase II samples was 0.14 µg/L with a standard deviation of 0.39 µg/L; the median concentration was 0.03 µg/L. During the third phase of the NOMS (November 1976 to January 1977), analyses revealed contamination by all three isomers of dichlorobenzene. Of the 89 systems analyzed, 27 systems showed p-dichlorobenzene contamination, at levels ranging from 0.01-0.75 µg/L. The average concentration among the 27 positive systems was 0.06 µg/L ± 0.14; the median value was 0.02 µg/L. For p-dichlorobenzene, the minimum quantifiable limit was 1.0 µg/L in Phase I, 0.1 µg/L in Phase II, and 0.005 µg/L in Phase III.

Surface water samples from 106 drinking water systems were analyzed for p-dichlorobenzene during the National Screening Program (NSP) between June 1977 and March 1981. Of these, 5 systems contained detectable levels of p-dichlorobenzene, ranging from 0.1-0.9 µg/L. Only two of these systems were contaminated at levels greater than 0.1 µg/L (0.2 and 0.9 µg/L). The average concentration among the 5 positive systems was 0.3 µg/L with a standard deviation of 0.3 µg/L; the median level was 0.15 µg/L. The quantification limit for the NSP was 0.1 µg/L.

4.3.5.5 Surface Water – State Data

The levels of dichlorobenzene in surface water systems at Niagara Falls were monitored. Eight surface water samples were analyzed for p-dichlorobenzene with four containing quantities ranging from 0.01 to 0.18 µg/L, the average being 0.05 µg/L. Of five surface water samples analyzed for dichlorobenzene undifferentiated as to isomer, three had concentrations of 0.02-0.26 µg/L (average of 0.16 µg/L for positive samples).

4.3.5.6 Surface Water – Miscellaneous Data

Drinking water samples from surface water sources, collected from three cities on Lake Ontario, were analyzed for the three isomers of dichlorobenzene. Positive results were found for each isomer. In the case of p-dichlorobenzene, concentrations ranged from 0.008-0.020 µg/L, with an average of 0.013 µg/L (Oliver and Nicol, 1982, as cited in JRB Associates, 1983).

4.3.5.7 Projected National Occurrence of Dichlorobenzene in Public Water Supplies

As reported in the JRB Associates (1983) report, public water systems fall into two major categories with respect to water source (surface water and groundwater) and into five size categories and twelve subcategories according to the number of individuals served. The JRB Associates (1983) report presented estimates of both the number of drinking water supplies nationally within each of the source/size categories expected to have dichlorobenzene present, and of the concentration of dichlorobenzene expected to be present in those supplies.

The key features of the methodology used and assumptions made to develop the national estimates are summarized here. The estimates are based on the data from the Federal surveys only. The State data and miscellaneous information were not included for several reasons. Generally, these data are from a few States and were not considered to be geographically representative. There was also a general lack of data on the population served by systems measured, the type of water sampled, and the methodologies used to sample, identify, and measure dichlorobenzene.

The Federal survey data from the NOMS, NSP, and GWSS were pooled together for developing the national projections. It was assumed in combining these surveys that the resulting data base would be representative of the nation's water supplies. In the case of the GWSS data, both the random and nonrandom samples were included in the projections because statistical test of the GWSS data showed that neither the frequency of occurrence of positive values nor the mean of the positive values for any of the three dichlorobenzene isomers was significantly different between the two samples.

Ideally, adequate data would be available to develop the national projections separately for each of the twelve system size categories within the groundwater and surface water groups; however, the available data were too limited for this. JRB Associates (1983) consolidated some of the size categories to have sufficient data for developing the projections. In consolidating data from various size categories, consideration was given to the potential for there being statistically significant differences in the frequency of occurrence of dichlorobenzene as a function of system size. The consolidation of size categories therefore involved a balancing of the need to group size categories together to have an adequate data base for developing the national projections against the need to treat size categories separately in order to preserve the influence of system size as a determinant of contamination potential. The consolidation of size categories also took into account EPA's classification of systems into the five major groups as very small (25500), small (501-3,300), medium (3,301-10,000), large (10,001-100,000), and very large (> 100,000) (Kuzmack, 1983, as cited in JRB Associates, 1983).

Once the data were consolidated, statistical models for extrapolating to the national level were tested and an appropriate model selected. In the case of the dichlorobenzenes, the multinomial method was used. The frequency of contamination of groundwater and surface water systems at various concentrations was determined for each consolidated size category. For completing the national estimates, it was assumed that the frequency of contamination observed for each consolidated category was directly applicable to each of the system sizes comprising it.

In the JRB Associates (1983) report, it is noted some of the data used in computing the national estimates are from samples held for a prolonged period of time prior to analysis, with possible biodegradation of the dichlorobenzenes. Therefore, these projections of national occurrence may underestimate actual contaminant levels.

4.3.5.7.1 Groundwater Supplies

Fourteen of 948 groundwater supplies sampled were found to have p-dichlorobenzene present at levels ranging from 0.34 to 1.3 µg/L. Based on the overall distribution of positive values and maximum possible values for those supplies in which the dichlorobenzenes were not found, 0.5 µg/L was selected as the common minimum quantifiable concentration for the combined survey data. That is, quantitative projections are made of supplies at several concentration ranges > 0.5 µg/L, while only a total number for supplies expected to have either no dichlorobenzene or levels below 0.5 µg/L can be determined.

Although some data indicate the presence of dichlorobenzene (specifically p-dichlorobenzene) in groundwater supplies at levels < 0.5 µg/L, it is not possible to determine the proportion of supplies that have dichlorobenzene present and the proportion that are actually free of dichlorobenzene contamination.

The survey data was combined across all system sizes for each of the dichlorobenzene isomers in order to develop the national estimates. The frequency of occurrence of each of the dichlorobenzenes that was determined on the basis of data for all size supplies was then applied to each of the separate size categories to complete the national estimates.

An estimated 510 groundwater supplies (range of 197-822), approximately 1.1% of the total groundwater supplies in the United States, are expected to have p-dichlorobenzene levels of > 0.5 µg/L; the remaining 47,948 supplies have either no p-dichlorobenzene or levels < 0.5 µg/L. No groundwater supplies are expected to have p-dichlorobenzene at levels above 5 µg/L.

4.3.5.7.2 Surface Water Systems

P-dichlorobenzene was observed in 38 of 150 supplies sampled. The concentrations ranged from 0.1 to 1.6 µg/L. Based on the overall distribution of positive values and maximum possible values for those supplies in which the dichlorobenzenes were not found, 0.5 µg/L was selected as the common minimum quantifiable concentration for the combined survey data. That is, quantitative projections are made of supplies at several concentration ranges > 0.5 µg/L, while only a total number for supplies expected to have either no dichlorobenzene or levels below 0.5 µg/L can be determined. Although some data indicate the presence of dichlorobenzene in surface water supplies at levels < 0.5 µg/L, it is not possible to determine the proportion that have dichlorobenzene present and the proportion that are free of dichlorobenzene contamination.

Twelve surface water supplies (range of 0-34), approximately 0.1% of the total surface water supplies in the United States, are expected to have p-dichlorobenzene levels of > 0.5 µg/L; the remaining 11,190 supplies have either no p-dichlorobenzene or levels < 0.5 µg/L. No surface water supplies are expected to have p-dichlorobenzene at levels > 5 µg/L.

4.3.6 Conclusion

1,4-Dichlorobenzene is primarily used as a space deodorant for toilets and refuse containers, and as a fumigant for control of moths, molds, and mildews. According to the latest data available, production of 1,4-dichlorobenzene was 78.8 million pounds in 1994, and production has generally increased over time. Industrial releases of 1,4-dichlorobenzene have been reported to TRI since 1988 from 22 States. 1,4-Dichlorobenzene was also an analyte for the NAWQA ambient occurrence studies. In the NAWQA study, 1,4-dichlorobenzene was detected in 1.8% of urban wells and 0.16% of rural wells, with median detection values of 1.0 µg/L and 1.3 µg/L, respectively. The Stage 2 analysis, based on the 16-State cross-section, estimated that 0% of combined ground water and surface water systems serving 0% of the population exceeded the MCL of 0.075 mg/L. Based on this estimate, no PWSs nationally are expected to have estimated mean concentrations of 1,4-dichlorobenzene greater than MCL.

The 16-State cross-section was designed to be nationally representative based upon VOC, SOC, and IOC pollution potentials as suggested by considerations of manufacturing, agriculture, and geographic diversity factors. Nationally, 1,4-dichlorobenzene is manufactured and/or processed in 16 States and has TRI releases in 22 States. 1,4-Dichlorobenzene is manufactured and/or processed in 6 out of the 16 cross-section States and has TRI releases in 9 of the 16 cross-section States. The cross-section should adequately represent the occurrence of 1,4-dichlorobenzene on a national scale based upon the use, production, and release patterns of the 16-State cross-section in relation to the patterns observed for all 50 States.

4.3.7 References

Agency for Toxic Substances and Disease Registry (ATSDR). 1998. *Toxicological Profile for 1,4-Dichlorobenzene*. U.S. Department of Health and Human Services, Public Health Service. 253 pp. + Appendices. Available on the Internet at http://www.atsdr.cdc.gov/toxprofiles/tp10.pdf

Brass, H.J., M.A. Feige, T. Halloran, J.W. Mello, D. Munch, and R.F. Thomas. 1977. The National Organic Monitoring Survey: A sampling and analysis for purgeable organic compounds. *Drinking water quality enhancement through source protection.* R.B. Pojasek (ed.). Ann Arbor, MI: Ann Arbor Science, pp. 393-416.

JRB Associates. 1983. *Dichlorobenzenes: Occurrence in Drinking Water, Food, and Air.* Draft report submitted to EPA for review November 17, 1983.

Kuzmack, A.M. 1983. Memorandum: Characterization of the water supply industry (FY82). Washington, D.C.: Office of Water, USEPA. May 16, 1983.

Mello, Wayne. 1983. Personal communication between Wayne Mello, Technical Support Division, Office of Drinking Water, USEPA, and author of JRB Associates, 1983, March 10, 1983.

National Toxicology Program (NTP). 1991. National Toxicology Program Health and Safety Information Sheet - 1,4-Dichlorobenzene. Available on the Internet at http://ntp-db.niehs.nih.gov/NTP_Reports/NTP_Chem_H&S/NTP_Chem1/Radian106-46-7.txt

Oliver, B.G., K.D. Nicol. 1982. Chlorobenzenes in sediments, water, and selected fish from Lakes Superior, Huron, Erie, and Ontario. *Envir. Sci. Technol.* 16:532-536.

Squillace, P.J., M.J. Moran, W.W. Lapham, C.V. Price, R.M. Clawges, and J.S. Zogorski. 1999. Volatile organic compounds in untreated ambient groundwater of the United States, 1985-1995. *Env. Sci. and Tech*. 33(23):4176-4187.

USEPA. 2000. *TRI Explorer: Trends*. Available on the Internet at: http://www.epa.gov/triexplorer/trends.htm, last updated May 5, 2000.

USEPA. 2001. *National Primary Drinking Water Regulations - Consumer Factsheet on: Para-dichlorobenzene.* Office of Ground Water and Drinking Water, USEPA. Available on the Internet at http://www.epa.gov/safewater/dwh/c-voc/p-dichlo.html (Last updated 04/12/2001)

USEPA. 2002. *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT.* EPA Report/815-D-02-005, Office of Water, 55 pp.

Westrick, J.J., J.W. Mello, and R.F. Thomas. 1983. *The Ground Water Supply Survey summary of volatile organic contaminant occurrence data.* EPA Technical Support Division, Office of Drinking Water, Cincinnati, Ohio.

4.4 1,2-Dichloroethane

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4.4.1 Introduction, Use and Production

1,2-Dichloroethane is a clear, manufactured liquid with the chemical formula $C_2H_4Cl_2$. It evaporates quickly at room temperature and has a pleasant smell and a sweet taste. 1,2-Dichloroethane burns with a smoky flame (ATSDR, 1999). The major routes of entry of 1,2-dichloroethane to drinking water are a consequence of industrial activity. It is expected that discharges to surface water and leaching from solid waste are the primary causes of 1,2-dichloroethane contamination of drinking water. Most discharges of 1,2-dichloroethane ultimately reach the atmosphere because of its high volatility (JRB Associates, 1983). Other names for 1,2-dichloroethane are ethylene dichloride, dichloroethane, and EDC.

Although large amounts of 1,2-dichloroethane are produced today, most of it is used as a chemical intermediate for vinyl chloride (ATSDR, 1999). This is, by far, the dominant use of 1,2-dichloroethane. (Ninety-eight percent of the 1,2-dichloroethane produced is produced for this use.) It is used in smaller amounts to synthesize other organic compounds such as vinylidene chloride, 1,1,1-trichloroethane, trichloroethylene, tetrachloroethylene, aziridines, ethylene diamines, and various chlorinated solvents. It can also be added to leaded gasoline to remove lead (ATSDR, 1999).

Some uses of 1,2-dichloroethane have been discontinued, especially in many consumer products. It is no longer used in varnish and finish removers, soaps and scouring compounds, metal degreasers, ore flotation, or paints, coatings, and adhesives; or in organic synthesis for extraction and cleaning purposes. It was also formerly used as a grain, household, and soil fumigant (ATSDR, 1999).

Most of the 1,2-dichloroethane produced is used captively by the manufacturers. In 1986 only 6% of the 1,2-dichloroethane produced was sold on the open market, and the most recent information indicates that about 85% of total 1,2-dichloroethane produced is used captively. Production totals for past years are as follows: 1984, 7.3 billion pounds; 1985, 12.1 billion pounds; 1986, 12.9 billion pounds; 1990, 13.8 billion pounds; 1992, 15.2 billion pounds; 1993, 17.9 billion pounds; and 1994, 16.8 billion pounds (ATSDR, 1999).

Table 4.4-1 shows the number of facilities in each State that manufacture and process 1,2-dichloroethane, the intended uses of the product, and the range of maximum amounts derived from the Toxics Release Inventory (TRI) of EPA. Table 4.4-2 shows the company names and locations of facilities that produce 1,2-dichloroethane and their annual capacities as of February 1, 1998 (ATSDR, 1999).

Table 4.4-1: 1,2-Dichloroethane Manufacturers and Processors by State

State[a]	Number of facilities	Range of maximum amounts on site in pounds[b]	Activities and uses[c]
AL	2	1,000-99,999	11
AR	3	10,000-999,999	7,11
CA	2	10,000-99,000	8
HI	1	10,000-99,999	8,11
IA	2	1,000-9,999	1,6
IL	3	0-99,999	7,11
IN	3	10,000-999,999	11,12
KS	4	100-999,999	2,4,10,11,13
KY	3	10,000-49,999,999	1,3,5,7,10
LA	15	1,000-499,999,999	1,3,4,5,6,7,10,11,13
MI	2	1,000-9,999	1,5,7,12,13
MO	2	100,000-9,999,999	1,3,5,7,8,11
MS	1	100,000-999,999	7,11
NC	3	1,000-999,999	11,13
NJ	2	10,000-99,999	10,11,13
NM	1	1,000-9,999	11

State[a]	Number of facilities	Range of maximum amounts on site in pounds[b]	Activities and uses[c]
NY	1	10,000-99,999	11
PA	6	10,000-999,999	1,5,11,13
PR	2	0-99,999	11,13
SC	2	10,000-999,999	7,11
TX	19	0-499,999,999	1,2,3,4,5,6,7,8,10,11,13

[a] Post office State abbreviations used
[b] Data in TRI are maximum amounts on site at each facility
[c] Activities/Uses include:

1. Produce
2. Import
3. For on-site use/processing
4. For sale/distribution
5. As a byproduct
6. As an impurity
7. As a reactant
8. As a formulation component
9. As a product component
10. For repackaging
11. As a chemical processing aid
12. As a manufacturing aid
13. Ancillary or other uses

Source: ATSDR, 1999 compilation of TRI96 1999 data

Table 4.4-2: United States Production of 1,2-Dichloroethane[a,b]

Manufacturer	Location	Annual capacity (millions of pounds)
Borden Chemicals and Plastics	Geismar, LA	745
CONDEA Vista Company	Lake Charles, LA	1,400
Dow Chemical USA	Freeport, TX Plaquemine, LA	4,500 2,300
Formosa Plastics Corporation USA	Baton Rouge, LA Point Comfort, TX	525 1,900
Geon Company	LaPorte, TX	4,000
Georgia Gulf Corporation	Plaquemine, LA	1,760
Occidental Chemical Corporation Electrochemicals and Proprietary Products Division Electrochemicals	Convent, LA Deer Park, TX Ingleside, TX	1,500 1,950 3,300
Oxymar	Ingleside, TX	3,000
PHH Monomers	Lake Charles, LA	1,400
PPG Industries, Inc. Chemicals Group	Lake Charles, LA	1,600
Vulcan Materials Company Vulcan Chemicals Division	Geismar, LA	500
Westlake Monomers Corporation	Calvert City, KY	1,950
TOTAL		32,330

[a] Derived from Anonymous 1998
[b] Estimates as of February 1, 1998

Source: ATSDR, 1999

4.4.2 Environmental Release

1,2-Dichloroethane is listed as a Toxics Release Inventory (TRI) chemical. Table 4.4-3 illustrates the environmental releases of 1,2-dichloroethane from 1988 - 1999. (1,2-Dichloroethane data are only available for these years.) Air emissions constitute most of the on-site releases, with a steady decrease over the years, except for a minor upturn in 1990. Surface water discharges have fluctuated with a decreasing trend, as releases have remained below 10,000 pounds since 1993. Underground injection has also generally declined, from a high of almost 1.5 million pounds in 1988 to about 1,200 pounds in 1999. Releases to land (such as spills or leaks within the boundaries of the reporting facility) have ranged from near zero to over 7,000 pounds, with no apparent trend. Off-site releases (including metals or metal compounds transferred off-site) decreased from 1988-1991, but have since risen, with by far the greatest release reported in 1999. The decreases in air emissions, underground injection, and surface water discharges have contributed to an overall decreasing trend of total 1,2-dichloroethane on- and off-site releases. These TRI data for 1,2-dichloroethane were reported from 37 States and Puerto Rico, with 18 States reporting every year (USEPA, 2000). Of the 37 States that reported, 11 are in the 16 State cross-section (used for analyses of 1,2-dichloroethane occurrence in drinking water; see Section 4.4.4). (For a map of the 16-State cross-section, see Figure 1.3-1.)

Table 4.4-3: Environmental Releases (in pounds) for 1,2-Dichloroethane in the United States, 1988-1999

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1999	545,225	833	1,171	2,983	679,749	1,229,961
1998	708,117	2,337	2,178	886	162,677	876,195
1997	910,890	1,826	4,549	27	120,476	1,037,768
1996	1,051,183	1,848	5,126	250	91,249	1,149,656
1995	1,292,842	5,194	24,339	256	23,671	1,346,302
1994	1,930,617	7,501	34,296	15	75,642	2,048,071
1993	2,382,308	9,871	5,198	303	61,675	2,459,355
1992	3,307,692	12,760	85,750	1,858	20,530	3,428,590
1991	4,089,523	26,264	6,334	7,051	6,789	4,135,961
1990	5,609,152	49,513	826,672	7,351	33,279	6,525,967
1989	4,251,586	225,824	1,046,661	714	110,085	5,634,870
1988	4,615,179	40,527	1,452,084	2,166	166,131	6,276,087

Source: USEPA, 2000

4.4.3 Ambient Occurrence

The local, State, and federal data set compiled by NAWQA reports that 1,2-dichloroethane was detected in 7 out of 351 urban wells (2.0%). The minimum and maximum concentrations detected were 0.2 µg/L and 3 µg/L, respectively. The median value of detection concentrations was 0.5 µg/L. 1,2-Dichloroethane was also detected in 18 of the rural 2,539 wells (0.71%) analyzed. The minimum and maximum concentrations detected were 0.2 µg/L and 2.8 µg/L, respectively. The median value of detection concentrations was 0.55 µg/L. These data (urban and rural) represent untreated ambient ground water of the conterminous United States for the years 1985-1995 (Squillace et al., 1999).

1,2-Dichloropropane was also an analyte in the NURP data. The NURP study found 1,2-dichloroethane in urban runoff (Lopes and Dionne, 1998). The minimum concentration detected was not reported, and the maximum concentration detected was 4 µg/L, with no mean value reported. The use of the land from which the samples were taken was unspecified.

4.4.3.1 Additional Ambient Occurrence Data

A summary document entitled "Occurrence of 1,2-Dichloroethane in Drinking Water, Food, and Air" (JRB Associates, 1983), was previously prepared for past USEPA assessments of 1,2-dichloroethane. However, no information on the ambient occurrence of 1,2-dichloroethane was included in that document. (The document did include information regarding 1,2-dichloroethane occurrence in drinking water, which is discussed in Section 4.4.5 of this report.)

4.4.4 Drinking Water Occurrence Based on the 16-State Cross-Section

The analysis of 1,2-dichloroethane occurrence presented in the following section is based on State compliance monitoring data from the 16 cross-section States. The 16-State cross-section is the largest and most comprehensive compliance monitoring data set compiled by EPA to date. These data were evaluated relative to several concentration thresholds of interest: 0.0005 mg/L; 0.0025 mg/L; and 0.005 mg/L.

All sixteen cross-section State data sets contained occurrence data for 1,2-dichloroethane. These data represent more than 180,000 analytical results from approximately 23,000 PWSs during the period from 1984 to 1998 (with most analytical results from 1992 to 1997). The number of sample results and PWSs vary by State, although the State data sets have been reviewed and checked to ensure adequacy of coverage and completeness. The overall modal detection limit for 1,2-dichloroethane in the 16 cross-section States is equal to 0.0005 mg/L. (For details regarding the 16-State cross-section, please refer to Section 1.3.5 of this report.)

4.4.4.1 Stage 1 Analysis Occurrence Findings

Table 4.4-4 illustrates the occurrence of in drinking water for the public water systems in the 16-State cross-section relative to three thresholds: 0.005 mg/L (the current MCL), 0.0025 mg/L, and 0.0005 mg/L (the modal MRL). Based on the 16-State cross-section data, less than one percent of all ground water and surface water systems had any threshold exceedances. A total of 29 (approximately 0.126% of) PWSs had analytical results exceeding the MCL; 0.239% of systems (55 systems) had results exceeding 0.0025 mg/L; and 0.977% of systems (225 systems) had results exceeding 0.0005 mg/L.

Approximately 0.112% of ground water systems (24 systems) had any analytical results greater than the MCL. About 0.214% of ground water systems (46 systems) had results above 0.0025 mg/L. The percentage of ground water systems with at least one result greater than 0.0005 mg/L was equal to 0.909% (195 systems).

Only 5 (0.317% of) surface water systems had results greater than the MCL. A total of 9 (0.571% of) surface water systems had at least one analytical result greater than 0.0025 mg/L. Thirty (1.91% of) surface water systems had results exceeding 0.0005 mg/L.

Table 4.4-4: Stage 1 1,2-Dichloroethane Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Ground Water	0.005	0.112%	24
	0.0025	0.214%	46
	0.0005	0.909%	195
Surface Water	0.005	0.317%	5
	0.0025	0.571%	9
	0.0005	1.91%	30
Combined Ground & Surface Water	0.005	0.126%	29
	0.0025	0.239%	55
	0.0005	0.977%	225

Reviewing 1,2-dichloroethane occurrence in the 16 cross-section States by PWS population served (Table 4.4-5) shows that approximately 8.40% of the population (over 9 million people) was served by PWSs (ground and surface water systems) with at least one analytical result of 1,2-dichloroethane greater than the MCL. Approximately 8.98% of the population (almost 10 million people) was exposed to 1,2-dichloroethane concentrations greater than 0.0025 mg/L. The percentage of population served by all PWSs with at least one analytical result of 1,2-dichloroethane greater than 0.0005 mg/L was equal to 11.2% (over 12 million people).

The percentage of population served by surface water systems with threshold exceedances was considerably greater than the percentage of population served by ground water systems with threshold exceedances. Approximately 0.789% of the population served by ground water systems (391,200 people) had at least one analytical result of 1,2-dichloroethane greater than 0.005 mg/L, compared to 14.6% of the population served by surface water systems (over 8.9 million people) with results greater than 0.005 mg/L. When evaluated relative to 0.0025 mg/L, the percent of population exposed by ground water systems was 1.30% (641,600 people) and the percent of population exposed by surface water systems was 15.2% (over 9.3 million people). Approximately 4.64% of the population was served by ground water systems (over 2.3 million people) with analytical detections greater than 0.0005 mg/L, as compared to 16.5% of the population served by surface water systems (about 10.1 million people) with analytical detections greater than 0.0005 mg/L.

Table 4.4-5: Stage 1 1,2-Dichloroethane Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Ground Water	0.005	0.789%	391,200

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
	0.0025	1.30%	641,600
	0.0005	4.64%	2,300,500
Surface Water	0.005	14.6%	8,916,000
	0.0025	15.2%	9,311,400
	0.0005	16.5%	10,113,500
Combined Ground & Surface Water	0.005	8.40%	9,307,200
	0.0025	8.98%	9,953,000
	0.0005	11.2%	12,414,000

4.4.4.2 Stage 2 Analysis Occurrence Findings

The Stage 2 occurrence findings, based on the cross-section data, are presented in Tables 4.4-6 and 4.4-7. The statistically generated best estimate values, as well as the ranges around the best estimate value, are presented. (For a review of the Stage 2 analytical approach, please refer to Section 1.4 of this report. For complete details regarding the Stage 2 analyses, please refer to *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT* (USEPA, 2002)).

Only 1 PWS in the 16 States (approximately 0.00479% of all systems in the 16 States) had an estimated mean concentration of 1,2-dichloroethane exceeding 0.005 mg/L. Four (about 0.0175% of) PWSs were estimated to have mean concentrations greater than 0.0025 mg/L. Approximately 30 (0.132% of) PWSs had estimated mean concentrations of 1,2-dichloroethane greater than 0.0005 mg/L.

The estimated number of ground water PWSs in the 16 States with mean concentrations exceeding the thresholds of 0.005 mg/L, 0.0025 mg/L, and 0.0005 mg/L was 1 (about 0.00514%), 4 (about 0.0187%), and 29 (about 0.135%), respectively. No surface water PWSs had estimated mean concentration exceeding 0.005 mg/L. One (approximately 0.000762% of) surface water PWSs in the 16 States was estimated to have a mean concentration greater than 0.0025 mg/L. The percentage of surface water PWSs in the 16 States with estimated mean concentration exceeding 0.0005 mg/L was equal to 0.0974% (approximately 2 systems).

Table 4.4-6: Stage 2 Estimated 1,2-Dichloroethane Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.005	0.00514%	0.000% - 0.0140%	1	0 - 3
	0.0025	0.0187%	0.00932% - 0.0326%	4	2 - 7
	0.0005	0.135%	0.0932% - 0.177%	29	20 - 38
Surface Water	0.005	0.000%	0.000% - 0.000%	0	0 - 0
	0.0025	0.000762%	0.000% - 0.000%	1	0 - 0
	0.0005	0.0974%	0.0635% - 0.191%	2	1 - 3
Combined Ground & Surface Water	0.005	0.00479%	0.000% - 0.0130%	1	0 - 3
	0.0025	0.0175%	0.00868% - 0.0304%	4	2 - 7
	0.0005	0.132%	0.0955% - 0.174%	30	22 - 40

Reviewing 1,2-dichloroethane occurrence by PWS population served (Table 4.4-7) shows that approximately 0.0003341% of population served by all PWSs in the 16 States (an estimate of approximately 400 people) were potentially exposed to 1,2-dichloroethane levels above 0.005 mg/L. About 39,400 (approximately 0.0357% of) people and about 370,300 (0.334% of) people served by the combined total of surface and ground water systems were potentially exposed to levels above 0.0025 mg/L and 0.0005 mg/L, respectively.

The percentage of population served by ground water systems in the 16 States with levels greater than 0.005 mg/L was approximately 0.000740% (over 400 people). When evaluated relative to thresholds of 0.0025 mg/L and 0.0005 mg/L, the population exposed was about 37,700 (0.0760%) and 189,200 (0.382%), respectively.

No surface water systems had estimated mean concentrations of 1,2-dichloroethane greater than 0.005 mg/L. About 0.00297% (approximately 1,800 people) of the population served by surface water in the 16 States were potentially exposed to levels above 0.0025 mg/L. When evaluated relative to thresholds of 0.0005 mg/L, the population exposed was equal to 0.296% (about 181,000 people).

Table 4.4-7: Stage 2 Estimated 1,2-Dichloroethane Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.005	0.000740%	0.000% - 0.00155%	400	0 - 800
	0.0025	0.0760%	0.00107% - 0.118%	37,700	500 - 58,400
	0.0005	0.382%	0.212% - 0.616%	189,200	105,100 - 305,000
Surface Water	0.005	0.000%	0.000% - 0.000%	0	0 - 0
	0.0025	0.00297%	0.000% - 0.000%	1,800	0 - 0
	0.0005	0.296%	0.246% - 0.548%	181,000	150,800 - 335,500
Combined Ground & Surface Water	0.005	0.000331%	0.000% - 0.000692%	400	0 - 800
	0.0025	0.0357%	0.000478% - 0.0542%	39,400	500 - 60,000
	0.0005	0.334%	0.231% - 0.518%	370,300	255,900 - 573,600

4.4.4.3 Estimated National Occurrence

Based on the Stage 2 estimated percent of systems (and population served by systems) exceeding each threshold, an estimated 3 PWSs nationally serving approximately 700 people could be exposed to 1,2-dichloroethane concentrations above 0.005 mg/L. About 11 systems serving almost 76,000 people had estimated mean concentrations greater than 0.0025 mg/L. Approximately 86 systems serving about 711,900 people nationally were estimated to have mean 1,2-dichloroethane concentrations greater than 0.0005 mg/L. (See Section 1.4 for a description of how Stage 2 16-State estimates are extrapolated to national values.)

For ground water systems, an estimated 3 PWSs serving about 600 people nationally had mean concentrations greater than 0.005 mg/L. Approximately 11 systems serving about 65,200 people nationally had estimated mean concentration values that exceeded 0.0025 mg/L. About 80 ground water systems serving almost 327,200 people had estimated mean concentrations greater than 0.0005 mg/L.

Zero surface water systems had estimated mean concentrations of 1,2-dichloroethane above 0.005 mg/L. About 1 surface water systems serving 3,800 people had estimated mean concentrations greater than 0.0025 mg/L. An estimated 5 surface water systems serving approximately 376,300 people had mean concentrations greater than 0.0005 mg/L.

Table 4.4-8: Estimated National 1,2-Dichloroethane Occurrence - Systems and Population Served

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.005	3	0 - 8	600	0 - 1,300
	0.0025	11	6 - 19	65,200	900 - 101,000
	0.0005	80	55 - 105	327,200	181,700 - 527,400
Surface Water	0.005	0	0 - 0	0	0 - 0
	0.0025	1	0 - 0	3,800	0 - 0
	0.0005	5	4 - 11	376,300	313,600 - 697,500
Combined Ground & Surface Water	0.005	3	0 - 8	700	0 - 1,500
	0.0025	11	6 - 20	75,900	1,000 - 115,400
	0.0005	86	62 - 113	711,900	492,000 - 1,102,700

4.4.5 Additional Drinking Water Occurrence Data

Several additional data sources regarding the occurrence of 1,2-dichloroethane in drinking water are also reviewed. Previously compiled occurrence information, from an OGWDW summary document entitled "Occurrence of 1,2-Dichloroethane in Drinking Water, Food, and Air" (JRB Associates, 1983), is presented in the following section. This variety of studies and information are presented regarding levels of 1,2-dichloroethane in drinking water, with the scope of the reviewed studies ranging from national to regional. Note that none of the studies presented in the following section provide the quantitative analytical results or comprehensive coverage that would enable direct comparison to the occurrence findings estimated with the cross-section occurrence data presented in Section 4.4.4. These additional studies, however, do enable a broader assessment of the Stage 2 occurrence estimates presented for this Six-Year Review. All the following information in Section 4.4.5 is taken directly from "Occurrence of 1,2-Dichloroethane in Drinking Water, Food, and Air" (JRB Associates, 1983).

JRB Associates (1983) found two major types of data available that were potentially useful for describing the occurrence of 1,2-dichloroethane in the nation's public drinking water supplies. First, there are several Federal surveys in which a number of public water supplies from throughout the U.S. were selected for analysis of chemical contamination, including 1,2-dichloroethane. Second, data are available from State surveys and from State investigations of specific incidents of known or suspected contamination of a supply. For accomplishing the basic objectives of this study, namely to estimate the number of public water supplies nationally within the various source and size categories contaminated with 1,2-dichloroethane, the distribution of 1,2-dichloroethane concentrations in those supplies, and the number of individuals, exposed to those concentrations, it was determined that the Federal survey data provides the most suitable data base. The State data tend to be poorly described with respect to the source and size categories of the supplies examined and the sampling and analysis methods used for determining contaminant levels. The lack of source and system size information precludes using the data for estimating levels in public water supplies of similar characteristics. The absence of details on sampling and analysis methods precludes evaluating those data for their qualitative and quantitative reliability. Although they are not used with the Federal data for the purpose of estimating contamination levels nationally, the available State data are presented here to provide some additional perspective on 1,2-dichloroethane occurrence in drinking water.

Data are presented only on drinking water samples taken from a consumer's tap (i.e., distribution water samples) or on treated water samples taken at the water supply (i.e., finished water samples) because these are considered to be most representative of the water consumed by the public. No data on raw (i.e., untreated) water are presented. It is recognized that for some groundwater supplies where no treatment of the water occurs, samples identified as raw may be representative of water consumed by the users of the supply. However, it was generally not possible to differentiate between those groundwater supplies that do and those that do not treat raw water from the available survey data.

4.4.5.1 Overview and Quality Assurance Assessment of Federal Drinking Water Surveys

Six Federal drinking water surveys provide data on 1,2-dichloroethane: the National Organics Reconnaissance Survey (NORS), the National Organic Monitoring Survey (NOMS), the National Screening Program for Organics in Drinking Water (NSP), the 1978 Community Water Supply Survey (CWSS), the Rural Water Survey (RWS), and the Groundwater Supply Survey (GWSS). The terms used in this report are those used in the individual surveys, recognizing that they may not always correspond to strict technical definitions.

The National Organics Reconnaissance Survey (NORS) was conducted in 1975 to determine the extent of the presence of 1,2-dichloroethane, carbon tetrachloride, and four trihalomethanes in drinking water supplies from 80 cities across the country (Symons et al., 1975, as cited in JRB Associates, 1983). The effect of the water source and treatment practices on the formation of these compounds were also examined in the NORS. Of the 80 supplies studied, 16 were indicated as having a groundwater source and 64 as having a surface water source. Symons et al. (1975, as cited in JRB Associates, 1983) did not provide data on the population served by the supplies studied in NORS; the populations served were estimated by JRB based on information available from other sources for the supplies studied and from census data for the locations of the supplies.

The National Organic Monitoring Survey (NOMS) was conducted to identify contaminant sources, to determine the frequency of occurrence of specific drinking water contaminants, and to provide data for the establishment of maximum contaminant levels (MCL's) for various organic compounds in drinking water (Brass et al., 1977, as cited in JRB Associates, 1983). The NOMS was conducted in three phases: March-April 1976, May-July 1976, and November 1976-January 1977. Finished drinking water samples from 113 communities were analyzed for 21 different compounds. Of the 113 community supplies sampled, 18 had groundwater sources, 91 had surface water sources, and 4 had a mixed groundwater/surface water source. For 1,2-dichloroethane, 18 groundwater supplies were examined in Phases I and II, and 14 groundwater supplies in Phase III; for surface water, 88, 91, and 87 supplies were analyzed for 1,2-dichloroethane in Phases I, II, and III, respectively.

The analytical results of the NOMS were made available in printed form by EPA's Technical Support Division, Office of Drinking Water. Additional information on the locations and source of the supplies, and on the populations served by the supplies in the NOMS were provided by Wayne Mello (1983, as cited in JRB Associates, 1983) at EPA's Technical Support Division, Office of Drinking Water. A single value for 1,2-dichloroethane was reported for each supply studied in the NOMS.

The National Screening Program for Organics in Drinking Water (NSP), conducted by SRI International from June 1977 to March 1981, examined both raw and finished drinking water samples from 166 water systems in 33 States for 51 organic chemical contaminants. Data are available for 1,2-dichloroethane on finished water samples from 12 groundwater and 103 surface water supplies.

In the Community Water Supply Survey (CWSS), carried out in 1978, 106 surface water supplies, 330 groundwater supplies, and 16 supplies with mixed sources were examined for volatile organic chemical contamination. Samples were taken of raw, finished, and distribution water. Only the latter two types of water are considered here. Data for 1,2-dichloroethane in finished and/or distribution samples were obtained from a total of 315 groundwater and 104 surface water supplies.

The Rural Water Survey (RWS), conducted in 1978, was carried out in response to Section 3 of the Safe Drinking Water Act, which mandated that EPA "conduct a survey of the quantity, quality, and availability of rural drinking water supplies." Drinking water samples were collected for analysis of inorganic chemicals, pesticides, and VOCs from 2,655 households throughout the United States located in areas defined in the survey as rural. Of these, a total of 855 household samples were examined for VOCs. The majority of these samples were obtained from households receiving water from private wells or small supplies serving fewer than 25 people. For 1,2-dichloroethane, data are available in the RWS for 206 groundwater and 35 surface water supplies serving 25 or more people.

The RWS did not obtain data on the number of persons in each household served by the supplies. However, data were obtained on the number of service connections at each supply. With the input of Dr. Bruce Brower at Cornell University, who participated in the statistical analysis of the RWS for parameters other than VOCs, the population served by each supply was estimated from the average number of persons per household (3.034) observed in the survey. A single value was reported for each household; in some cases it was necessary to average two or three households obtaining water from the same supply. Brass (1981, as cited in JRB Associates, 1983) cautions that the RWS water samples were analyzed 6 to 27 months after collection and that degradation of some VOCs may have occurred during this holding period.

The Groundwater Supply Survey (GWSS) was conducted from December 1980 to December 1981 to develop additional data on the occurrence of volatile organic chemicals in the nation's groundwater supplies (Westrick et al., 1983, as cited in JRB Associates, 1983). It was hoped that this study would stimulate State efforts toward the detection and control of groundwater contamination and the identification of potential chemical "hot spots." A total of 944 systems were sampled for 1,2-dichloroethane, of which 466 were chosen at random. The remaining 478 systems were chosen non randomly based on information from States encouraged to identify locations believed to have a higher than normal probability of VOC contamination (e.g., locations near landfills or industrial activity). The file provided a single analytical result for each supply sampled. One sample of finished water was collected from each supply at a point near the entrance to the distribution system.

Each of the drinking water surveys was evaluated with respect to the validity of the reported occurrence data for a number of organic chemicals, including 1,2-dichloroethane. The evaluations were carried out by analyzing information about the procedures used for collection and analysis of samples as well as the quality control protocols used. The analyzed compounds dealt with in each study were assigned one of three possible ratings: quantitatively acceptable, qualitatively acceptable (i.e., the substance measured was 1,2-dichloroethane), and totally unacceptable. In the case of 1,2-dichloroethane, a qualitatively acceptable rating was given for data from the CWSS and RWS because of suspected biodegradation of the samples, which were held unrefrigerated for prolonged periods before analysis. 1,2-Dichloroethane values in excess of the quantitation limit reported for some samples in these studies are qualitatively valid and can be taken as minimum values, representative of samples which probably originally contained 1,2-dichloroethane at higher concentrations. In the case of the NORS, NOMS, NSP, and GWSS, all data were rated both quantitatively and qualitatively acceptable.

4.4.5.2 Groundwater – Federal Surveys

The National Organics Reconnaissance Survey (NORS), the National Organic Monitoring Survey (NOMS), the National Screening Program for Organics in Drinking Water (NSP), the Community Water Supply Survey (CWSS), the Rural Water Survey (RWS), and the Groundwater Supply Survey (GWSS) all contain data concerning the levels of 1,2-dichloroethane in groundwater supplies from across the country.

In the NORS, finished water samples were taken from 16 groundwater systems from across the country. Of these, 4 supplies were reported to have 1,2-dichloroethane present, although the level of contamination in these 4 supplies was below the minimum quantifiable concentration of 0.2 μg/L for those analyses. All other groundwater supplies were indicated as having "none found," with the minimum quantifiable concentration ranging from 0.2 to 0.4 μg/L.

Eighteen groundwater systems were analyzed for 1,2-dichloroethane during Phase I of NOMS (March to April 1976), with none of the systems containing quantifiable levels. These 18 systems were sampled again during Phase II of the study (May to July 1976) with one containing 1,2-dichloroethane at 0.2 μg/L. Samples analyzed during Phase III of the study (November 1976 to January 1977) proved negative for all of the 14 systems examined. The minimum quantifiable limits for 1,2-dichloroethane ranged from 1-2 μg/L in Phase I, 0.05-1 μg/L in Phase II, and 0.05-1 μg/L in Phase III.

Twelve groundwater supplies were tested for 1,2-dichloroethane contamination in the NSP. Of these 12 systems, one was found to be contaminated with 1,2-dichloroethane at 0.2 μg/L. The quantification limit for 1,2-dichloroethane was 0.1 μg/L.

The 1978 CWSS provided information on 1,2-dichloroethane levels in 315 groundwater systems. Of these systems, 4 contained detectable levels of 1,2-dichloroethane, with values ranging from 0.56-1.1 μg/L. The mean value was 0.9 μg/L with a standard deviation of 0.3 μg/L; the median value was 0.9 μg/L. The minimum quantitation limit for 1,2-dichloroethane in the CWSS was 0.5 μg/L.

The RWS examined 206 groundwater supplies for 1,2-dichloroethane and found none to have levels above the minimum quantification limit of 0.5 μg/L.

In the GWSS, 3 of the 456 randomly chosen water systems serving 25 or more individuals were contaminated with 1,2-dichloroethane, at concentrations of 0.53, 0.57, and 0.95 μg/L. Of the 472 nonrandom locations sampled serving 25 or more individuals, 7 were contaminated with 1,2-dichloroethane, at concentrations between 1.1-9.8 μg/L, the highest values being 2.9, 3.4, and 9.8 μg/L. Of the 7 positive samples, 4 were from systems serving populations in excess of 10,000 people. The average 1,2-dichloroethane level for the nonrandom systems was 3.4 μg/L with a standard deviation of 2.9 μg/L; the median value was 2.5 μg/L. The minimum quantitation limit for 1,2-dichloroethane was 0.2 μg/L.

4.4.5.3 Groundwater – State Data

Six States (California, Connecticut, Delaware, Indiana, Massachusetts, and New Jersey) provided EPA with information concerning 1,2-dichloroethane contamination in groundwater supplies. Analytical results for samples from four locations in California ranged from undetectable to 21 μg/L. Samples from two locations in Connecticut gave 1,2-dichloroethane readings of not detectable and 7.8 µg/L. Delaware reported data from three locations, with four samples having no detectable 1,2-dichloroethane. Data on 26 samples from two cities in Indiana showed 17 samples with undetectable 1,2-dichloroethane and nine samples with concentrations ranging from 19-2,100 µg/L (averaging 624 µg/L). In data from Massachusetts, there was no detectable 1,2-dichloroethane in five groundwater samples from two cities, while levels ranging from 10.1-19.1 µg/L (averaging 14.7 µg/L) were reported in samples taken from two other cities. In New Jersey data, 405 samples showed no detectable 1,2-dichloroethane and 26 additional samples were contaminated at 0.1-100 µg/L (ranges were the only data reported for groups of samples, so no averages can be taken).

4.4.5.4 Surface Water – Federal Surveys

The National Organics Reconnaissance Survey (NORS), the National Organic Monitoring Survey (NOMS), the National Screening Program for Organics in Drinking Water (NSP), the Community Water Supply Survey (CWSS), and the Rural Water Survey (RWS) all contain data concerning the levels of 1,2-dichloroethane in surface water supplies from across the country.

In the NORS, finished water from 64 surface water systems were studied, 22 of which were found to have 1,2-dichloroethane present. Sixteen of the 22 positive systems reported 1,2-dichloroethane to be present, but below the minimum quantifiable concentration range of 0.2 to 0.4 µg/L. Of six systems with quantifiable levels, the concentrations ranged from 0.2-6 µg/L. The 42 negative surface water systems were indicated as having "none found," with the minimum quantifiable concentration ranging from 0.2 to 0.4 µg/L. It should be noted that confirmatory quantitative analyses were performed for 8 surface water supplies in NORS, using a method able to quantify 1,2-dichloroethane at 0.1 µg/L. Three of these 8 supplies were originally reported as having 1,2-dichloroethane present, but below the minimum quantifiable concentration of 0.2 µg/L in 2 cases and 0.4 µg/L in the third case; 1,2-dichloroethane was not observed in any of these 3 systems in the confirmatory analysis. Of the 5 supplies originally reported as having "none found," one was observed in the confirmatory analysis to have 1,2-dichloroethane present at 0.2 µg/L.

In Phase I of the National Organic Monitoring Survey (March to April 1976), water samples from 88 surface water systems were analyzed for 1,2-dichloroethane. Of these 88 systems, only one was found to contain 1,2-dichloroethane, at 2 µg/L. Ninety-one systems were sampled during the second phase of the survey (May to July 1979) and one was found to be contaminated at 1.8 µg/L. During the third phase of the NOMS (November 1976 to January 1977), analyses revealed 1,2-dichloroethane contamination in one out of a total of 87 systems, at 1.2 µg/L. The minimum quantifiable limits for 1,2-dichloroethane ranged from 1-3 µg/L in Phase I, 0.05-1 µg/L in Phase II, and 0.05-2 µg/L in Phase III.

Surface water samples from 106 drinking water systems were analyzed for 1,2-dichloroethane during the National Screening Program (NSP) between June 1977 and March 1981. Of these, only one system contained a detectable level of 1,2-dichloroethane, at 4.8 µg/L. The quantification limit for the NSP was 0.1 µg/L.

None of the 104 surface water systems sampled during the Community Water Supply Survey (CWSS) contained quantifiable levels of 1,2-dichloroethane. The minimum quantitation limit for 1,2-dichloroethane in the CWSS was 0.5 µg/L.

The RWS examined drinking water from 35 surface water supplies; only one supply was found to have 1,2-dichloroethane present above the minimum quantification limit range of 0.5-2.0 µg/L. The concentration of 1,2-dichloroethane observed in that supply was 19 µg/L.

4.4.5.5 Surface Water – State Data

The only State supplied surface water information on 1,2-dichloroethane was from New York. One sample from Poughkeepsie assayed for 1,2-dichloroethane was positive at 5.9 µg/L.

4.4.5.6 Projected National Occurrence of 1,2-Dichloroethane in Public Water Supplies

As reported in the JRB Associates (1983) report, public water systems fall into two major categories with respect to water source (surface water and groundwater) and into five size categories and twelve subcategories according to the number of individuals served. The JRB Associates (1983) report presented estimates of both the number of drinking water supplies nationally within each of the source/size categories expected to have 1,2-dichloroethane present, and of the concentration of 1,2-dichloroethane expected to be present in those supplies.

The key features of the methodology used and assumptions made to develop the national estimates are summarized here. The estimates are based on the data from the Federal surveys only. The State data were not included for several reasons. These data are from a few States and were not considered to be geographically representative. There was also a general lack of data on the population served by systems measured, the type of water sampled, and the methodologies used to sample, identify, and measure 1,2-dichloroethane.

The Federal survey data from the NORS, NOMS, NSP, CWSS, RWS, and GWSS (random only) were pooled together for developing the national projections. It was assumed in combining these surveys that the resulting data base would be representative of the nation's water supplies. In the case of the GWSS data, only the randomly selected samples were included in the projections because a statistical test of the GWSS data showed that the mean of the positive values for 1,2-dichloroethane was significantly higher in the nonrandom portion. Therefore, these data were not included in the national projections to avoid biasing the results. Ideally, adequate data would be available to develop the national projections separately for each of the twelve system size categories within the groundwater and surface water groups; however, the available data were too limited for this. It was, therefore, necessary to consolidate some of the size categories to have sufficient data for developing the projections. In consolidating data from various size categories, consideration was given to the potential for there being statistically significant differences in the frequency of occurrence of 1,2-dichloroethane as a function of system size. The consolidation of size categories therefore involved a balancing of the need to group size categories together to have an adequate data base for developing the national projections against the need to treat size categories separately in order to preserve the influence of system size as a determinant of contamination potential. The consolidation of size categories also took into account EPA's classification of systems into the five major groups as very small (25-500), small (501-3,300), medium (3,301-10,000), large (10,001-100,000), and very large (> 100,000) (Kuzmack, 1983, as cited in JRB Associates, 1983).

Once the data were consolidated, statistical models for extrapolating to the national level were tested and an appropriate model selected. In the case of 1,2-dichloroethane, the multinominal method was used. The frequency of contamination of groundwater and surface water systems at various concentrations was determined for each consolidated size category. For completing the national estimates, it was assumed that the frequency of contamination observed for each consolidated category was directly applicable to each of the system sizes comprising it.

In the JRB Associates (1983) report, it is noted that some of the data used in computing the national estimates are from samples held for a prolonged period of time prior to analysis, with possible biodegradation of 1,2-dichloroethane. Therefore, these projections of national occurrence may underestimate actual contaminant levels.

4.4.5.6.1 Groundwater Supplies

JRB Associates (1983) reported that data were available for a total of 1,001 supplies from the combined surveys (NORS, NOMS, NSP, CWSS, RWS, and GWSS (random)). Of these, 12 supplies were reported to have 1,2-dichloroethane present, at concentrations ranging from 0.2 µg/L to 1.1 µg/L.

Based on the overall distribution of positive values and maximum possible values for those supplies in which 1,2-dichloroethane was not found, 0.5 µg/L was selected as the common minimum quantifiable concentration for the combined survey data. An estimate is made of supplies having concentrations > 0.5 µg/L, while only a total number for supplies expected to have either no 1,2-dichloroethane or levels below 0.5 µg/L can be determined. Although some data indicate the presence of 1,2-dichloroethane in groundwater supplies at levels < 0.5 µg/L, it is not possible to determine the proportion of supplies that have 1,2-dichloroethane present and the proportion that are actually free of 1,2-dichloroethane contamination.

Of the 989 supplies reporting no 1,2-dichloroethane to be present, 968 were assumed to have maximum possible levels of < 0.5 µg/L based on the minimum quantifiable concentrations reported for the various surveys. The other 21 supplies reporting no 1,2-dichloroethane to be present had maximum possible levels ranging from approximately 0.53 µg/L to 1.5 µg/L. It is assumed, based on the overall distribution of values, that 1,2-dichloroethane if present in these 21 supplies is so at a concentration of < 0.5 µg/L, although a rigorous, conservative argument could be made for assuming a level equal to the maximum possible value. The impact of this assumption is considerable both in terms of the national projection of groundwater systems above 0.5 µg/L, and in terms of the population exposed.

Nine of the 1,001 supplies examined had measured values of 1,2-dichloroethane > 0.5 µg/L. When the twelve size categories were consolidated into the five major EPA groupings, there was an apparent relationship between the frequency of values > 0.5 µg/L and system size:

Very small	0%	(0/352)
Small	0.7%	(2/290)
Medium	0%	(0/100)
Large	2.7%	(6/225)
Very large	3.0%	(1/34)
Overall	0.9%	(9/1,001)

A test for statistical significance revealed that at the $\alpha = 0.05$ level, the difference among the very small, small, and medium categories was not significant; nor was the difference between the large and very large categories. However, the combined very small, small, and medium categories were different from the combined large and very large categories. Two consolidated categories were, therefore, selected for developing the national estimates:

Very small/small/medium (< 10,000)
Large/Very large (> 10,000)

As noted previously, the frequency of occurrence of 1,2-dichloroethane at various concentrations was determined for the consolidated groups and then applied to the number of supplies nationally within each of the size categories comprising each group.

About 161 groundwater supplies (range of 0-337), approximately 0.3% of the total groundwater supplies in the United States, are expected to have 1,2-dichloroethane at levels of > 0.5 µg/L; the remaining 48,297 supplies have either no 1,2-dichloroethane or levels < 0.5 µg/L. It is estimated that no groundwater supplies will have levels exceeding 5 µg/L.

It is interesting to note the impact on the national projections of the assumption made that the 21 supplies with undetected but maximum potential values of 0.53-1.5 µg/L had < 0.5 µg/L. Had it been assumed that 1,2-dichloroethane was present in those supplies at their maximum possible values, the national projection of supplies with 1,2-dichloroethane levels of 0.5-5 µg/L would have increased to 791 (381-1,200) with no differences in levels > 5 µg/L. These differences would be found primarily in systems serving < 2,500 people.

It is also interesting to compare these national estimates to estimates that include the nonrandom portion of the GWSS. Inclusion of the nonrandom data results in an estimated 258 supplies exceeding 0.5 µg/L. Of these, 3 supplies are estimated to exceed 5 µg/L, based on one observation in the 25,001-50,000 category. None, however, are expected to have levels > 10 µg/L. These data indicate that, while the projections for levels > 5 µg/L based on the random data only may underestimate actual conditions, the error is very small.

4.4.5.6.2 Surface Water

Data are available for a total of 301 surface water supplies. Of these, 25 supplies were reported by JRB Associates (1983) to have 1,2-dichloroethane present at concentrations ranging from 0.2 µg/L to 19 µg/L, although this high value is the only one reported above 4.8 µg/L.

Based on the overall distribution of positive values and maximum possible values for those supplies in which 1,2-dichloroethane was not found, 0.5 µg/L was selected as the common minimum quantifiable concentration for the combined survey data. That is, quantitative projections are made of supplies at several concentration ranges ≥ 0.5 µg/L, while only a total number for supplies expected to have either no 1,2-dichloroethane or levels below 0.5 µg/L can be determined. Although some data indicate the presence of 1,2-dichloroethane in surface water supplies at levels < 0.5 µg/L, it is not possible to determine the proportion that have 1,2-dichloroethane present and the proportion that are free of 1,2-dichloroethane contamination.

Of the 276 supplies reporting no 1,2-dichloroethane to be present, 129 had maximum possible levels of < 0.5 µg/L based on the minimum quantifiable concentrations reported for the various surveys. The other 147 supplies reporting no 1,2-dichloroethane to be present had maximum possible levels ranging from approximately 0.52 µg/L to 2 µg/L. It is assumed, based on the overall distribution of values, that 1,2-dichloroethane if present in these 147 supplies is so at a concentration of < 0.5 µg/L, although a rigorous conservative argument could be made for assuming a level equal to the maximum possible value. As will be noted further below, the difference between these alternatives is very large for both the estimate of the number of surface water supplies with 1,2-dichloroethane ≥ 0.5 µg/L and for the estimated population exposed to 1,2-dichloroethane at levels > 0.5 µg/L in surface water supplies.

Eighteen of the 301 supplies examined had measured values of 1,2,-dichloroethane ≥ 0.5 µg/L. When the twelve size categories were consolidated into the five major EPA groupings, there was an apparent relationship between the frequency of values > 0.5 µg/L and system size:

Very smal	l0%	(0/20)
Small	0%	(0/55)

Medium	5.0%	(2/40)
Large	5.6%	(4/71)
Very large	10.4%	(12/115)
Overall	6.0%	(18/301)

A test for statistical significance revealed that at the $\alpha = 0.05$ level, the very small, small, and medium groups were not different from one another and that the large and very large groups are not different; however, the combined very small, small, and medium groups and the combined large and very large groups are different. These two consolidated categories were selected for developing the national estimates:

Very small/small/medium (< 10,000)
Large/very large (> 10,000)

As noted previously, the frequency of occurrence of 1,2-dichloroethane at various concentrations was determined for the consolidated groups and then applied to the number of supplies nationally within each of the size categories comprising each group.

About 317 surface water supplies (range of 82-551), approximately 2.8% of the total surface water systems in the United States, are expected to have 1,2-dichloroethane at levels > 0.5 µg/L; the remaining 10,885 supplies have either no 1,2-dichloroethane or levels < 0.5 µg/L. It is estimated that 82 surface water supplies (range of 0-241) will have levels > 10 µg/L and none are projected to have levels above 20 µg/L.

There was a notable impact on the national projections by the assumption made that the 147 supplies with undetected but maximum potential values of 0.52-2 µg/L had < 0.5 µg/L. Had it been assumed that 1,2-dichloroethane was present in these supplies at their maximum possible values, the national projections of supplies with 1,2-dichloroethane levels ≥0.5 µg/L would be 5,993 (range of 5,125-6,860) supplies. However, there would be no difference in the projected number of surface water supplies with levels > 5 µg/L.

4.4.5.7 Drinking Water Intake - Estimated Population Exposed

The values given here were obtained using Federal Reporting Data Systems data on populations served by primary water supply systems and the estimated number of these water systems that contain a given level of 1,2-dichloroethane. An estimated 12,232,000 individuals (5.7% of the population of 214,419,000 using public water supplies) are exposed to levels of 1,2-dichloroethane in drinking water at or above 0.5 µg/L, while 143,000 individuals (0.1%) are exposed to levels above 5 µg/L. It is estimated that no individuals are exposed to levels greater than 20 µg/L. Of the approximately 12 million people exposed to levels ranging from 0.5 to 5 µg/L, 11 million (90%) obtain water from surface water supplies. All exposure to 1,2-dichloroethane in drinking water at levels above 5 µg/L is expected to be from surface water sources.

The previous section also presented estimates of the number of public water supplies exceeding various concentrations when the GWSS nonrandom data was included in the analysis. Had the GWSS nonrandom data been included, an increased estimate in the population exposed to 1,2-dichloroethane at levels below 10 µg/L would be seen, notably an increase of 104,000 individuals at levels between 5 and 10 µg/L.

Also presented in the previous section were estimates of the number of public water supplies exceeding various concentrations using an alternative assumption for 168 supplies in which no 1,2-dichloroethane was observed, but which may have contained concentrations exceeding 0.5 µg/L owing to relatively high minimum quantifiable levels in the analysis of those supplies. Had it been assumed that the 168 supplies sampled had been contaminated at the maximum quantifiable level, the national projections would have indicated that 82 million individuals were exposed to levels at or above 0.5 µg/L. This population represents an increase of about 70 million individuals over the estimate used here that assumes the supplies do not have contamination at the maximum quantifiable level but rather at a level less than 0.5 µg/L. Note, however, that no change occurs in the estimated population exposed to levels exceeding 5 µg/L.

4.4.6 Conclusion

1,2-Dichloroethane is used primarily to manufacture other organic compounds. Ninety-eight percent of the 1,2-dichloroethane produced in the U.S. is used to make vinyl chloride. Most 1,2-dichloroethane produced in the United States is used captively by the manufacturers. Data from the 1990s indicates that production is increasing, with almost 17 billion pounds of 1,2-dichloroethane being produced in 1994. 1,2-Dichloroethane is also a TRI chemical. Industrial releases of 1,2-dichloroethane have been reported from 1988-1999 in 37 States and Puerto Rico. 1,2-Dichloroethane was an analyte for the NAWQA and NURP ambient occurrence studies. In the NAWQA study, 1,2-dichloroethane was detected in 2.0% of urban wells and 0.71% of rural wells, with median detection values of 0.5 µg/L and 0.55 µg/L, respectively. In the Stage 2 analysis of 16-State occurrence of 1,2-dichloroethane, 0.00479% of combined ground water and surface water systems serving 0.000331% of the population exceeded the MCL of 0.005 mg/L. Nationally, 3 ground water and/or surface water systems (serving approximately 700 people) are estimated to have levels greater than the MCL.

The 16-State cross-section was designed to be nationally representative based upon VOC, SOC, and IOC pollution potentials as suggested by considerations of manufacturing, agriculture, and geographic diversity factors. Nationally, 1,2-dichloroethane is manufactured and/or produced in 21 States and has TRI releases in 37 States. 1,2-dichloroethane is manufactured and/or processed in 10 out of the 16 cross-section States and has TRI releases in 11 of the 16 cross-section States. The cross-section should adequately represent occurrence of 1,2-dichloroethane on a national scale based upon the use, production, and release patterns in the 16-State cross-section in relation to the patterns observed for all 50 States.

4.4.7 References

Agency for Toxic Substances and Disease Registry (ATSDR). 1999. *Toxicological Profile for 1,2-Dichloroethane*. U.S. Department of Health and Human Services, Public Health Service. 239 pp. + Appendices. Available on the Internet at http://www.atsdr.cdc.gov/toxprofiles/tp38.pdf

Anonymous. 1998. Chemical profile: Ethylene dichloride. Chem Mark Rep. February 16, 1998.

Brass, H.J., M.A. Feige, T. Halloran, J.W. Mello, D. Munch, and R.F. Thomas. 1977. The National Organic Monitoring Survey: A sampling and analysis for purgeable organic compounds. *Drinking water quality enhancement through source protection.* R.B. Pojasek (ed.). Ann Arbor, MI: Ann Arbor Science, pp. 393-416.

Brass, H.J. 1981. Rural Water Survey organics data. Memorandum of March 17, 1981 to Hugh Hanson, Chief, Science and Technology Branch, Office of Drinking Water, and David Schnare, Office of Drinking Water, USEPA, Washington, DC.

JRB Associates. 1983. *Occurrence of 1,2-Dichloroethane in Drinking Water Food and Air*. Draft report submitted to EPA for review November 18, 1983.

Kuzmack, A.M. 1983. Memorandum: Characterization of the water supply industry (FY82). Washington, D.C.: Office of Water, USEPA. May 16, 1983.

Lopes, T.J. and S.G. Dionne. 1998. *A Review of Semivolatile and Volatile Organic Compounds in Highway Runoff and Urban Stormwater*. U.S. Geological Survey Open-File Report 98-409. 67 pp.

Mello, Wayne. 1983. Personal communication between Wayne Mello, Technical Support Division, Office of Drinking Water, USEPA, and author of JRB Associates, 1983, March 10, 1983.

Squillace, P.J., M.J. Moran, W.W. Lapham, C.V. Price, R.M. Clawges, and J.S. Zogorski. 1999. Volatile organic compounds in untreated ambient groundwater of the United States, 1985-1995. *Env. Sci. and Tech*. 33(23):4176-4187.

Symons, J.M., T.A. Bellar, J.K. Carswell, et al. 1975. National Organics Reconnaissance Survey for Halogrenated Organics. *Journal of the American Water Works Association*. 667(11): 634-647.

USEPA. 2000. *TRI Explorer: Trends*. Available on the Internet at: http://www.epa.gov/triexplorer/trends.htm, last updated May 5, 2000.

USEPA. 2002. *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT*. EPA Report/815-D-02-005, Office of Water, 55 pp.

Westrick, J.J., J.W. Mello, and R.F. Thomas. 1983. *The Ground Water Supply Survey summary of volatile organic contaminant occurrence data.* EPA Technical Support Division, Office of Drinking Water, Cincinnati, Ohio.

4.5 1,1-Dichloroethylene

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Tables and Figures

4.5.1 Introduction, Use and Production

1,1-Dichloroethylene (chemical formula $C_2H_2Cl_2$) is a man-made chemical known that is never found naturally in the environment. It is a colorless liquid that evaporates quickly at room temperature, has a mild sweet smell, and burns quickly. 1,1-Dichloroethylene can be found in landfills as the result of the breakdown of polyvinylidene chloride products. Its major routes of entry to drinking water are a consequence of industrial activity. Quantities of 1,1-dichloroethylene in water may result from industrial discharge, atmospheric fallout, or the release of quantities remaining as impurities in products (JRB Associates, 1983). Other names for 1,1-dichloroethylene include vinylidene chloride, 1,1-dichloroethene, and DCE.

Although 1,1-dichloroethylene is manufactured in large quantities, most of it is used to make other substances or products such as polyvinylidene chloride (ATSDR, 1994). Single molecules of 1,1-dichloroethylene are used in the production of polyvinylidene chloride copolymers and as intermediates for captive organic chemical synthesis and (ATSDR, 1994). Ninety-six percent of the 1,1-dichloroethylene produced is used in the production of copolymers with vinyl chloride or acrylonitrile (USEPA, 2001). The polymers, which have been commercially important since their introduction in the early 1940s, are used extensively in many types of flexible packing materials, as flame retardant coatings for fiber and carpet backing, and in piping, coating for steel pipes, and adhesive applications. The major application of polyvinylidene chloride copolymers is the production of flexible films for food packaging (SARAN and VELON wraps). At one time, SARAN wrap was found to contain up to 30 parts per million (ppm) 1,1-dichloroethylene. Currently, the plastic packaging films can contain no more than 10 ppm 1,1-dichloroethylene (ATSDR, 1994).

The two major producers of 1,1-dichloroethylene are Dow Chemical and Pittsburgh Paint and Glass (PPG) Industries. Production capacity in 1977 was 270 million pounds/year, but by 1985, production capacity had declined to 178 million pounds/year. In 1989, production was estimated at 230 million pounds (ATSDR, 1994).

Table 4.5-1 shows the number of facilities in each State that manufacture or process 1,1-dichloroethylene, the activities and uses of the product, and the range of maximum amounts on site derived from the Toxics Release Inventory (TRI) of EPA (ATSDR, 1994).

Table 4.5-1: Facilities that Manufacture or Process 1,1-Dichloroethylene[a]

Facility	Location[b]	Range of maximum amounts on site in	Activities and uses
3M	Decatur, AL	1,000-9,999	As a reactant
Monsanto Co. Chemical	Decatur, AL	100,000-999,999	As a reactant
Eastman Kodak Co.	Windsor, CO	1,000-9,999	As a reactant
Dow Chemical Dalton Site	Dalton, GA	0-99	As a reactant
Morton International Inc.	Ringwood, IL	1,000,000-9,999,999	As a reactant
BF Goodrich Co. Louisville	Louisville, KY	10,000-99,999	As a reactant
W.R. Grace & Co.	Owensboro, KY	100,000-999,999	As a reactant
Marine Shale Processors Inc.	Amelia, LA	10,000-99,999	As a reactant
Vulcan Materials Co. Chemical Div.	Geismar, LA	10,000-99,999	Produce; as a byproduct; as an impurity; as a reactant
Dow Chemical Co. Louisiana	Plaquemine, LA	1,000-9,999	Produce; as a byproduct; as a reactant; in ancillary or
PPG Industries Inc.	Westlake, LA	10,000,000-49,999,999	Produce; for sale/distribution; as a byproduct; as an
Dow Chemical USA Midland	Midland, MI	10,000,000-49,999,999	As a reactant; in ancillary or other uses
Rhone-Poulenc Inc. Walsh	Gastonia, NC	10,000-99,999	As a reactant
Allied-Signal Inc. Elizabeth	Elizabeth, NJ	10,000-99,999	As a reactant

Facility	Location[b]	Range of maximum amounts on site in	Activities and uses
Du Pont Parlin Plant	Parlin, NJ	1,000-9,999	As a reactant
Allied Signal Inc.	Buffalo, NY	10,000,000-49,999,999	As a reactant
Eastman Kodak Co. Kodak	Rochester, NY	1,000-9,999	As a reactant
Gencorp Polymer Products	Mogadore, OH	100,000-999,999	As a reactant
Occidental Chemical Corp. VCM Plant	Deer Park, TX	10,000-99,999	Produce; as a byproduct
Dow Chemical Co. Texas Operations	Freeport, TX	1,000,000-9,999,999	Produce; for sale/distribution; as a byproduct; as an impurity; in repackaging; as a processing aid; in
Occidental Chemical Co. Corpus Christi Plant	Gregory, TX	100-999	Produce; as a byproduct
Hercules Inc.	Covington, VA	100,000-999,999	As a reactant
Arco Chemical Co.	South Charleston,	100,000-999,999	As a reactant

[a] Derived from TRI91 (1993)
[b] Post Office State abbreviations used

Source: ATSDR, 1993 compilation of TRI91 1993 data

4.5.2 Environmental Release

1,1-Dichloroethylene is listed as a Toxics Release Inventory (TRI) chemical (as vinylidene chloride). Table 4.5-2 illustrates the environmental releases for 1,1-dichloroethylene from 1988 - 1999 (1,1-dichloroethylene data are only available for these years). Air emissions constitute most of the on-site releases, with a downward trend in emissions. The decrease in air emissions has contributed to decreases in 1,1-dichloroethylene total on- and off-site releases in recent years. Releases to land (such as spills or leaks within the boundaries of the reporting facility) decreased significantly from 1988-1991, and they have been at or near zero from 1994-1999. Releases from surface water discharges and underground injection have fluctuated over the years with no discernable trends; also, underground injections data are incomplete because they were not monitored from 1991-1996. Since 1989, off-site releases (including metals or metal compounds transferred off-site) have fluctuated, from zero to over 6,000 pounds, with no apparent trend. These TRI data for 1,1-dichloroethylene were reported from 19 States and Puerto Rico, with 11 States reporting every year (USEPA, 2000). Of the 19 States that reported, 10 are included in the 16 State cross-section (used for analyses of 1,1-dichloroethylene occurrence in drinking water; see Section 4.5.4). (For a map of the 16-State cross-section, see Figure 1.3-1.)

Table 4.5-2: Environmental Releases (in pounds) for 1,1-Dichloroethylene in the United States, 1988-1999

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1999	155,891	132	99	0	8	156,130
1998	179,391	311	218	0	3	179,923
1997	199,243	662	323	--	104	200,332
1996	192,815	466	--	1	33	193,315
1995	193,550	642	--	0	260	194,452
1994	165,743	215	--	0	2,031	167,989
1993	204,814	192	--	20	1	205,027
1992	253,920	1,306	--	14	0	255,240

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1991	287,640	794	--	15	7	288,456
1990	305,686	251	150	463	12	306,562
1989	222,738	2,691	720	540	6,307	232,996
1988	296,353	3,462	170	429	44,281	344,695

Source: USEPA, 2000

4.5.3 Ambient Occurrence

The local, State, and federal data set compiled by NAWQA reports that 1,1-dichloroethylene was detected in 12 out of 397 urban wells (3.0%). The minimum and maximum concentrations detected were 0.2 µg/L and 11 µg/L, respectively. The median value of detection concentrations was 0.9 µg/L. 1,1-Dichloroethylene was also detected in 7 of the 2,414 rural wells (0.29%) analyzed The minimum and maximum concentrations detected were 0.4 µg/L and 39 µg/L, respectively. The median value of detection concentrations was 1.0 µg/L. These data (urban and rural) represent untreated ambient ground water of the conterminous United States for the years 1985-1995 (Squillace et al., 1999).

1,1-Dichloroethylene was also an analyte in the NURP data. The NURP study found 1,1-dichloroethylene in urban runoff (Lopes and Dionne, 1998). The minimum and maximum concentrations detected were 1.5 µg/L and 4 µg/L, respectively, with no mean value reported. The use of the land from which the samples were taken was unspecified.

4.5.3.1 Additional Ambient Occurrence Data

A summary document entitled "Occurrence of 1,1-Dichloroethylene in Drinking Water, Food, and Air" (JRB Associates, 1983), was previously prepared for past USEPA assessments of 1,1-dichloroethylene. However, no information on the ambient occurrence of 1,1-dichloroethylene was included in that document. (The document did include information regarding 1,1-dichloroethylene occurrence in drinking water, which is discussed in Section 4.5.5 of this report.)

4.5.4 Drinking Water Occurrence Based on the 16-State Cross-Section

The analysis of 1,1-dichloroethylene occurrence presented in the following section is based on State compliance monitoring data from the 16 cross-section States. The 16-State cross-section is the largest and most comprehensive compliance monitoring data set compiled by EPA to date. These data were evaluated relative to several concentration thresholds of interest: 0.007 mg/L; 0.005 mg/L; 0.001 mg/L; and 0.0005 mg/L.

All sixteen cross-section State data sets contained occurrence data for 1,1-dichloroethylene. These data represent more than 146,000 analytical results from approximately 19,000 PWSs during the period from 1984 to 1998 (with most analytical results from 1992 to 1997). The number of sample results and PWSs vary by State, although the State data sets have been reviewed and checked to ensure adequacy of coverage and completeness. The overall modal detection limit for 1,1-dichloroethylene in the 16 cross-section States is equal to 0.0005 mg/L. (For details regarding the 16-State cross-section, please refer to Section 1.3.5 of this report.)

4.5.4.1 Stage 1 Analysis Occurrence Findings

Table 4.5-3 illustrates the occurrence of 1,1-dichloroethylene in drinking water for the public water systems in the 16-State cross-section. Based on the 16-State cross-section data, 0.236% of ground water or surface water PWSs (45 systems) had analytical results of 1,1-dichloroethylene exceeding the MCL (0.007 mg/L). Approximately 0.309% of PWSs (59 systems) had at least one analytical result greater than 0.005 mg/L. The percentage of PWSs with results greater than 0.001 mg/L was equal to 0.869% (166 systems). Approximately 1.18% of PWSs (225 systems) in the 16 States had at least one analytical result greater than 0.0005 mg/L.

Less than 1% of ground water systems had analytical results greater than any of the four thresholds. Approximately 0.211% of ground water systems (37 systems) had results exceeding the MCL. The percentage of ground water systems in the 16 States with at least one analytical result greater than 0.005 mg/L was equal to 0.273% (48 systems). Approximately 0.819% of ground water systems (144 systems), and 0.944% of ground water systems (166 systems) had any analytical results exceeding 0.001 mg/L, and 0.0005 mg/L, respectively.

For surface water PWSs, 0.525% (8 systems) had analytical results exceeding 0.007 mg/L. Approximately 0.721% of surface water systems (11 systems) had results exceeding 0.005 mg/L. The percentage of surface water systems with at least one analytical result greater than 0.001 mg/L was equal to 1.44% (22 systems). Approximately 1.90% of surface water systems (29 systems) had analytical results of 1,1-dichloroethylene 0.0005 mg/L.

Table 4.5-3: Stage 1 1,1-Dichloroethylene Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Ground Water	0.007	0.211%	37
	0.005	0.273%	48
	0.001	0.819%	144
	0.0005	0.944%	166
Surface Water	0.007	0.525%	8
	0.005	0.721%	11
	0.001	1.44%	22
	0.0005	1.90%	29
Combined Ground & Surface Water	0.007	0.236%	45
	0.005	0.309%	59
	0.001	0.869%	166
	0.0005	1.18%	225

Reviewing 1,1-dichloroethylene occurrence in the 16 cross-section States by PWS population served (Table 4.5-4) shows that approximately 8.69% of the population (almost 9.3 million people) was served by PWSs with analytical detections of 1,1-dichloroethylene greater than the MCL (0.007 mg/L). Approximately 9.44% of the population (over 10 million people) was served by PWSs with at least one analytical result greater than 0.005 mg/L. The percentage of population served by systems with results greater than 0.001 mg/L was equal to 12.8% (about 13.6 million people). Approximately 14.4% of the population (about 15.3 million people) was exposed to levels of 1,1-dichloroethylene greater than 0.0005 mg/l.

A much greater proportion of population was served by surface water systems with threshold exceedances, as compared to ground water systems with threshold exceedances. The percentage of population served by ground water systems and surface water systems with analytical detections of 1,1-dichloroethylene greater than the MCL was equal to 2.53% (almost 1.2 million people), and 13.3% (over 8 million people), respectively. Relative to 0.005 mg/L, 3.42% of the ground water population (over 1.5 million people) was served by systems exceeding that limit, whereas 13.9% of the surface water population (approximately 8.5 million people) was served by systems exceeding 0.005 mg/L. In addition, 7.75% of the population was served by ground water systems with results that exceeded 0.001 mg/L, while 16.5% of the population was served by surface water systems with results exceeding 0.001 mg/L. Approximately 9.30% of the population served by ground water systems was exposed to levels of 1,1-dichloroethylene greater than 0.0005 mg/L, compared to 18.2% of the population served by surface water systems exposed to levels greater than 0.0005 mg/L.

Table 4.5-4: Stage 1 1,1-Dichloroethylene Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Ground Water	0.007	2.53%	1,152,600
	0.005	3.42%	1,556,600
	0.001	7.75%	3,528,900
	0.0005	9.30%	4,237,200
Surface Water	0.007	13.3%	8,114,700
	0.005	13.9%	8,506,200
	0.001	16.5%	10,088,600
	0.0005	18.2%	11,098,300
Combined Ground & Surface Water	0.007	8.69%	9,267,400
	0.005	9.44%	10,062,800
	0.001	12.8%	13,617,500
	0.0005	14.4%	15,335,500

4.5.4.2 Stage 2 Analysis Occurrence Findings

The Stage 2 occurrence findings, based on the cross-section data, are presented in Tables 4.5-5 and 4.5-6. The statistically generated best estimate values, as well as the ranges around the best estimate value, are presented. (For a review of the Stage 2 analytical approach, please refer to Section 1.4 of this report. For complete details regarding the Stage 2 analyses, please refer to *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT* (USEPA, 2002)).

Seventeen (0.0911% of) systems nationally were estimated to have a mean concentration greater than 0.007 mg/L. Twenty-one (0.111% of) systems nationally were estimated to exceed a mean concentration of 0.005 mg/L. Approximately 67 (0.350% of) systems were estimated to exceed 0.001 mg/L, while 118 (0.616% of) systems had estimated mean concentrations exceeding 0.0005 mg/L.

Approximately 15 (0.0875% of) ground water systems had estimated mean concentrations of 1,1-dichloroethylene greater than 0.007 mg/L. An estimated 19 (0.109% of) ground water systems had estimated mean concentrations greater than 0.005 mg/L. Approximately 62 (0.351% of) ground water systems and 108 (0.613% of) ground water systems had estimated mean concentrations exceeding 0.001 mg/L and 0.0005 mg/L, respectively.

Only 2 (0.132% of) surface water systems in the 16 States was estimated to have a mean concentration greater than 0.007 mg/L. Two (0.134% of) surface water systems had an estimated mean concentration greater than 0.005 mg/L. Approximately 5 (0.329% of) surface water systems had estimated mean concentrations of 1,1-dichloroethylene greater than 0.001 mg/L. Ten (about 0.657% of) surface water systems had estimated mean concentration values greater than 0.0005 mg/L.

Table 4.5-5: Stage 2 Estimated 1,1-Dichloroethylene Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.007	0.0875%	0.0626%-0.120%	15	11 - 21
	0.005	0.1090%	0.0740%-0.148%	19	13 - 26
	0.001	0.351%	0.273%-0.433%	62	48 - 76
	0.0005	0.613%	0.507%-0.723%	108	89 - 127
Surface Water	0.007	0.132%	0.131% - 0.1311%	2	2 - 2
	0.005	0.134%	0.131% - 0.197%	2	2 - 3
	0.001	0.329%	0.262% - 0.459%	5	4 - 7
	0.0005	0.657%	0.459% - 0.92%	10	7 - 14
Combined Ground & Surface Water	0.007	0.0911%	0.0681% - 0.120%	17	13 - 23
	0.005	0.1110%	0.0786% - 0.147%	21	15 - 28

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
	0.001	0.350%	0.272% - 0.424%	67	52 - 81
	0.0005	0.616%	0.513% - 0.717%	118	98 - 137

Reviewing 1,1-dichloroethylene occurrence by PWS population served (Table 4.5-6) shows that approximately 0.331% of population served by all PWSs in the 16 States (an estimate of approximately 352,700 people) was potentially exposed to 1,1-dichloroethylene levels above 0.007 mg/L. Approximately 0.340% of the total population served by PWSs in the 16 States (exposure to an estimated 362,900 people) was exposed to levels of 1,1-dichloroethylene exceeding the limit of 0.005 mg/L, and 0.898% of the population served by PWSs in the 16 States (exposure to an estimated 956,800 people) was potentially exposed to levels exceeding 0.001 mg/L. The percentage of population exposed substantially increased to 8.58% (over 9.1 million people) when evaluated relative to 0.0005 mg/L.

When the ground water PWSs were evaluated relative to a thresholds of 0.007 mg/L, 0.005 mg/L, 0.001 mg/L, and 0.0005 mg/L, the percentages of population exposed in the 16 States were equal to 0.398% (an estimated 181,200 people), 0.417% (an estimated 190,000 people), 0.973% (an estimated 443,000 people), and 2.08% (an estimated 945,000 people), respectively.

The percentage of population served by surface water systems in the 16 States that exceeded the limit of 0.007 mg/L was 0.281% (exposure to an estimated 171,400 people). The percentage that exceeded 0.005 mg/L was 0.283% (exposure to an estimated 172,900 people in the 16 States). Approximately 0.841% of the population served by surface water systems was potentially exposed to 1,1-dichloroethylene levels greater than 0.001 mg/L (exposure to an estimated 513,800 people). The percentage of surface water systems that exceeded the limit of 0.0005 mg/L was 13.4% (exposure to an estimated 8.2 million people in the 16 States).

Table 4.5-6: Stage 2 Estimated 1,1-Dichloroethylene Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.007	0.398%	0.370% - 0.459%	181,200	168,600 - 209,000
	0.005	0.417%	0.385% - 0.479%	190,000	175,400 - 218,300
	0.001	0.973%	0.727% - 1.435%	443,000	331,100 - 653,900
	0.0005	2.08%	1.593% - 2.68%	945,000	725,900 - 1,222,200
Surface Water	0.007	0.281%	0.280% - 0.280%	171,400	171,700 - 171,700
	0.005	0.283%	0.280% - 0.291%	172,900	171,700 - 178,300
	0.001	0.841%	0.611% - 1.762%	513,800	374,400 - 1,079,100

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
	0.0005	13.4%	13.0% - 14.5%	8,195,300	7,986,100 - 8,861,900
Combined Ground & Surface Water	0.007	0.331%	0.319%-0.357%	352,700	340,400 - 381,100
	0.005	0.340%	0.325%-0.380%	362,900	347,200 - 405,500
	0.001	0.898%	0.673%-1.326%	956,800	719,000 - 1,416,300
	0.0005	8.58%	8.24%-9.19%	9,141,600	8,797,000 - 9,811,700

4.5.4.3 Estimated National Occurrence

Based on the Stage 2 estimated percent of systems (and population served by systems) exceeding each threshold, an estimated 59 PWSs nationally serving approximately 704,600 people could be exposed to 1,1-dichloroethylene concentrations above 0.007 mg/L. About 72 systems serving almost 725,100 people had estimated mean concentrations greater than 0.005 mg/L. Approximately 227 systems serving over 1.9 million people nationally were estimated to have mean 1,1-dichloroethylene concentrations greater than 0.001 mg/L. A total of 401 systems serving over 18 million people had estimated mean concentrations greater than 0.0005 mg/L. (See Section 1.4 for a description of how Stage 2 16-State estimates are extrapolated to national values.)

For ground water systems, an estimated 52 PWSs serving about 341,000 people nationally had mean concentrations greater than 0.007 mg/L. Approximately 65 systems serving about 357,500 people nationally had estimated mean concentration values that exceeded 0.005 mg/L. About 209 ground water systems serving almost 833,500 people had estimated mean concentrations greater than 0.001 mg/L. An estimated 364 ground water PWSs nationally exposed over 1.7 million people to concentrations of 1,1-dichloroethylene greater than 0.0005 mg/L.

Approximately 1 surface water system serving 357,400 people was estimated to have a mean concentration of 1,1-dichloroethylene above 0.007 mg/L. About 7 surface water systems serving 360,500 people had estimated mean concentrations greater than 0.005 mg/L. An estimated 18 surface water systems serving approximately 1.1 million people had mean concentrations greater than 0.001 mg/L. Approximately 73 surface water PWSs serving over 17 million people had estimated mean concentrations of 1,1-dichloroethylene greater than 0.0005 mg/L.

Table 4.5-7: Estimated National 1,1-Dichloroethylene Occurrence - Systems and Population Served

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.007	52	37 - 71	341,000	317,100 - 392,900
	0.005	65	44 - 88	357,500	329,800 - 410,500

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
	0.001	209	162 - 257	833,500	622,600 - 1,229,500
	0.0005	364	301 - 430	1,777,900	1,364,900 - 2,298,000
Surface Water	0.007	1	7 - 7	357,400	357,000 - 357,000
	0.005	7	7 - 11	360,500	357,000 - 370,600
	0.001	18	15 - 26	1,071,200	778,500 - 2,243,500
	0.0005	37	26 - 51	17,087,200	16,603,400 - 18,424,100
Combined Ground & Surface Water	0.007	59	44 - 78	704,600	678,900 - 760,000
	0.005	72	51 - 95	725,100	692,500 - 808,600
	0.001	227	177 - 276	1,911,700	1,433,800 - 2,824,500
	0.0005	401	334 - 467	18,265,500	17,543,400 - 19,566,900

4.5.5 Additional Drinking Water Occurrence Data

Several additional data sources regarding the occurrence of 1,1-dichloroethylene in drinking water are also reviewed. Previously compiled occurrence information, from an OGWDW summary document entitled “Occurrence of 1,1-Dichloroethylene in Drinking Water, Food, and Air” (JRB Associates, 1983), is presented in the following section. This variety of studies and information are presented regarding levels of 1,1-dichloroethylene in drinking water, with the scope of the reviewed studies ranging from national to regional. Note that none of the studies presented in the following section provide the quantitative analytical results or comprehensive coverage that would enable direct comparison to the occurrence findings estimated with the cross-section occurrence data presented in Section 4.5.4. These additional studies, however, do enable a broader assessment of the Stage 2 occurrence estimates presented for this Six-Year Review. All the following information in Section 4.5.5 is taken directly from “Occurrence of 1,1-Dichloroethylene in Drinking Water, Food, and Air” (JRB Associates, 1983).

JRB Associates (1983) found two major types of data available that are potentially useful for describing the occurrence of 1,1-dichloroethylene in the nation's public drinking water supplies. First, there are several Federal surveys in which a number of public water supplies from throughout the U.S. were selected for analysis of chemical contamination, including 1,1-dichloroethylene. Second, data are available from State surveys and from State investigations of specific incidents of known or suspected contamination of a supply. For accomplishing the basic objectives of this study, namely to estimate the number of public water supplies nationally within the various source and size categories contaminated with 1,1-dichloroethylene, the distribution of 1,1-dichloroethylene concentrations in those supplies, and the number of individuals exposed to those concentrations, it was determined that the Federal survey data provides the most suitable data base. The State data tend to be poorly described with respect to the source and size categories of the supplies examined and the sampling and analysis methods used for determining contaminant levels. The lack of source and system size information precludes using the data for estimating levels in public water supplies of similar characteristics. The absence of details on sampling and analysis methods precludes evaluating those data for their qualitative and quantitative reliability. Also, because much of the State data are from investigations in response to incidents of known or suspected contamination (e.g., spills), they were judged to be not representative of contaminant levels in the nation's water supplies in general. Although they are not used with the Federal data for the purpose of estimating contamination levels nationally, the available State data are presented here to provide some additional perspective on 1,1-dichloroethylene occurrence in drinking water.

Data are presented only on drinking water samples taken from a consumer's tap (i.e., distribution water samples) or on treated water samples taken at the water supply (i.e., finished water samples) because these are considered to be most representative of the water consumed by the public. No data on raw (i.e., untreated) water are presented. It is recognized that for some groundwater supplies where no treatment of the water occurs, samples identified as raw may be representative of water consumed by the users of the supply. However, it was generally not possible to differentiate between those groundwater supplies that do and those that do not treat raw water from the available survey data

4.5.5.1 Overview and Quality Assurance Assessment of Federal Drinking Water Surveys

Two Federal drinking water surveys provide data on 1,1-dichloroethylene: the National Screening Program for Organics in Drinking Water (NSP) and the Groundwater Supply Survey (GWSS). The terms used in this report are those used in the individual surveys, recognizing that they may not always correspond to strict technical definitions.

The National Screening Program for Organics in Drinking Water (NSP), conducted by SRI International from June 1977 to March 1981, examined both raw and finished drinking water samples from 166 water systems in 33 States for 51 organic chemical contaminants. Data are available for 1,1-dichloroethylene on finished water samples from 12 groundwater and 103 surface water supplies.

The Groundwater Supply Survey (GWSS) was conducted from December 1980 to December 1981 to develop additional data on the occurrence of volatile organic chemicals in the nation's groundwater supplies (Westrick et al. 1983, as cited in JRB Associates, 1983). It was hoped that this study would stimulate State efforts toward the detection and control of groundwater contamination and the identification of potential chemical “hot spots.” A total of 945 systems were sampled, of which 466 were chosen at random. The remaining 479 systems were chosen nonrandomly based on information from States encouraged to identify locations believed to have a higher than normal probability of VOC contamination (e.g., locations near landfills or industrial activity). The file provided a single analytical result for each supply sampled. One sample of finished water was collected from each supply at a point near the entrance to the distribution system.

Each of the drinking water surveys was evaluated with respect to the validity of the reported occurrence data for a number of organic chemicals, including 1,1-dichloroethylene. The evaluations were carried out by analyzing information about the procedures used for collection and analysis of samples as well as the quality control protocols used. The analyzed compounds dealt with in each study were assigned one of three possible ratings: quantitatively acceptable, qualitatively acceptable (i.e., the substance measured was 1,1-dichloroethylene), and totally unacceptable. In the case of 1,1-dichloroethylene, a qualitatively acceptable rating was given for data from the NSP because of suspected biodegradation of the samples, which were held unrefrigerated for prolonged periods before analysis. 1,1-Dichloroethylene values in excess of the quantitation limit reported for some samples in these studies are qualitatively valid and can be taken as minimum values, representative of samples which probably originally contained 1,1-dichloroethylene at higher concentrations. In the case of the GWSS, all data were rated both quantitatively and qualitatively acceptable.

4.5.5.2 Groundwater – Federal Surveys

The National Screening Program for Organics in Drinking Water (NSP) and the Groundwater Supply Survey (GWSS) both contain data concerning the levels of 1,1-dichloroethylene in groundwater supplies from across the country.

Twelve groundwater supplies were tested for ,1,1-dichloroethylene contamination in the NSP. Of these 12 systems, only one was found to be contaminated with 1,1-dichloroethylene at a level of 0.2 µg/L. The quantification limit for 1,1-dichloroethylene was 0.1 µg/L.

In the GWSS, 9 of the 456 randomly chosen water systems serving 25 or more individuals were contaminated with 1,1-dichloroethylene, at concentrations ranging from 0.22-6.3 µg/L. The three systems with the highest values were contaminated at 2.1, 2.2, and 6.3 µg/L. Of the 9 positive systems, 5 were from systems serving populations in excess of 10,000 people. The average for all randomly chosen systems was 1.4 µg/L with a standard deviation of 2.0 µg/L; the median was 0.28 µg/L. Of the 473 nonrandom locations sampled serving 25 or more individuals, 15 were contaminated with 1,1-dichloroethylene, at concentrations between 0.22-3 µg/L, the highest values being 0.04, 1.2, and 3 µg/L. Of the 15 positive samples, 10 were from systems serving populations in excess of 10,000 people. The average 1,1-dichloroethylene level for the nonrandom systems was 0.59 µg/L with a standard deviation of 0.71 µg/L; the median value was 0.35 µg/L. The minimum quantitation limit for 1,1-dichloroethylene was 0.2 µg/L.

4.5.5.3 Groundwater – State Data

Three States (California, Massachusetts, and New Jersey) provided the USEPA with information concerning 1,1-dichloroethylene contamination in groundwater supplies. Analytical results for samples from three locations in California ranged from undetectable to 50 µg/L.
1,1-Dichloroethylene levels ranged from undetectable to 261 µg/L in 22 samples from six Massachusetts cities. New Jersey provided data from 19 samples from Fair Lawn and Mahwah; 12 of the samples contained undetectable 1,1-dichloroethylene while the other seven samples ranged from 2.7-3.5 µg/L at Mahwah and 0.9-27 µg/L at Fair Lawn.

4.5.5.4 Surface Water – Federal Surveys

Only one federal survey, the National Screening Program (NSP), contains data concerning 1,1-dichloroethylene levels in surface water supplies. During this survey, 106 drinking water systems were analyzed for 1,1-dichloroethylene between June 1977 and March 1981. Of these, two systems contained detectable levels of 1,1-dichloroethylene, with concentrations of 0.2 and 0.51 µg/L.

4.5.5.5 Surface Water – State Data

Data from two surface water samples were reported from Niagara Falls, New York. Of the two finished water samples, one contained no detectable 1,1-dichloroethylene. The other sample was contaminated with 1,1-dichloroethylene at 0.22 µg/L.

4.5.5.6 Projected National Occurrence of 1,1-Dichloroethylene in Public Water Supplies

As reported by the JRB Associates (1983) report, public water systems fall into two major categories with respect to water source (surface water and groundwater) and into five size categories and twelve subcategories according to the number of individuals served. The JRB Associates (1983) report presented estimates of both the number of drinking water supplies nationally within each of the source/size categories expected to have 1,1-dichloroethylene present, and of the concentration of 1,1-dichloroethylene expected to be present in those supplies.

The key features of the methodology used and assumptions made to develop the national estimates are summarized here. The estimates are based on the data from the Federal surveys only. The State data were not included for several reasons. Generally, these data are from a few States and were not considered to be geographically representative. There was also a general lack of data on the population served by systems measured, the type of water sampled, and the methodologies used to sample, identify, and measure 1,1-dichloroethylene.

The Federal survey data from the NSP and GWSS were pooled together for developing the national projections. It was assumed in combining these surveys that the resulting data base would be representative of the nation's water supplies. In the case of the GWSS data, both the random and nonrandom samples were included in the projections because a statistical test of the GWSS data showed no statistically significant difference in the frequency of occurrence of positive values or the mean of the positive values of vinyl chloride between the random and nonrandom samples.

Ideally, adequate survey data would be available to develop the national projections separately for each of the twelve system size categories within the groundwater and surface water groups; however, the available data were too limited for this. JRB (1983) consolidated some of the size categories to have sufficient data for developing the projections. In consolidating data from various size categories, consideration was given to the potential for there being statistically significant differences in the frequency of occurrence of 1,1-dichloroethylene as a function of system size. The consolidation of size categories therefore involved a balancing of the need to group size categories together to have an adequate data base for developing the national projections against the need to treat size categories separately in order to preserve the influence of system size as a determinant of contamination potential. The consolidation of size categories also took into account EPA's classification of systems into the five major groups as very small (25-500), small (501-3,300), medium (3,301-10,000), large (10,001-100,000), and very large (> 100,000) (Kuzmack, 1983, as cited in JRB Associates, 1983).

Once the data were consolidated, statistical models for extrapolating to the national level were tested and an appropriate model selected. In the case of 1,1-dichloroethylene, the multinominal method was used. The frequency of contamination of groundwater and surface water systems at various concentrations was determined for each consolidated size category. For completing the national estimates, it was assumed that the frequency of contamination observed for each consolidated category was directly applicable to each of the system sizes comprising it.

In the JRB Associates (1983) report, it is noted that some of the data used in computing the national estimates are from samples held for a prolonged period of time prior to analysis, with possible biodegradation of 1,1-dichloroethylene. Therefore, these projections of national occurrence may underestimate actual contaminant levels.

4.5.5.6.1 Groundwater Supplies

JRB Associates (1983) reported data that were available for a total of 938 supplies from the combined surveys. Of these, 25 supplies were reported to have 1,1-dichloroethylene present, at concentrations ranging from 0.2 µg/L to 6.3 µg/L. Based on the overall distribution of positive values and maximum possible values for those supplies in which 1,1-dichloroethylene was not found, 0.2 µg/L was selected as the common minimum quantifiable concentration for the combined survey data. That is, quantitative projections are made of supplies at several concentration ranges > 0.2 µg/L, while only a total number for supplies expected to have either no 1,1-dichloroethylene or levels below 0.2 µg/L can be determined.

When the twelve size categories were consolidated into the five major EPA groupings, there was an apparent trend in the frequency of values > 0.2 µg/L as a function of size:

Very small	0.9%	(2/230)
Small	2.0%	(4/203)
Medium	2.6%	(4/154)
Large	4.5%	(14/312)
Very large	2.6%	(1/39)
Overall	2.7%	(25/938)

A test for statistical significance revealed that at the $\alpha = 0.05$ level, the difference among the very small, small, and medium categories was not significant; nor was the difference between the large and very large size categories. However, the combined very small, small, and medium categories and the combined large and very large categories were found to be different. Therefore, two consolidated categories were selected for developing the national estimates:

Very small/small/medium (25-10,000)
Large/very large (> 10,000)

As noted previously, the frequency of occurrence of 1,1-dichloroethylene at various concentrations was determined for the two consolidated groups and then applied to the number of supplies nationally within each of the size categories comprising each group.

Approximately 1.8% of the total groundwater supplies in the United States (858 supplies, with a range of 366-1,349), are expected to have 1,1-dichloroethylene at levels of > 0.2 µg/L; the remaining 47,600 supplies have either no 1,1-dichloroethylene or levels < 0.2 µg/L. It is estimated that 81 supplies (range of 0-237) are expected to have 1,1-dichloroethylene levels > 5 µg/L; while no supplies are expected to have levels > 10 µg/L. Most of the supplies with 1,1-dichloroethylene levels > 0.2 µg/L are expected to be in the smaller size categories. Although, as noted previously, the frequency of 1,1-dichloroethylene occurrence appears to increase with increasing system size, the number of systems affected nationally is greater for the small sizes because there are many more small systems in existence.

4.5.5.6.2 Surface Water Systems

Data are available for a total of 103 surface water supplies. Of these, 2 supplies were reported by JRB Associates (1983) to have 1,1-dichloroethylene present at concentrations of 0.2 µg/L and 0.5 µg/L. All but one of the 103 surface water supplies sampled in the NSP fall in the large and very large size categories (i.e., serving > 10,000 people). Consequently, it was not possible to evaluate the frequency of occurrence of 1,1-dichloroethylene as a function of system size for the very small, small, and medium size categories. In the large size category (serving 10,001-100,000), none of the 19 supplies were found to have 1,1-dichloroethylene present, while 2 of 83 in the very large category (serving > 100,000) had 1,1-dichloroethylene present. The difference in the frequency of occurrence between the large and very large groups was not statistically significant at the $\alpha = 0.05$ level. For the purpose of the national estimates, the groundwater supplies were consolidated into two groups:

Very small/small/medium (25-10,000)
Large/very large (> 10,000)

Again, the frequency of occurrence of 1,1-dichloroethylene at various concentrations was determined for the two consolidated groups and then applied to the number of supplies nationally within each of the size categories comprising each group.

Thirty-five surface water supplies (range of 0-81), approximately 0.3% of the total surface water systems in the United States, are expected to have 1,1-dichloroethylene at levels > 0.2 µg/L; the remaining 11,167 supplies have either no 1,1-dichloroethylene or levels < 0.2 µg/L. It is estimated that no surface water supplies will have levels > 5 µg/L. Note that all of the supplies with levels in the 0.2-5 µg/L range are in the large and very large category. The estimate of no occurrence in the smaller categories is based on only one sample and is probably not a reliable estimate.

4.5.6 Conclusion

1,1-Dichloroethylene does not occur naturally, but it is found as the result of the breakdown of polyvinylidene chloride products in landfills. Virtually all 1,1-dichloroethylene produced is used in the production of copolymers with vinyl chloride or acrylonitrile, and only a small percentage (4%) is used as chemical intermediates. The primary producers of 1,1-dichloroethylene are Dow Chemical and Pittsburgh Paint and Glass (PPG) Industries, and the most recent data available suggests that production is relatively stable. 1,1-Dichloroethylene is also a TRI chemical. Under the TRI program, industrial releases of 1,1-dichloroethylene have been recorded since 1988 in 19 States and Puerto Rico. 1,1-Dichloroethylene was an analyte for the NAWQA and NURP ambient occurrence studies. In the NAWQA study, 1,1-dichloroethylene was detected in 3.0% of urban wells and 0.29% of rural wells, with median detection values of 0.9 µg/L and 1.0 µg/L, respectively. In the Stage 2 analysis of 16-State occurrence of 1,1-dichloroethylene, 0.0144% of combined ground water and surface water systems serving 0.0135% of the population exceeded the MCL of 0.007 mg/L. Nationally, 9 ground water and surface water systems combined (serving approximately 28,800 people) are estimated to have levels greater than the MCL.

The 16-State cross-section was designed to be nationally representative based upon VOC, SOC, and IOC pollution potentials as suggested by considerations of manufacturing, agriculture, and geographic diversity factors. Nationally, 1,1-dichloroethylene is manufactured and/or processed in 14 States and has TRI releases have been reported in 19 States. 1,1-Dichloroethylene is manufactured and/or processed in 6 out of the 16 cross-section States and has TRI releases in 10 of the 16 cross-section States. The cross-section should adequately represent occurrence of 1,1-dichloroethylene on a national scale based upon the use, production, and release patterns of the 16-State cross-section in relation to the patterns observed for all 50 States.

4.5.7 References

Agency for Toxic Substances and Disease Registry (ATSDR). 1994. *Toxicological Profile for 1,1-Dichloroethene*. U.S. Department of Health and Human Services, Public Health Service. 174 pp. + Appendices. Available on the Internet at http://www.atsdr.cdc.gov/toxprofiles/tp39.pdf

JRB Associates. 1983. *Occurrence of 1,1-Dichloroethylene in Drinking Water, Food and Air - DRAFT.* Draft report submitted to EPA for review December 18, 1983.

Kuzmack, A.M. 1983. Memorandum: Characterization of the water supply industry (FY82). Washington, D.C.: Office of Water, USEPA. May 16, 1983.

Lopes, T.J. and S.G. Dionne. 1998. *A Review of Semivolatile and Volatile Organic Compounds in Highway Runoff and Urban Stormwater*. U.S. Geological Survey Open-File Report 98-409. 67 pp.

Squillace, P.J., M.J. Moran, W.W. Lapham, C.V. Price, R.M. Clawges, and J.S. Zogorski. 1999. Volatile organic compounds in untreated ambient groundwater of the United States, 1985-1995. *Env. Sci. and Tech*. 33(23):4176-4187.

USEPA. 2000. *TRI Explorer: Trends*. Available on the Internet at: http://www.epa.gov/triexplorer/trends.htm, last updated May 5, 2000.

USEPA. 2001. *National Primary Drinking Water Regulations - Consumer Factsheet on: 1,1-Dichloroethylene.* Office of Ground Water and Drinking Water, USEPA. Available on the Internet at http://www.epa.gov/safewater/dwh/c-voc/11-dichl.html (Last updated 04/12/2001)

USEPA. 2002. *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT*. EPA Report/815-D-02-005, Office of Water, 55 pp.

Westrick, J.J., J.W. Mello, and R.F. Thomas. 1983. *The Ground Water Supply Survey summary of volatile organic contaminant occurrence data.* EPA Technical Support Division, Office of Drinking Water, Cincinnati, Ohio.

4.6 Dichloromethane

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Tables and Figures

4.6.1 Introduction, Use and Production

Dichloromethane, also known as methylene chloride, has the chemical formula CH_2Cl_2. It is a colorless liquid that has a mild sweet odor, evaporates easily, and does not burn easily. Dichloromethane does not appear to occur naturally in the environment. It is made from methane gas or wood alcohol. Most of the dichloromethane released to the environment results from its use as an end product by various industries and the use of aerosol products and paint removers in the home (ATSDR, 2000).

The breakdown of dichloromethane use is as follows: paint strippers and removers, 25%; propellant in aerosols, 25%; as a process solvent in the manufacture of drugs, pharmaceuticals, and film coatings, 20%; as a metal cleaning and finishing solvent, 10%; in electronics manufacturing, 10%; and as an agent in urethane foam blowing, 10% (ATSDR, 2000). Dichloromethane has been the primary substitute for Chlorofluorocarbon 11 as a flexible polyurethane foam blowing agent (Chemexpo, 2001).

Dichloromethane is also used as a solvent in the production of polycarbonate resins and triacetate fibers, in film processing, in ink formulation, and as an extraction solvent for spice oleoresin, caffeine and hops. It is registered in the U.S. as an insecticide for commodity fumigation of strawberries, citrus fruits, and a variety of grains (NSC, 2001).

Many consumer products may also contain dichloromethane. These include spray shoe polish, water repellant/protectors, spot removers, wood floor and panel cleaners, contact cement, superglue, spray adhesives, adhesive removers, silicone lubricants, specialized electronic cleaners, wood stains, paint thinners, aerosol rust removers, and glass frosting/artificial snow (NSC, 2001). Concerns over health and environmental issues have led to a decrease in use of dichloromethane in some products, such as consumer aerosol products and as a decaffeinator. Its use in hair sprays was banned in 1989 (ATSDR, 2000).

Production of dichloromethane increased steadily through the 1970s and early 1980s, with a peak production volume of about 620 million pounds in 1984. Demand has declined in the years since the early 1980s, primarily because manufacturers have moved towards water-based aerosol systems in anticipation of further regulation of dichloromethane. In 1994, the most recent year for which information is available, production of dichloromethane was 403 million pounds. Dichloromethane is produced in a number of States, and the major manufacturers are Dow Chemical in Freeport, TX and Plaquemine, LA and Vulcan Materials Company in Geismar, LA and Wichita, KS (ATSDR, 2000).

Table 4.6-1 shows the number of facilities in each State that manufacture and process dichloromethane, the intended uses of the product, and the range of maximum amounts derived from the Toxics Release Inventory (TRI) of EPA (ATSDR, 2000).

Table 4.6-1: Dichloromethane Manufacturers and Processors by State

State[a]	Number of facilities	Range of maximum amounts on site in thousands of pounds[b]	Activities and uses[c]
AL	12	100-999,999	1,4,7,8,10,11,12,13
AR	7	1,000-999,999	2,3,7,10,11,12,13
AZ	5	100-999,999	8,10,11,12,13
CA	23	0-9,999,999	2,3,4,8,9,10,11,12,13
CO	4	1,000-999,999	8,10,11,13
CT	8	1,000-99,999	2,3,10,11,12,13
DE	2	10,000-99,999	8,11
FL	12	100-999,999	8,10,11,12,13

State[a]	Number of facilities	Range of maximum amounts on site in thousands of pounds[b]	Activities and uses[c]
GA	18	0-999,999	2,3,8,9,10,11,12,13
IA	10	100-999,999	8,10,11,12,13
IL	23	0-9,999,999	1,2,3,5,7,8,9,10,11,12,13
IN	21	100-9,999,999	1,2,3,5,8,9,10,11,12,13
KS	8	100-999,999	1,2,3,4,8,10,11,12,13
KY	9	100-99,999	1,5,7,8,10,11,13
LA	8	1,000-9,999,999	1,4,5,6,7,8,10,12,13
MA	10	1,000-999,999	2,3,8,9,10,11,12,13
MD	5	1,000-99,999	8,10,12,13
ME	1	1,000-9,999	13
MI	17	100-999,999	1,2,3,4,5,7,8,10,11,12,13
MN	8	100-99,999	2,3,8,11,12,13
MO	13	1,000-999,999	4,8,10,11,12,13
MS	11	100-999,999	1,2,3,8,11,12,13
MT	1	1,000-9,999	12
NC	17	100-999,999	1,2,4,5,7,8,10,11,12,13
NE	3	1,000-999,999	11,13
NH	3	1,000-99,999	8,12,13
NJ	19	0-999,999	1,2,3,4,7,8,9,10,11,12,13
NM	2	1,000-99,999	8,12
NV	3	100-9,999	1,2,3,8,11,13
NY	14	1,000-9,999,999	2,3,4,7,8,9,10,11,12,13
OH	17	100-9,999,999	2,3,7,8,10,11,12,13
OK	9	100-999,999	8,10,11,13
OR	6	1,000-999,999	2,4,8,10,11,12,13
PA	17	1,000-999,999	8,9,10,11,12,13
PR	12	1,000-9,999,999	1,2,5,6,8,9,10,11,12,13
RI	2	10,000-99,999	10,13
SC	14	100-999,999	7,8,10,11,12,13
TN	15	100-9,999,999	8,9,10,11,12,13
TX	27	0-49,999,999	1,2,3,4,5,6,7,8,9,10,11,12,13
UT	6	1,000-999,999	8,10,11,12,13
VA	10	1,000-999,999	8,10,11,12,13
WA	10	0-99,999	1,6,7,10,11,12,13
WI	14	1,000-999,999	1,4,5,8,10,11,12,13
WV	5	0-9,999,999	8,11,13

[a] Post office State abbreviations used
[b] Data in TRI are maximum amounts on site at each facility
[c] Activities/Uses include:

1. Produce
2. Import
3. For on-site use/processing
4. For sale/distribution
5. As a byproduct
6. As an impurity
7. As a reactant
8. As a formulation component
9. As an article component
10. For repackaging only
11. As a chemical processing aid
12. As a manufacturing aid
13. Ancillary or other uses

Source: ATSDR, 2000 compilation of TRI98 2000 data

4.6.2 Environmental Release

Dichloromethane is listed as a Toxics Release Inventory (TRI) chemical. Table 4.6-2 illustrates the environmental releases for dichloromethane from 1988 - 1999. (Dichloromethane data are only available for these years.) Air emissions constitute the vast majority of the on-site releases, with a substantial decrease over the years. Surface water discharges have also generally declined, with a slight upturn since 1997. Underground injection fluctuated between about 1 and 2 million pounds from 1988-1995, and releases have steadily decreased since. Releases to land (such as spills or leaks within the boundaries of the reporting facility) have fluctuated and show no apparent trend. Off-site releases (including metals or metal compounds transferred off-site) have declined from the releases of 1988-1991, and numbers since have remained between about 150,000 and 300,000 pounds. The decrease in air emissions has contributed to a considerable decrease in dichloromethane total on- and off-site releases over the course of monitoring. These TRI data for dichloromethane were reported from 46 States and Puerto Rico. Forty-one States and Puerto Rico reported TRI data every year (USEPA, 2000). Of the 46 States, 15 are included in the 16 State cross-section (used for analyses of dichloromethane occurrence in drinking water; see Section 4.6.4). (For a map of the 16-State cross-section, see Figure 1.3-1.)

Table 4.6-2: Environmental Releases (in pounds) for Dichloromethane in the United States, 1988-1999

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1999	35,556,474	12,056	107,386	8,344	154,374	35,838,634
1998	40,302,462	15,492	456,962	173,592	267,633	41,216,141
1997	48,315,635	9,493	528,030	11,180	230,405	49,094,743
1996	54,143,761	10,064	749,507	4,957	168,475	55,076,764
1995	58,305,923	28,620	1,140,335	2,064	180,137	59,657,079
1994	63,714,204	52,289	960,942	41,645	314,976	65,084,056
1993	65,499,529	62,909	956,098	69,467	144,479	66,732,482
1992	75,011,911	233,786	1,183,867	77,208	209,916	76,716,688
1991	84,224,528	99,220	1,317,706	96,559	502,795	86,240,808
1990	101,000,812	194,764	850,018	21,024	1,001,707	103,068,325
1989	125,604,691	227,025	1,937,469	15,894	1,530,916	129,315,995
1988	129,124,529	349,960	1,478,833	157,156	7,806,328	138,916,806

Source: USEPA, 2000

4.6.3 Ambient Occurrence

Dichloromethane was detected in 8 out of 336 wells (2.4%) in urban areas of the local, State, and federal data set compiled by NAWQA. The minimum and maximum concentrations detected were 0.2 µg/L and 1.5 µg/L, respectively. The median value of detection concentrations was 0.45 µg/L. Dichloromethane was also detected in 20 of the 2,345 wells (0.86%) with analysis in rural areas. The minimum and maximum concentrations detected were 0.2 µg/L and 4 µg/L, respectively. The median value of detection concentrations was 0.45 µg/L. These data (urban and rural) represent untreated ambient ground water of the conterminous United States for the years 1985-1995 (Squillace et al., 1999).

Dichloromethane was also an analyte in both the NURP and NPDES programs (Lopes and Dionne, 1998). A comparison of the results of the NURP and NPDES studies found that the frequency of detection of dichloromethane in the NURP data was 11%, whereas for the NPDES data it was 7%. The NURP study found dichloromethane in urban runoff. The minimum and maximum concentrations detected were 4 µg/L and 14.5 µg/L, respectively, with no mean value reported. The NPDES related investigations analyzing urban and highway runoff detected dichloromethane. The minimum and maximum concentrations detected were <0.2 µg/L and 13 µg/L, respectively, with no mean value reported. The use of the land from which both sets of samples were taken was unspecified.

4.6.3.1 Additional Ambient Occurrence Data

Additional studies of ambient data are unavailable for dichloromethane.

4.6.4 Drinking Water Occurrence Based on the 16-State Cross-Section

The analysis of dichloromethane occurrence presented in the following section is based on State compliance monitoring data from the 16 cross-section States. The 16-State cross-section is the largest and most comprehensive compliance monitoring data set compiled by EPA to date. These data were evaluated relative to several concentration thresholds of interest: 0.005 mg/L; 0.0025 mg/L; 0.0005 mg/L; and 0.00025 mg/L.

All sixteen cross-section State data sets, with the exception of Montana, contained occurrence data for dichloromethane. These data represent more than 170,000 analytical results from approximately 22,000 PWSs during the period from 1984 to 1998 (with most analytical results from 1992 to 1997). The number of sample results and PWSs vary by State, although the State data sets have been reviewed and checked to ensure adequacy of coverage and completeness. The overall modal detection limit for dichloromethane in the 16 cross-section States is equal to 0.0005 mg/L. (For details regarding the 16-State cross-section, please refer to Section 1.3.5 of this report.)

4.6.4.1 Stage 1 Analysis Occurrence Findings

Table 4.6-3 illustrates the occurrence of dichloromethane in drinking water for the public water systems in the 16-State cross-section. About 0.669% of all PWSs in the 16 States (144 systems) had analytical results of dichloromethane exceeding the MCL (0.005 mg/L). Approximately 1.72% of PWSs (370 systems) had at least one analytical result greater than 0.0025 mg/L. The percentage of PWSs with results greater than 0.0005 mg/L was equal to 7.72% (1,663 systems). Approximately 8.51% of PWSs in the 16 States (1,832 systems) had at least one analytical result greater than 0.00025 mg/L.

Approximately 0.569% of ground water systems (114 systems) had results exceeding the MCL. The percentage of ground water systems in the 16 States with at least one analytical result greater than 0.0025 mg/L was equal to 1.46% (292 systems). Approximately 7.15% of ground water systems (1,432 systems), and 7.93% of ground water systems (1,587 systems) had any analytical results exceeding 0.0005 mg/L, and 0.00025 mg/L, respectively.

For surface water PWSs, 1.99% (30 systems) had analytical results exceeding 0.005 mg/L. Approximately 5.16% of surface water systems (78 systems) had results exceeding 0.0025 mg/L. The percentage of surface water systems with at least one analytical result greater than 0.0005 mg/L was equal to 15.3% (231 systems). Approximately 16.2% of surface water systems (245 systems) had analytical results of dichloromethane 0.00025 mg/L.

Table 4.6-3: Stage 1 Dichloromethane Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Ground Water	0.005	0.569%	114
	0.0025	1.46%	292
	0.0005	7.15%	1,432
	0.00025	7.93%	1,587

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Surface Water	0.005	1.99%	30
	0.0025	5.16%	78
	0.0005	15.3%	231
	0.00025	16.2%	245
Combined Ground & Surface Water	0.005	0.669%	144
	0.0025	1.72%	370
	0.0005	7.72%	1,663
	0.00025	8.51%	1,832

Reviewing dichloromethane occurrence by PWS population served (Table 4.6-4) shows that approximately 9.50% of the 16-State population (about 10.5 million people) was served by PWSs with analytical detections of dichloromethane greater than the MCL. Approximately 17.7% of the population (almost 19.5 million people) was served by PWSs with at least one analytical result greater than 0.0025 mg/L. The percentage of population served by systems with results greater than 0.0005 mg/L was equal to 27.6% (over 30 million people). Approximately 28.5% of the population (over 31 million people) was exposed to levels of dichloromethane greater than 0.00025 mg/L.

A much greater proportion of the 16-State population was served by surface water systems with threshold exceedances, as compared to ground water systems with threshold exceedances. The percentage of population served by ground water systems and surface water systems with analytical detections of dichloromethane greater than the MCL was equal to 3.91% (almost 2 million people), and 14.0% (approximately 8.5 million people), respectively. Relative to 0.0025 mg/L, 6.16% of the population (about 3 million people) was served by ground water systems with threshold exceedances, whereas 26.9% of the population (over 16 million people) was served by surface water systems with threshold exceedances. In addition, 16.9% of the population was served by ground water systems with results that exceeded 0.0005 mg/L, while 36.2% of the population was served by surface water systems with results exceeding 0.0005 mg/L. Approximately 17.5% of the population served by ground water systems was exposed to levels of dichloromethane greater than 0.00025 mg/L, compared to 37.3% of the population served by surface water systems exposed to levels greater than 0.00025 mg/L.

Table 4.6-4: Stage 1 Dichloromethane Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Ground Water	0.005	3.91%	1,916,200
	0.0025	6.16%	3,019,600
	0.0005	16.9%	8,315,100

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
	0.00025	17.5%	8,599,000
Surface Water	0.005	14.0%	8,548,400
	0.0025	26.9%	16,434,700
	0.0005	36.2%	22,125,500
	0.00025	37.3%	22,769,400
Combined Ground & Surface Water	0.005	9.50%	10,464,600
	0.0025	17.7%	19,454,400
	0.0005	27.6%	30,440,600
	0.00025	28.5%	31,368,400

4.6.4.2 Stage 2 Analysis Occurrence Findings

The Stage 2 occurrence findings, based on the cross-section data, are presented in Tables 4.6-5 and 4.6-6. The statistically generated best estimate values, as well as the ranges around the best estimate value, are presented. (For a review of the Stage 2 analytical approach, please refer to Section 1.4 of this report. For complete details regarding the Stage 2 analyses, please refer to *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT* (USEPA, 2002)).

Dichloromethane occurs in a small proportion of PWSs when evaluated relative to the MCL. Only 3 (about 0.0131% of) ground water and surface water PWSs had an estimated mean concentration of dichloromethane exceeding 0.005 mg/L, the MCL. Approximately 13 (0.0601% of) systems were estimated to have mean concentrations greater than 0.0025 mg/L. An estimated 348 (1.62% of) systems had estimated mean concentration values greater than 0.0005 mg/L. About 1,067 (4.96% of) systems in the 16 States were estimated to have mean concentrations greater than 0.00025 mg/L.

For ground water systems, 3 (about 0.0130% of) systems were estimated to have a mean concentration greater than 0.005 mg/L. About 11 (0.0564% of) ground water systems in the 16 States had an estimated mean concentration exceeding 0.0025 mg/L. An estimated 303 (1.51% of) ground water systems in the 16 States had an estimated mean concentration above 0.0005 mg/L, and 954 (4.77% of) ground water systems had an estimated mean concentration greater than 0.00025 mg/L.

Only 1 surface water system in the 16-State cross-section had an estimated mean concentration value of dichloromethane greater than 0.005 mg/L. Approximately 2 (about 0.133% of) surface water systems had estimated mean concentrations greater than 0.0025 mg/L. In addition, 44 (2.94% of) surface water systems, and 113 (7.50% of) surface water systems were estimated to have mean concentrations above 0.0005 mg/L, and 0.00025 mg/L, respectively.

Table 4.6-5: Stage 2 Estimated Dichloromethane Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.005	0.0130%	0.00500% - 0.0300%	3	1 - 6
	0.0025	0.0546%	0.0250% - 0.0849%	11	5 - 17
	0.0005	1.51%	1.31% - 1.73%	303	262 - 346
	0.00025	4.77%	4.36% - 5.19%	954	872 - 1,038
Surface Water	0.005	0.0142%	0.000% - 0.0662%	1	0 - 1
	0.0025	0.133%	0.000% - 0.331%	2	0 - 5
	0.0005	2.94%	2.25% - 3.84%	44	34 - 58
	0.00025	7.50%	6.22% - 8.93%	113	94 - 135
Combined Ground & Surface Water	0.005	0.0131%	0.00465% - 0.0279%	3	1 - 6
	0.0025	0.0601%	0.0325% - 0.0929%	13	7 - 20
	0.0005	1.62%	1.41% - 1.84%	348	304 - 395
	0.00025	4.96%	4.54% - 5.37%	1,067	977 - 1,157

Reviewing dichloromethane occurrence in the 16 cross-section States by PWS population served (Table 4.6-6) shows that approximately 0.119% of the 16-State population (over 131,000 people) was served by PWSs with estimated mean concentrations of dichloromethane greater than the 0.005 mg/L. Approximately 1.36% of the population (just over 1.5 million people) was served by PWSs with an estimated mean concentration greater than 0.0025 mg/L. The percentage of population served by systems with estimated mean concentrations of dichloromethane greater than 0.0005 mg/L was equal to 6.59% (about 7.3 million people). Approximately 9.40% of the population (over 10 million people) was potentially exposed to levels of dichloromethane greater than 0.00025 mg/l.

Although fewer surface water systems than ground water systems had estimated mean concentration values greater than the thresholds, a much larger population was served by surface water systems with threshold exceedances because surface water systems tend to serve much larger populations. The percentage of the 16-State population served by ground water systems and surface water systems with estimated mean concentrations of dichloromethane greater than the MCL was equal to 0.00203% (approximately 1,000 people), and 0.213% (over 130,000 people), respectively. Relative to 0.0025 mg/L, 0.0189% of the population (about 9,300 people) was served by ground water systems with estimated mean concentrations exceeding that limit, whereas 2.44% of the population (almost 1.5 million people) was served by surface water systems with estimated mean concentrations exceeding 0.0025 mg/L. In addition, 1.06% of the population served by ground water systems was potentially exposed to levels of dichloromethane that exceeded 0.0005 mg/L, while 11.0% of the population was served by surface water systems with estimated mean concentrations of dichloromethane exceeding 0.0005 mg/L. Approximately 3.56% of the population served by ground water systems was potentially exposed to levels of dichloromethane greater than 0.00025 mg/L, compared to 14.1% of the population served by surface water systems potentially exposed to levels greater than 0.00025 mg/L.

Table 4.6-6: Stage 2 Estimated Dichloromethane Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.005	0.00203%	0.000357% - 0.0103%	1,000	200 - 5,000
	0.0025	0.0189%	0.00242% - 0.0815%	9,300	1,200 - 40,000
	0.0005	1.06%	0.720% - 1.91%	518,100	353,000 - 938,000
	0.00025	3.56%	2.85% - 4.83%	1,748,000	1,396,700 - 2,368,600
Surface Water	0.005	0.213%	0.000% - 0.449%	130,100	0 - 274,500
	0.0025	2.44%	0.000% - 8.98%	1,490,500	0 - 5,483,700
	0.0005	11.0%	9.93% - 12.3%	6,737,800	6,063,400 - 7,531,900
	0.00025	14.1%	12.7% - 16.2%	8,600,900	7,739,600 - 9,895,900
Combined Ground & Surface Water	0.005	0.119%	0.000159% - 0.250%	131,200	200 - 275,300
	0.0025	1.36%	0.00221% - 4.99%	1,500,200	2,400 - 5,494,100
	0.0005	6.59%	5.92% - 7.34%	7,256,400	6,518,400 - 8,089,100
	0.00025	9.40%	8.52% - 10.6%	10,350,400	9,383,400 - 11,642,400

4.6.4.3 Estimated National Occurrence

Based on the Stage 2 estimated percent of systems (and population served by systems) exceeding each threshold, an estimated 9 PWSs nationally serving approximately 253,700 people could be exposed to dichloromethane concentrations above 0.005 mg/L. About 39 systems serving almost 3 million people nationally were estimated to have mean concentrations greater than 0.0025 mg/L. Approximately 1,050 systems serving over 14 million people nationally were estimated to have mean dichloromethane concentrations greater than 0.0005 mg/L. A total of 3,224 systems serving over 20 million people were estimated to have mean concentrations greater than 0.00025 mg/L. (See Section 1.4 for a description of how Stage 2 16-State estimates are extrapolated to national values.)

For ground water systems, an estimated 8 PWSs serving about 1,700 people nationally had mean concentrations greater than 0.005 mg/L. Approximately 32 systems serving about 16,200 people nationally were estimated to have mean concentration values that exceeded 0.0025 mg/L. About 900 ground water systems serving almost 905,200 people were estimated to have mean concentrations greater than 0.0005 mg/L. An estimated 2,833 ground water PWSs nationally could potentially expose over 3 million people to concentrations of dichloromethane greater than 0.00025 mg/L.

Approximately 1 surface water system serving 271,200 people nationally was estimated to have mean concentrations of dichloromethane above 0.005 mg/L. About 7 surface water systems serving approximately 3.1 million people were estimated to have mean concentrations greater than 0.0025 mg/L. An estimated 164 surface water systems serving approximately 14 million people had mean concentrations greater than 0.0005 mg/L. Approximately 419 surface water PWSs serving almost 18 million people were estimated to have mean concentrations of dichloromethane greater than 0.00025 mg/L.

Table 4.6-7: Estimated National Dichloromethane Occurrence - Systems and Population Served

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.005	8	3 - 18	1,700	300 - 8,800
	0.0025	32	15 - 50	16,200	2,100 - 69,800
	0.0005	900	778 - 1,027	904,800	616,600 - 1,638,200
	0.00025	2,833	2,589 - 3,082	3,052,800	2,439,400 - 4,136,700
Surface Water	0.005	1	0 - 4	271,200	0 - 572,200
	0.0025	7	0 - 18	3,106,800	0 - 11,430,100
	0.0005	164	126 - 215	14,044,100	12,638,400 - 15,699,400
	0.00025	419	348 - 499	17,927,600	16,132,300 - 20,626,900
Combined Ground & Surface Water	0.005	9	3 - 18	253,700	300 - 532,300
	0.0025	39	21 - 60	2,901,200	4,700 - 10,624,800
	0.0005	1,050	918 - 1,193	14,033,000	12,605,800 - 15,643,300
	0.00025	3,224	2,951 - 3,495	20,016,400	18,146,200 - 22,515,000

4.6.5 Additional Drinking Water Occurrence Data

Additional studies of drinking water occurrence data are unavailable for dichloromethane.

4.6.6 Conclusion

Dichloromethane is used in paint strippers and removers, as a propellant in aerosols, as a process solvent in the manufacture of drugs, pharmaceuticals, and film coatings, as a metal cleaning and finishing solvent, in electronics manufacturing, and as an agent in urethane foam blowing. It is also used in many consumer products. Production of dichloromethane has declined since the early 1980s, and the most recent data indicates that 403 million pounds of dichloromethane were produced in 1994. Dichloromethane is also a TRI chemical. Industrial releases of dichloromethane have occurred since 1988 in 46 States and Puerto Rico. Dichloromethane was an analyte for the NAWQA, NURP, and NPDES ambient occurrence studies. In the NAWQA study, dichloromethane was detected in 3.0% of urban wells and 0.29% of rural wells, with a median detection value of 0.45 µg/L for all wells. In the Stage 2 analysis of 16-State occurrence of dichloromethane, 0.0131% of combined ground water and surface water systems serving 0.119% of the population exceeded the MCL of 0.005 mg/L. Nationally, 9 ground water and surface water systems combined (serving approximately 253,700 people) are estimated to have levels greater than the MCL.

The 16-State cross-section was designed to be nationally representative based upon VOC, SOC, and IOC pollution potentials as suggested by considerations of manufacturing, agriculture, and geographic diversity factors. Nationally, dichloromethane is manufactured and/or processed in 43 States and has TRI releases in 46 States. Dichloromethane is manufactured and/or processed in 14 out of the 16 cross-section States and has TRI releases in 15 of the 16 cross-section States. The cross-section should adequately represent the occurrence of dichloromethane on a national scale based upon the use, production, and release patterns of the 16-State cross-section in relation to the patterns observed for all 50 States.

4.6.7 References

Agency for Toxic Substances and Disease Registry (ATSDR). 2000. *Toxicological Profile for Methylene Chloride*. U.S. Department of Health and Human Services, Public Health Service. 268 pp. + Appendices. Available on the Internet at http://www.atsdr.cdc.gov/toxprofiles/tp14.pdf..

Chemexpo. 2001. Methylene Chloride Chemical Profile. Available on the Internet at http://www.chemexpo.com/news/PROFILE001009.cfm.

Lopes, T.J. and S.G. Dionne. 1998. *A Review of Semivolatile and Volatile Organic Compounds in Highway Runoff and Urban Stormwater*. U.S. Geological Survey Open-File Report 98-409. 67 pp.

National Safety Council (NSC). 2001. *Dichloromethane Chemical Backgrounder*. Itasca, IL: National Safety Council. Available on the Internet at: http://www.crossroads.nsc.org/ChemicalTemplate.cfm?id=104&chempath=chemicals, accessed July 23, 2001.

Squillace, P.J., M.J. Moran, W.W. Lapham, C.V. Price, R.M. Clawges, and J.S. Zogorski. 1999. Volatile organic compounds in untreated ambient groundwater of the United States, 1985-1995. *Env. Sci. and Tech*. 33(23):4176-4187.

USEPA. 2000. *TRI Explorer: Trends*. Available on the Internet at: http://www.epa.gov/triexplorer/trends.htm, last updated May 5, 2000.

USEPA. 2002. *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT*. EPA Report/815-D-02-005, Office of Water, 55 pp.

4.7 1,2-Dichloropropane

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Tables and Figures

4.7.1 Introduction, Use and Production

1,2-Dichloropropane (chemical formula $C_3H_6Cl_2$) is a colorless liquid that has a chloroform-like odor and evaporates quickly at room temperature. It is a man-made chemical, whose releases are almost all anthropogenic in nature. 1,2-Dichloropropane is now used in the United States only in research and industry. 1,2-Dichloropropane is also known as propylene dichloride and DCP.

Based on 1982 production data supplied by Dow Chemical (USEPA, 1986, as cited in ATSDR, 1989), it has been estimated that over 95% of the isolated 1,2-dichloropropane manufactured by Dow was used on-site as a captive intermediate in the production of perchloroethylene and other chlorinated products by their ‘per-tet’ process (USEPA, 1986; Dow Chem. Co., 1983, all as cited in ATSDR, 1989). Approximately 3 million pounds per year of 1,2-dichloropropane were marketed by Dow Chemical in 1982 for minor uses as an industrial solvent for oils, fats, resins, waxes, and rubber, in ion exchange manufacture, in toluene diisocyanate (TDI) production, in photographic film manufacture, for paper coating, and for petroleum catalyst regeneration (HSDB, 1988; IARC, 1986; USEPA, 1986, all as cited in ATSDR, 1989). Outside of its use as a chemical intermediate, Dow Chemical Company's use pattern for 1,2-dichloropropane in 1982 was as follows: 41% in ion exchange manufacturing, 34% in toluene diisocyanate (TDI) production, 19% in photographic film production, 4% in paper coating, and 2% in petroleum catalyst regeneration (Dow Chem. Co., 1983, as cited in ATSDR, 1989).

Production for sale, as opposed to internal consumption by manufacturers, was greatly curtailed in the early 1980s. By 1983, 1,2-dichloropropane was no longer sold for consumer use in paint strippers, paint varnish, and furniture finish removers (USEPA, 1986; Dow Chem. Co., 1983, all as cited in ATSDR, 1989). By the end of 1983, its use as a solvent for film production was to be phased out in favor of l,l,l-trichloroethane (Dow, 1983, as cited in ATSDR, 1989). According to comments submitted by Dow to ATSDR (USEPA, 1989, as cited in ATSDR, 1989), the phaseout of use of 1,2-dichloropropane as a solvent for film production had not occurred as of June, 1989, although it is still planned. They further stated that the use of 34% of 1,2-dichloropropane in TDI production has now been discontinued.

Before the early 1980s, it was used in farming as a soil fumigant and was found in some paint strippers, varnishes, and furniture finish removers (ATSDR, 1989). An estimated 20 million pounds/year of dichloropropane were produced as a by-product in a mixture marketed as a soil fumigant which was used in the cultivation of a variety of crops, including citrus fruits, pineapple, soy beans, cotton, tomatoes, and potatoes (IARC, 1986; HSDB, 1988, all as cited in ATSDR, 1989). Dow has discontinued production of soil fumigants containing 1,2-dichloropropane, and pesticidal formulations containing this chemical are no longer available in the U.S. (Meister, 1987, as cited in ATSDR, 1989). Other uses of 1,2-dichloropropane include use as an intermediate in the synthesis of carbon tetrachloride, lead scavenger in gasoline, textile stain remover, oil and paraffin extractant, scouring compound, and metal degreasing agent, especially prior to electroplating (IARC, 1986, as cited in ATSDR, 1989).

1,2-Dichloropropane was produced by Columbia Organics in Cassatt, SC, Dow Chemical in Freeport, TX and Dow Chemical in Plaquemine, LA (SRI, 1988; USITC, 1987, all as cited in ATSDR, 1989); however, Dow Chemical Company was the only manufacturer of the isolated chemical in the United States (USEPA, 1986, as cited in ATSDR, 1989), and Dow discontinued the production of 1,2-dichloropropane in 1991 (USEPA, 2001). The total output of 1,2-dichloropropane by U.S. manufacturers remained relatively stable until 1984 when a major manufacturer, Mannsville Chemical Products Corporation, discontinued production. Production of 1,2-dichloropropane in 1980 was 77 million pounds (USEPA, 2001), and domestic production volume during 1984 was 59.8 million pounds (IARC, 1986, as cited in ATSDR, 1989).

4.7.2 Environmental Release

1,2-Dichloropropane is listed as a Toxics Release Inventory (TRI) chemical. Table 4.7-1 illustrates the environmental releases for 1,2-dichloropropane from 1988 - 1999. (1,2-Dichloropropane data are only available for these years.) Air emissions constitute most of the on-site releases, with a relatively steady decrease over the years. Surface water discharges decreased from a high of over 23,000 pounds in 1988 to under 4,000 pounds in 1994, but have since fluctuated between 1,000-9,000 pounds. The significant decrease in air emissions, as well as a decrease in surface water discharges, has contributed to decreases in 1,2-dichloropropane total on- and off-site releases from 1988-1999. Underground injection has not been monitored for most of the years, and otherwise registers zero, with the exception of a measurement in 1994. Releases to land (such as spills or leaks within the boundaries of the reporting facility) show no apparent trend, ranging from zero to over 3,000 pounds. However, releases to land have been 150 pounds or less since 1993. Off-site releases (including metals or metal compounds transferred off-site) vary between under 300 pounds to over 12,000 pounds, displaying no discernable trend. These TRI data for 1,2-dichloropropane were reported from 15 States, with five States reporting every year (USEPA, 2000). Five of the 16 cross-section States (used for analyses of 1,2-dichloropropane occurrence in drinking water; see Section 4.7.4) reported releases of 1,2-dichloropropane. (For a map of the 16-State cross-section, see Figure 1.3-1.)

Table 4.7-1: Environmental Releases (in pounds) for 1,2-Dichloropropane in the United States, 1988-1999

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1999	249,656	9,242	--	30	6,856	265,784
1998	298,150	1,122	--	32	267	299,571
1997	378,454	2,609	--	30	12,375	393,468
1996	514,428	1,855	--	150	5,337	521,770
1995	616,470	4,344	--	20	1,371	622,205
1994	709,547	3,609	215	12	699	714,082
1993	577,439	4,749	0	19	567	582,774
1992	619,917	6,755	--	1,206	1,952	629,830
1991	772,543	6,570	--	0	2,073	781,186
1990	1,038,614	10,453	--	300	1,639	1,051,006
1989	1,280,220	11,577	0	5	1,446	1,293,248
1988	1,395,304	23,785	--	3,400	1,131	1,423,620

Source: USEPA, 2000

4.7.3 Ambient Occurrence

1,2-Dichloropropane was detected in 3 out of 359 wells (0.84%) in urban areas of the local, State, and federal data set compiled by NAWQA. The minimum and maximum concentrations detected were 0.2 µg/L and 1.3 µg/L, respectively. The median value of detection concentrations was 0.2 µg/L. 1,2-Dichloropropane was also detected in 23 of the 2,508 wells (0.92%) analyzed in rural areas. The minimum and maximum concentrations detected were 0.2 µg/L and 7.5 µg/L, respectively. The median value of detection concentrations was 0.5 µg/L. These urban and rural data represent untreated ambient ground water of the conterminous United States for the years 1985-1995 (Squillace et al., 1999).

1,2-Dichloropropane was also an analyte in the NPDES data. NPDES-related investigations analyzing urban and highway runoff detected 1,2-dichloropropane (Lopes and Dionne, 1998). The minimum concentration detected was not reported, and the maximum concentration detected was 3 µg/L, with no mean value reported. The use of the land from which the samples were taken was unspecified.

4.7.3.1 Additional Ambient Occurrence Data

A summary document entitled "Occurrence of Synthetic Organic Chemicals in Drinking Water, Food, and Air" (USEPA, 1987), was previously prepared for past USEPA assessments of 1,2-dichloropropane. Several studies were included that addressed levels of 1,2-dichloropropane in water other than drinking water. The following information is taken directly from "Occurrence of Synthetic Organic Chemicals in Drinking Water, Food, and Air" (USEPA, 1987).

4.7.3.1.1 Ground Water Sources

Five State studies from California were obtained, including a study of various shallow and deep wells in Kern County, California (near Bakersfield) for DCP (Cohen and Bowes, 1984, as cited in USEPA, 1987). Seventeen positive samples were reported with a range of concentrations from 0.1 to 7.9 µg/L. No other information on the study was reported.

Another State study of wells in Lathrop, California (San Joaquin County), near the Occidental Chemical Company, was conducted in 1979, and again in 1983 (Cohen and Bowes, 1984, as cited in USEPA, 1987). In 1979, seven of 14 samples from seven locations were positive for DCP with a range of concentrations from 0.2 to 5.0 µg/L. The mean concentration and detection limit were not reported. Analyzed subsequently in 1983, none of the samples from the seven locations had detectable levels of DCP.

Ground water wells in 25 counties from California were analyzed as part of a toxics special project by the California Water Resources Control Board (Cohen and Bowes, 1984; Holden, 1986, all as cited in USEPA, 1987). Positive results for DCP were found in 68 out of 266 samples taken from as many sites. A high value of 1,200 µg/L was reported for a sample from Crescent City, California. No further information was presented in either report on this study.

Ground water from 24 feet below surface level was sampled in 1982 as part of the California State Board Toxic Substances Control Program (Cohen and Bowes, 1984, as cited in USEPA, 1987). One sample was reported to have a concentration of 4.6 µg/L. No other information was reported on this study.

Ground water well samples from California, Maryland, New York, and Washington were reported by the USEPA Office of Pesticide Programs (Cohen et al., 1986, as cited in USEPA, 1987) to show typical positive concentrations for DCP in the range of 1.0 to 50 µg/L. No further information was reported.

4.7.3.1.2 Surface Water Sources

Urban stormwater runoff in Eugene, Oregon, was sampled as part of USEPA's Nationwide Urban Runoff Program (Cole et al. 1984, as cited in USEPA, 1987). Of the 15 sites sampled, only 1 of 86 samples was positive for DCP, at a concentration of 3.0 µg/L. The detection limit was not reported.

Surface water from rivers in Delaware, Ohio, and West Virginia, as well as 14 other U.S. river basins, were sampled during various studies reported in USEPA (1985, as cited in USEPA, 1987). In total, more than 8 samples from over 207 sites tested positive, with some reported levels between “trace” and 2.0 µg/L. No other specific information was reported.

4.7.3.1.3 Unidentified Sources

Water samples have been compiled by USEPA's STORET data base from national studies without specification as to type of source (USEPA, 1985, as cited in USEPA, 1987). For a total of 22,670 “observations,” DCP concentrations ranged from 0 to 25,000 µg/L, with a mean concentration of 10.0 µg/L. Whether “observations” referred to positive samples or to the total samples collected was unspecified. No other information on the studies was reported.

4.7.4 Drinking Water Occurrence Based on the 16-State Cross-Section

The analysis of 1,2-dichloropropane occurrence presented in the following section is based on State compliance monitoring data from the 16 cross-section States. The 16-State cross-section is the largest and most comprehensive compliance monitoring data set compiled by EPA to date. These data were evaluated relative to several concentration thresholds of interest: 0.005 mg/L; 0.0005 mg/L; and 0.0004 mg/L.

All sixteen cross-section State data sets contained occurrence data for 1,2-dichloropropane. These data represent more than 180,000 analytical results from approximately 22,000 PWSs during the period from 1984 to 1998 (with most analytical results from 1992 to 1997). The number of sample results and PWSs vary by State, although the State data sets have been reviewed and checked to ensure adequacy of coverage and completeness. The overall modal detection limit for 1,2-dichloropropane in the 16 cross-section States is equal to 0.0005 mg/L. (For details regarding the 16-State cross-section, please refer to Section 1.3.5 of this report.)

4.7.4.1 Stage 1 Analysis Occurrence Findings

Table 4.7-2 illustrates the occurrence of in drinking water for the public water systems in the 16-State cross-section relative to three thresholds: 0.005 mg/L (the current MCL), 0.0005 mg/L (the modal MRL), and 0.0004 mg/L. According to the 16-State cross-section data, a total of 15 (approximately 0.0682% of) ground water and surface water PWSs had analytical results exceeding the MCL; 0.432% of systems (95 systems) had results exceeding 0.0005 mg/L; and 0.637% of systems (140 systems) had results exceeding 0.0004 mg/L.

Approximately 0.0588% of ground water systems (12 systems) had any analytical results greater than the MCL. About 0.402% of ground water systems (82 systems) had results above 0.0005 mg/L. The percentage of ground water systems with at least one result greater than 0.0004 mg/L was equal to 0.539% (110 systems).

Approximately 3 (0.190% of) surface water systems had results greater than the MCL. A total of 13 (0.824% of) surface water systems had at least one analytical result greater than 0.0005 mg/L. Thirty (1.90% of) surface water systems had results exceeding 0.0004 mg/L.

Table 4.7-2: Stage 1 1,2-Dichloropropane Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Ground Water	0.005	0.0588%	12
	0.0005	0.402%	82
	0.0004	0.539%	110
Surface Water	0.005	0.190%	3
	0.0005	0.824%	13
	0.0004	1.90%	30
Combined Ground & Surface Water	0.005	0.0682%	15
	0.0005	0.432%	95
	0.0004	0.637%	140

Reviewing 1,2-dichloropropane occurrence in the 16 cross-section States by PWS population served (Table 4.7-3) shows that approximately 1.18% of the 16-State population (over 1.3 million people) was served by PWSs with at least one analytical result of 1,2-dichloropropane greater than the MCL (0.005 mg/L). Over 11 million (10.1% of) people were served by systems with an exceedance of 0.0005 mg/L. A total of about 12 million (10.9% of) people were served by systems with at least one analytical result greater than 0.0004 mg/L.

The percentage of population served by ground water systems in the 16 States with analytical results greater than the MCL was equal to 2.22% (approximately 1 million people). When evaluated relative to 1, 2-dicloropropane detections of 0.0005 mg/L or 0.0004 mg/L, the percent of population exposed was equal to 3.48% (over 1.7 million people) and 3.80% (almost 1.9 million people), respectively.

The percentage of population served by surface water systems with exceedances of 0.005 mg/L was equal to 0.347% (approximately 212,200 people). Approximately 15.4% of the population served by surface water systems (about 9.4 million people) was exposed to 1,2-dichloropropane concentrations greater than 0.0005 mg/L. When evaluated relative to 0.0004 mg/L, the percent of population exposed was equal to 16.7% (over 10 million people).

Table 4.7-3: Stage 1 1,2-Dichloropropane Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Ground Water	0.005	2.22%	1,091,000
	0.0005	3.48%	1,715,000

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
	0.0004	3.80%	1,871,100
Surface Water	0.005	0.347%	212,200
	0.0005	15.4%	9,443,700
	0.0004	16.7%	10,216,500
Combined Ground & Surface Water	0.005	1.18%	1,303,200
	0.0005	10.1%	11,158,700
	0.0004	10.9%	12,087,600

4.7.4.2 Stage 2 Analysis Occurrence Findings

The Stage 2 occurrence findings, based on the cross-section data, are presented in Tables 4.7-4 and 4.7-5. The statistically generated best estimate values, as well as the ranges around the best estimate value, are presented. (For a review of the Stage 2 analytical approach, please refer to Section 1.4 of this report. For complete details regarding the Stage 2 analyses, please refer to *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT* (USEPA, 2002)).

One (0.00358% of) PWS in the 16 States had an estimated mean concentration of 1,2-dichloropropane exceeding 0.005 mg/L, while 8 (0.0382% of) systems in the 16 States had an estimated mean concentration exceeding 0.0005 mg/L and 11 (0.0506% of) systems had an estimated mean concentration exceeding 0.0004 mg/L.

Zero ground water PWSs in the 16 States were estimated to have a mean concentration greater than 0.005 mg/L. Seven (0.0347% of) ground water PWSs were estimated to exceed a mean concentration of 0.0005 mg/L and 10 (0.0472% of) systems are estimated to exceed a mean concentration of 0.0004 mg/L. For surface water PWSs in the 16 States, 0.0176%, 0.0837%, and 0.0947% had estimated mean concentrations exceeding 0.005 mg/L, 0.0005 mg/L, and 0.0004 mg/L, respectively.

Table 4.7-4: Stage 2 Estimated 1,2-Dichloropropane Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.005	0.00250%	0.000% - 0.00980%	0	0 - 2
	0.0005	0.0347%	0.0196% - 0.0539%	7	4 - 11
	0.0004	0.0472%	0.0245% - 0.0686%	10	5 - 14

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
Surface Water	0.005	0.0176%	0.000% - 0.0634%	1	0 - 1
	0.0005	0.0837%	0.0634% - 0.127%	1	1 - 2
	0.0004	0.0947%	0.0634% - 0.190%	1	1 - 3
Combined Ground & Surface Water	0.005	0.00358%	0.000% - 0.00910%	1	0 - 2
	0.0005	0.0382%	0.0227% - 0.0546%	8	5 - 12
	0.0004	0.0506%	0.0318% - 0.0728%	11	7 - 16

Reviewing 1,2-dichloropropane occurrence by PWS population served (Table 4.7-6) shows that approximately 0.0358% of population served by all PWSs in the 16 States (an estimate of approximately 39,500 people) was potentially exposed to 1,2-dichloropropane levels above 0.005 mg/L. For all PWSs, an estimated 0.137% of population served (an estimate of over 151,000 people served in the 16 States) was exposed to levels above 0.0005 mg/L and 0.150% (an estimated 165,700 people in the 16-State cross-section) was exposed to levels above 0.0004 mg/L.

When the population exposed by ground water systems in the 16 States was evaluated relative to thresholds of 0.005 mg/L, 0.0005 mg/L, and 0.0004 mg/L, the percentages of population exposed were equal to 0.0000401%, 0.0167% (8,200 people), and 0.0446% (22,000 people), respectively.

The percentage of population served by surface water systems in the 16 States with levels above 0.005 mg/L was 0.0645% (an estimated 39,500 people in the 16 States), while the population served with levels above 0.0005 mg/L and 0.0004 mg/L was 0.234% (an estimated 143,200 people in the 16 States) and 0.235% (an estimate of 143,700 people in the 16 States), respectively.

Table 4.7-5: Stage 2 Estimated 1,2-Dichloropropane Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	**Range**	**Best Estimate**	**Range**
Ground Water	0.005	0.0000401%	0.000% - 0.000136%	0	0 - 100
	0.0005	0.0167%	0.00205% - 0.0649%	8,200	1,000 - 32,000
	0.0004	0.0446%	0.00466% - 0.0962%	22,000	2,300 - 47,400
Surface Water	0.005	0.0645%	0.000% - 0.232%	39,500	0 - 142,000
	0.0005	0.234%	0.232% - 0.235%	143,200	142,000 - 143,500
	0.0004	0.235%	0.232% - 0.250%	143,700	142,000 - 153,000

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
Combined Ground & Surface Water	0.005	0.0358%	0.000% - 0.129%	39,500	0 - 142,000
	0.0005	0.137%	0.130% - 0.158%	151,400	143,000 - 174,700
	0.0004	0.150%	0.131% - 0.179%	165,700	145,000 - 197,400

4.7.4.3 Estimated National Occurrence

Based on the Stage 2 estimated percent of systems (and population served by systems) with mean 1,2-dichloropropane occurrence exceeding each threshold, an estimated 2 PWSs nationally, serving over 76,000 people total could be exposed to 1,2-dichloropropane concentrations above 0.005 mg/L. About 25 systems, serving a total of about 292,000 people, had estimated mean concentrations greater than 0.0005 mg/L. Approximately 33 systems, serving a total of about 319,500 people nationally, were estimated to have mean 1,2-dichloropropane concentrations greater than 0.0004 mg/L. (See Section 1.4 for a description of how Stage 2 16-State estimates are extrapolated to national values.)

For ground water systems, an estimated 1 PWS in the nation, serving less than 100 people, had a mean concentration greater than 0.005 mg/L. Approximately 21 systems serving 14,300 people nationally had estimated mean concentration values that exceeded 0.0005 mg/L. About 28 ground water systems serving about 38,200 people had estimated mean concentrations greater than 0.0004 mg/L.

Although fewer surface water systems than ground water systems nationally had estimated mean concentration values greater than the thresholds, a much larger population was served by surface water systems with threshold exceedances because surface water systems tend to serve much larger populations. Approximately 1 surface water system, serving about 82,100 people, was estimated to have mean concentrations of 1,2-dichloropropane above 0.005 mg/L. About 5 surface water systems serving almost 298,000 people had estimated mean concentrations greater than 0.0005 mg/L. An estimated 5 surface water systems, serving approximately 299,000 people, had mean concentrations greater than 0.0004 mg/L.

Table 4.7-6: Estimated National 1,2-Dichloropropane Occurrence - Systems and Population Served

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.005	1	0 - 6	< 100	0 - 100
	0.0005	21	12 - 32	14,300	1,800 - 55,600
	0.0004	28	15 - 41	38,200	4,000 - 82,400
Surface Water	0.005	1	0 - 4	82,100	0 - 295,500
	0.0005	5	4 - 7	297,900	295,500 - 298,600

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
	0.0004	5	4 - 11	299,000	295,500 - 318,300
Combined Ground & Surface Water	0.005	2	0 - 6	76,200	0 - 273,900
	0.0005	25	15 - 35	292,000	275,800 - 337,000
	0.0004	33	21 - 47	319,500	279,700 - 380,600

4.7.5 Additional Drinking Water Occurrence Data

Several additional data sources regarding the occurrence of 1,2-dichloropropane in drinking water are also reviewed. Previously compiled occurrence information on 1,2-dichloropropane, from an OGWDW summary document entitled "Occurrence of Synthetic Organic Chemicals in Drinking Water, Food, and Air" (USEPA, 1987), is presented in this section. This variety of studies and information are presented regarding levels of 1,2-dichloropropane in drinking water, with the scope of the reviewed studies ranging from national to regional. Note that none of the studies presented in the following section provide the quantitative analytical results or comprehensive coverage that would enable direct comparison to the occurrence findings estimated with the cross-section occurrence data presented in Section 4.7.4. These additional studies, however, do enable a broader assessment of the Stage 2 occurrence estimates presented for this Six-Year Review. All the following information in Section 4.7.5 is taken directly from "Occurrence of Synthetic Organic Chemicals in Drinking Water, Food, and Air" (USEPA, 1987).

4.7.5.1 Groundwater – National Studies

The Ground Water Supply Survey was conducted from December 1980 to December 1981 to develop data on the occurrence of volatile organic chemicals in the nation's ground water supplies (USEPA, 1983; Westrick et al., 1983, all as cited in USEPA, 1987). The GWSS involved the sampling of 945 water supply- systems, of which 466 were selected randomly while the remaining 479 systems were chosen by the States as having a high potential for contamination. DCP was observed in 6 of the 466 randomly selected systems. One of the six positive values obtained came from a supply serving fewer than 10,000 persons; the positive value was 0.75 µg/L. The other five positive values, found in supplies serving greater than 10,000 people, had a median value of 0.86 µg/L (range = 0.48 to 21 µg/L). In the nonrandom portion of the GWSS, DCP was detected in 7 of 479 systems sampled. Three positives were from systems serving fewer than 10,000 people, and had values of 0.51, 1.2, and 1.4 µg/L. The four positive values from supplies serving more than 10,000 people had a median value of 0.7 µg/L (range = 0.21 to 18 µg/L). The quantitation limit for both random and nonrandom systems was 0.2 µg/L.

The American Water Works Association (AWWA) surveyed water utilities nationwide that were monitoring for unregulated contaminants including 1,2-dichloropropane in raw and finished water from ground and surface water sources. Of the 114 utilities monitoring for 1,2-dichloropropane, 3 utilities whose primary water source is ground water detected 1,2-dichloropropane in 1 of 1,382 raw water samples and 5 of 5 finished water samples. Concentrations ranged from less than 1.0 to 4.0 in finished water. The concentration detected in raw water was 3.0 µg/L. No detection limits were reported (AWWA, 1988, as cited in USEPA, 1987). The American Water Works Association advises caution in utilizing this data as it appears there are discrepancies in the units reported by some utilities (Achtermann, 1990, as cited in USEPA, 1987).

4.7.5.2 Groundwater – Regional Studies

Twelve towns in Connecticut were examined by the Connecticut Agricultural Experiment Station in New Haven, Connecticut (Waggoner, 1985, as cited in USEPA, 1987). Drinking water wells representing the major drinking water sources for those 12 towns were analyzed during 1984-1985. The population served by the wells sampled exceeded 570,000 persons. None of the wells, at a total of 42 locations, were positive for DCP. The detection limit was 0.05 µg/L.

Community ground water wells were sampled during 1982 in Visalia (Tulare County) and Reedley (Fresno County), California, as part of the USEPA National Groundwater Monitoring Program (Cohen and Bowes, 1984, as cited in USEPA, 1987). DCP was found in three samples, at a mean concentration of 9.93 µg/L (range = 1.0 to 25.9 µg/L). The total number of samples, number of locations, and detection limit were not reported.

Domestic and irrigation wells were sampled for DCP on Long Island, New York, by the Suffolk County Department of Health Services (Holden, 1986, as cited in USEPA, 1987). Out of 1,000 samples taken, about 500 were contaminated with DCP at concentrations ranging from 30 to 300 µg/L. More specific information was not reported.

Community wells in Del Norte County, California, were sampled in 1983 for DCP (Cohen and Bowes, 1984, as cited in USEPA, 1987). Twenty-five of 37 samples were found positive, with a maximum concentration of greater than 10.0 µg/L. No other information on this study was reported.

Private domestic wells from three other California counties were analyzed as part of the California State Board Toxic Substances Control Program during 1982 (Cohen and Bowes, 1984, as cited in USEPA, 1987). DCP was found in 12 out of 95 samples, with a range of concentrations between 0.4 and 16 µg/L. The mean concentration and detection limit were not reported.

4.7.5.3 Surface Water – National Study

The American Water Works Association (AWWA) surveyed water utilities nationwide that were monitoring for unregulated contaminants including 1,2-dichloropropane in raw and finished water from ground and surface water sources. Of the 114 utilities monitoring for 1,2-dichloropropane, 10 utilities whose primary water source is surface water detected 1,2-dichloropropane in 793 of 11,394 raw water samples and 257 of 885 finished water samples. Concentrations ranged from 0.1 µg/L to 15.0 µg/L in raw water samples and less than 0.1 µg/L to 9.0 µg/L in finished water samples. No detection limits were reported (AWWA, 1988, as cited in USEPA, 1987). The American Water Works Association advises caution in utilizing this data as it appears there are discrepancies in the units reported by some utilities (Achtermann, 1990, as cited in USEPA, 1987).

4.7.5.4 Surface Water – Regional Studies

To assemble a database which would reflect the status of Great Lakes drinking water quality, the Canadian Public Health Association gathered data from October 1984 through August 1985. The data collected covered the period from the mid 1970s to early 1985. A research team, appointed by the Association, reviewed data on the quality of water at 31 representative Canadian and United States communities and 24 offshore sites to evaluate the human health implications.

For each of the 31 communities, data consisted of: 1) background information on the community; 2) treatment plant schematics and associated treatment process information; and 3) water quality data. Water sample types included raw water (treatment plant intake), distribution water (treated water), and tap water. Water quality data collected included general parameters (e.g., alkalinity, turbidity), microbiological and radiological parameters, inorganic parameters, and organic parameters (including volatiles, base/neutrals, pesticides and PCBs, and phenols and acids). For each parameter, the water type, time period, concentration (mean, range), number of samples, and detection limit were recorded.

For most of the volatile organics, including DCP, the available data indicated that these contaminants did not occur at significant levels in the raw, treated, or tap water. Most of the values found were "not detected" or near the detection limit (Canadian Public Health Association, 1986, as cited in USEPA, 1987).

4.7.5.5 Unidentified Sources

Drinking water samples were collected and analyzed in the Love Canal area, New York, during 1980 by Barkley et al. (1980, as cited in USEPA, 1987). The only information reported was that one sample contained a DCP concentration of 1,200 µg/L (detection limit not given).

4.7.6 Conclusion

1,2-Dichloropropane was mostly used captively by manufacturers as a chemical intermediate in the production of chlorinated products. At one time, it was also used in various consumer products such as paint and finish removers and was found in soil fumigants as a processing byproduct. Domestic production of 1,2-dichloropropane as an isolated chemical ceased in 1991. 1,2-Dichloropropane is also a TRI chemical. Industrial releases of 1,2-dichloropropane have occurred since 1988 in 15 States. 1,2-Dichloropropane was an analyte for the NAWQA and NPDES ambient occurrence studies. In the NAWQA study, 1,2-dichloropropane was detected in 0.84% of urban wells and 0.92% of rural wells, with median detection values of 0.2 µg/L and 0.5 µg/L, respectively. In the Stage 2 analysis of 16-State occurrence of 1,2-dichloropropane, 0.00358% of combined ground water and surface water systems serving 0.0358% of the population exceeded the MCL of 0.005 mg/L. Nationally, 2 ground water and surface water systems combined (serving approximately 76,200 people) are estimated to have levels greater than the MCL.

The 16-State cross-section was designed to be nationally representative based upon VOC, SOC, and IOC pollution potentials as suggested by considerations of manufacturing, agriculture, and geographic diversity factors. Nationally, TRI releases have been reported for 1,2-dichloropropane from 15 States, including 5 of 16 cross-section States. As an isolated chemical, 1,2-Dichloropropane is no longer produced in any State. The cross-section should adequately represent the occurrence of 1,2-dichloropropane on a national scale based upon the use, production, and release patterns of the 16-State cross-section in relation to the patterns observed for all 50 States.

4.7.7 References

Agency for Toxic Substances and Disease Registry (ATSDR). 1989. *Toxicological Profile for 1,2-Dichloropropane*. U.S. Department of Health and Human Services, Public Health Service. 118 pp. + Appendices. Available on the Internet at http://www.atsdr.cdc.gov/toxprofiles/tp134.pdf.

Dow Chem Co. 1983. *Letter summarizing the EPA/DOW Chemical Co. meeting regarding the manufacture of 1,2-dichloropropane.* OTS Section 4 submission by Dow Chemical Co. Document No. 40-8367072. Microfiche No, OTS 0511731.

Hazardous Substances Data Bank (HSDB). 1988. Hazard Substances Data Bank. On-line: July 27, 1988.

International Agency for Research on Cancer (IARC). 1986. IARC Monograph on the Evaluation of Carcinogenic Risks to Humans: Some halogenated hydrocarbon and pesticide exposure. v. 41, pp. 131-147.

Lopes, T.J. and S.G. Dionne. 1998. *A Review of Semivolatile and Volatile Organic Compounds in Highway Runoff and Urban Stormwater*. U.S. Geological Survey Open-File Report 98-409. 67 pp.

Meister, R.T. 1987. *Farm chemicals handbook '87.* Willoughby, OH: Meister Publishing Co.

Squillace, P.J., M.J. Moran, W.W. Lapham, C.V. Price, R.M. Clawges, and J.S. Zogorski. 1999. Volatile organic compounds in untreated ambient groundwater of the United States, 1985-1995. *Env. Sci. and Tech*. 33(23):4176-4187.

SRI. 1988. *Directory of Chemical Producers: United States of America*. p. 921.

USEPA. 1986. Toxic substances; 1,2-dichloropropane; testing requirements. Final rule. Fed Reg 51:32079-32087.

USEPA. 1987. *Occurrence of Synthetic Organic Chemicals in Drinking Water, Food, and Air.* Office of Drinking Water, USEPA. July 1987.

USEPA. 1989. *Comments of the Dow Chemical Company on ATSDR's Toxicology Profile for 1,2-Dichloride.* Submitted to ATSDR May 1, 1989.

USEPA. 2000. *TRI Explorer: Trends*. Available on the Internet at: http://www.epa.gov/triexplorer/trends.htm, last updated May 5, 2000.

USEPA. 2001. *Consumer Factsheet on: 1,2-Dichloropropane*. Available on the Internet at: http://www.epa.gov/safewater/dwh/c-voc/12-dich3.html, last updated April 12, 2001.

USEPA. 2002. *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT.* EPA Report/815-D-02-005, Office of Water, 55 pp.

United States International Trade Commission (USITC). 1987. *Synthetic Organic Chemicals: United States Production and Sales, 1986.* USITC Pub 2009. pp. 233; 238.

Still need references cited in USEPA, 1987

4.8 Tetrachloroethylene

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Tables and Figures

4.8.1 Introduction, Use and Production

Tetrachloroethylene is a manufactured organic compound with the chemical formula C_2Cl_4. It is a nonflammable liquid at room temperature, evaporates easily into the air, and has a sharp, sweet odor. The major routes of entry of tetrachloroethylene to drinking water are a consequence of its production and industrial use. It is expected that discharges into surface water would volatilize into the atmosphere fairly rapidly. It is expected that discharges during production and use, and leaching into groundwater from wastes deposited in landfills are primary causes of tetrachloroethylene contamination of drinking water. Additionally, tetrachloroethylene may enter drinking water through the use of vinyl-lined A/C pipe (JRB Associates, 1983). Other names for tetrachloroethylene include 1,1,2,2,-tetrachloroethylene, perchloroethylene, PCE, perc, tetrachloroethene, perclene, and perchlor (ATSDR, 1997).

Tetrachloroethylene is a commercially important chlorinated hydrocarbon solvent and chemical intermediate in the production of chlorofluorocarbons. It is used as a dry cleaning and textile-processing solvent and for vapor degreasing in metal-cleaning operations. Tetrachloroethylene was first commercially produced in the U.S. in 1925. There has been an overall decline in production of about 50% between 1983 and 1993, from 547 to 271 million pounds (ATSDR, 1997). In 1986, production of tetrachloroethylene totaled 405 million pounds (USEPA, 2001) and 1991 production has been reported as 310 million pounds. The major reasons for the decline in production are solvent recycling and reduced demand for chlorofluorocarbons (USEPA, 1994).

The 1995 Directory of Chemical Producers in the U.S. lists three major manufacturers of tetrachloroethylene with a total annual capacity of 490 million pounds. Tetrachloroethylene is also produced naturally by various temperate and subtropical marine macroalgae at the rate of 0.0026-8.2 ng/g fresh weight/hour, a potentially significant amount in the global chlorine budget (ATSDR, 1997).

It is widely used for dry cleaning of fabrics and for metal-degreasing operations and is also used as a starting material (building block) for making other chemicals and in some consumer products (ATSDR, 1997). In 1995, the estimated end-use breakdown for tetrachloroethylene was as follows: 55% as a chemical intermediate, 25% for metal cleaning and vapor degreasing, 15% for dry cleaning and textile processing, and 5% miscellaneous (ATSDR, 1997). In small amounts, tetrachloroethylene is used in rubber coatings, solvent soaps, printing inks, adhesives and glues, sealants, polishes, lubricants, and pesticides (NSC, 2001).

Other uses of tetrachloroethylene include use in veterinary medicine as an anthelmintic; as a fumigant for insects and rodents; as a vermifuge; as a heat-transfer medium; in copying machines; in the manufacture of paint removers; and in removing soot from industrial boilers (NTP, 1991). Formerly tetrachloroethylene was used as an anthelmintic against hookworms, intestinal flukes, and nematodes; but it has since been supplanted by drugs that are less toxic and easier to administer (ATSDR, 1997).

Table 4.8-1 shows the number of facilities in each State that manufacture and process tetrachloroethylene, the intended uses of the product, and the range of maximum amounts derived from the Toxics Release Inventory (TRI) of EPA (ATSDR, 1997).

Table 4.8-1: Tetrachloroethylene Manufacturers and Processors by State

State[a]	Number of facilities	Range of maximum amounts on site in thousands of pounds[b]	Activities and uses[c]
AL	5	1-100	2,3,4,10,13
AR	4	1-100	2,3,8,12,13
AZ	2	1-10	13
CA	63	0-10,000	2,3,4,7,8,9,10,11,12,13
CO	2	1-100	12,13
CT	16	1-1,000	11,12,13
FL	11	1-1,000	8,11,12,13
GA	12	0-1,000	2,3,5,8,10,11,13
IA	7	0-1,000	11,12,13
IL	35	0-10,000	2,3,4,8,10,11,12,13
IN	26	0-100	2,3,8,10,11,12,13
KS	8	1-10,000	1,3,4,7,8,11,12,13
KY	10	1-1,000	1,3,7,8,11,12,13
LA	16	0-50,000	1,3,4,5,6,7,8,9,11,12,13
MA	7	1-1,000	8,10,12,13
MD	2	1-10	12,13
ME	1	1-10	12
MI	10	1-1,000	7,8,10,11,12,13
MN	11	1-100	2,3,11,12,13
MO	12	1-1,000	8,11,12,13
MS	5	10-1,000	8,11,12,13
MT	2	1-100	11,13
NC	20	0-1,000	2,3,5,7,8,11,12,13
NE	4	1-100	12,13
NH	4	1-100	13
NJ	6	0-100	8,11,12,13
NY	20	0-1,000	8,10,11,12,13
OH	48	0-1,000	2,3,8,10,11,12,13
OK	8	1-1,000	11,12,13
OR	1	10-100	11
PA	18	0-10,000	8,10,11,12,13
PR	2	0-10	2,5,8,13
SC	12	1-100	8,12,13
TN	8	1-1,000	8,11,12,13
TX	25	1-50,000	1,2,3,4,5,6,7,8,10,11,12,13
UT	3	1-100	11,13
VA	7	0-1,000	2,3,9,11,13
VT	1	100-1,000	12
WA	1	1-10	12
WI	12	1-100	7,8,10,12,13
WY	1	0-1	11,13

[a] Post office State abbreviations used
[b] Data in TRI are maximum amounts on site at each facility
[c] Activities/Uses include:

1. Produce
2. Import
3. For on-site use/processing
4. For sale/distribution
5. As a by-product
6. As an impurity
7. As a reactant
8. As a formulation component
9. As an article component
10. For repackaging only
11. As a chemical processing aid
12. As a manufacturing aid
13. Ancillary or other uses

Source: ATSDR, 1997 compilation of TRI93 1995 data

4.8.2 Environmental Release

Tetrachloroethylene is listed as a Toxics Release Inventory (TRI) chemical. Table 4.8-2 illustrates the environmental releases for tetrachloroethylene from 1988 - 1999. (Tetrachloroethylene data are only available for these years.) Air emissions constitute the vast majority of the on-site releases, with a steady decrease over the years. The decrease in air emissions, as well as surface water discharges and a general decrease in off-site emissions (including metals or metal compounds transferred off-site), have contributed to decreases in tetrachloroethylene total on- and off-site releases in recent years. Releases to land (such as spills or leaks within the boundaries of the reporting facility) display no particular trend, and underground injection has fluctuated between 5,000 and 20,000 pounds, with the exception of high levels of releases in 1988-1989. These TRI data for tetrachloroethylene were reported from 48 States (with the exceptions of Alaska and Wyoming), Puerto Rico, and the Virgin Islands (USEPA, 2000). Thirty-one of the 48 States reported every year. All 16 of the cross-section States (used for analyses of tetrachloroethylene occurrence in drinking water; see Section 4.8.4) reported releases of tetrachloroethylene. (For a map of the 16-State cross-section, see Figure 1.3-1.)

Table 4.8-2: Environmental Releases (in pounds) for Tetrachloroethylene in the United States, 1988-1999

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1999	3,648,732	1,793	8,897	19,885	27,966	3,707,273
1998	5,463,597	1,490	5,916	2,992	130,927	5,604,922
1997	7,213,469	2,282	15,118	5,074	29,228	7,265,171
1996	7,995,845	1,561	13,436	5,472	23,212	8,039,526
1995	9,674,185	2,407	20,481	6	78,953	9,776,032
1994	10,826,150	3,877	4,051	4,349	80,255	10,918,682
1993	11,357,864	10,157	15,041	618,026	56,340	12,057,428
1992	12,816,529	10,322	12,780	9,754	113,324	12,962,709
1991	17,384,881	7,453	14,005	23,309	115,933	17,545,581
1990	23,000,633	21,510	11,012	1,260	796,846	23,831,261
1989	27,813,294	53,940	50,000	10,791	1,044,249	28,972,274
1988	36,124,485	33,314	72,250	82,144	1,385,378	37,697,571

Source: USEPA, 2000

4.8.3 Ambient Occurrence

Tetrachloroethylene was detected in 67 out of 403 wells (16.6%) in urban areas of the local, State, and federal data set compiled by NAWQA. The minimum and maximum concentrations detected were 0.2 µg/L and 260 µg/L, respectively. The median value of detection concentrations was 1.1 µg/L. Tetrachloroethylene was also detected in 64 of the 2,526 wells (2.5%) with analysis in rural areas. The minimum and maximum concentrations detected were 0.2 µg/L and 250 µg/L, respectively. The median value of detection concentrations was 0.8 µg/L. These data (urban and rural) represent untreated ambient ground water of the conterminous United States for the years 1985-1995 (Squillace et al., 1999).

Tetrachloroethylene was also an analyte in both the NURP and NPDES data (Lopes and Dionne, 1998). In a comparison of the two data sets, the frequency of detection of tetrachloroethylene for NURP was 5%, while the frequency of detection for NPDES was 8%. The NURP study found tetrachloroethylene in urban runoff. The minimum and maximum concentrations detected were 4.5 µg/L and 43 µg/L, respectively, with no mean value reported. The NPDES related investigations analyzing urban and highway runoff detected tetrachloroethylene. The minimum and maximum concentrations detected were <0.2 µg/L and 42 µg/L, respectively, with no mean value reported. The use of the land from which the samples were taken was unspecified.

4.8.3.1 Additional Ambient Occurrence Data

A summary document, entitled "Occurrence of Tetrachloroethylene in Drinking Water, Food and Air" (JRB Associates, 1983), was previously prepared for past USEPA assessments of tetrachloroethylene. However, no information on the ambient occurrence of tetrachloroethylene was included in that document. (The document did include information regarding tetrachloroethylene occurrence in drinking water, which is discussed in Section 4.8.5 of this report.)

4.8.4 Drinking Water Occurrence Based on the 16-State Cross-Section

The analysis of tetrachloroethylene occurrence presented in the following section is based on State compliance monitoring data from the 16 cross-section States. The 16-State cross-section is the largest and most comprehensive compliance monitoring data set compiled by EPA to date. These data were evaluated relative to two concentration thresholds of interest: 0.005 mg/L; and 0.0005 mg/L.

All sixteen cross-section State data sets contained occurrence data for tetrachloroethylene. These data represent more than 195,000 analytical results from approximately 22,000 PWSs during the period from 1984 to 1998 (with most analytical results from 1992 to 1997). The number of sample results and PWSs vary by State, although the State data sets have been reviewed and checked to ensure adequacy of coverage and completeness. The overall modal detection limit for tetrachloroethylene in the 16 cross-section States is equal to 0.0005 mg/L. (For details regarding the 16-State cross-section, please refer to Section 1.3.5 of this report.)

4.8.4.1 Stage 1 Analysis Occurrence Findings

Table 4.8-3 illustrates the occurrence of tetrachloroethylene in drinking water for the public water systems in the 16-State cross-section. The percentage of total ground and surface water PWSs with any analytical results exceeding the MCL (0.005 mg/L) was equal to 0.778% (a total of 174 systems). Approximately 2.89% of total ground and surface water systems (646 PWSs) had any analytical results greater than the modal detection limit (0.0005 mg/L).

A greater *proportion* of surface water systems, as compared to ground water systems, exceeded each threshold. Yet, a greater *number* of ground water systems exceeded each threshold, as compared to surface water systems. Approximately 0.692% of ground water PWSs (144 systems) had any analytical results exceeding the MCL, compared to 1.91% of surface water systems (30 systems). The percentage of ground water PWSs with any analytical results exceeding 0.0005 mg/L was equal to about 2.72% (565 ground water systems). Close to 5.2% of surface water PWSs (a total of 81 systems) had at least one analytical result greater than 0.0005 mg/L.

Table 4.8-3: Stage 1 Tetrachloroethylene Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Ground Water	0.005	0.692%	144
	0.0005	2.72%	565
Surface Water	0.005	1.91%	30
	0.0005	5.17%	81
Combined Ground & Surface Water	0.005	0.778%	174
	0.0005	2.89%	646

Reviewing tetrachloroethylene occurrence by PWS population served (Table 4.8-4) shows approximately 13.5% of the total 16-State cross-section population (almost 15 million people) was served by PWSs with at least one analytical result greater than the MCL. Approximately 22.9% of the population (over 25 million people) was served by systems with analytical results greater than 0.0005 mg/L.

About 7.13% of the population served by ground water systems (over 3.5 million people) was exposed to tetrachloroethylene levels above the MCL. Approximately 19.5% of the population (almost 10 million people) was served by ground water systems with at least one analytical result greater than 0.0005 mg/L.

Approximately 18.6% of the population (over 11 million people) was served by surface water PWSs with at least one analytical results greater than the MCL. About 25.7% of the population (almost 16 million people) was served by surface water PWSs with any analytical results greater than 0.0005 mg/L.

Table 4.8-4: Stage 1 Tetrachloroethylene Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Ground Water	0.005	7.13%	3,524,300
	0.0005	19.5%	9,633,800
Surface Water	0.005	18.6%	11,390,000
	0.0005	25.7%	15,717,500
Combined Ground & Surface Water	0.005	13.5%	14,914,300
	0.0005	22.9%	25,351,400

4.8.4.2 Stage 2 Analysis Occurrence Findings

The Stage 2 occurrence findings, based on the cross-section data, are presented in Tables 4.8-5 and 4.8-6. The statistically generated best estimate values, as well as the ranges around the best estimate value, are presented. (For a review of the Stage 2 analytical approach, please refer to Section 1.4 of this report. For complete details regarding the Stage 2 analyses, please refer to *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT* (USEPA, 2002)).

Approximately 45 (0.202% of all) ground water and surface water PWSs in the 16 States were estimated to have mean concentrations of tetrachloroethylene above 0.005 mg/L. The percentage of PWSs with estimated mean concentrations exceeding 0.0005 mg/L was about 1.62% of PWSs in the 16 States (362 systems).

Similar to the Stage 1 analysis, Stage 2 analysis estimated a greater *proportion* of surface water systems, as compared to ground water systems, exceeding each threshold, but a greater *number* of ground water systems exceeding each threshold. Approximately 40 (0.194% of) ground water systems in the 16 States had estimated mean concentrations of tetrachloroethylene above 0.005 mg/L, compared to approximately 5 (0.317% of) surface water systems in the 16 States. The estimated mean concentration values for approximately 324 (1.56%) ground water PWSs in the 16 States exceeded 0.0005 mg/L. About 39 (2.48% of) surface water systems in the 16 States had estimated mean concentrations exceeding the modal detection limit.

Table 4.8-5: Stage 2 Estimated Tetrachloroethylene Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	**Threshold (mg/L)**	**Percent of Systems Estimated to Exceed Threshold**		**Number of Systems in the 16 States Estimated to Exceed Threshold**	
		Best Estimate	**Range**	**Best Estimate**	**Range**
Ground Water	0.005	0.194%	0.154% - 0.231%	40	32 - 48
	0.0005	1.56%	1.43% - 1.68%	324	297 - 349
Surface Water	0.005	0.317%	0.191% - 0.447%	5	3 - 7
	0.0005	2.48%	2.17% - 2.87%	39	34 - 45
Combined Ground & Surface Water	0.005	0.202%	0.166% - 0.237%	45	37 - 53
	0.0005	1.62%	1.50% - 1.74%	362	335 - 390

Reviewing tetrachloroethylene occurrence by PWS population served (Table 4.8-6) shows that over 757,000 (0.685% of) people in the 16 States were served by systems with mean tetrachloroethylene concentrations above 0.005 mg/L. When evaluated relative to a threshold of 0.0005 mg/L, the percent of population exposed increased significantly to about 12.2% (approximately 13.5 million people served in the 16 States).

Of the 16-State cross-section population served by ground water, approximately 0.833% of the population was served by PWSs (almost 412,000 people served in the 16 States) with estimated mean concentrations of tetrachloroethylene above 0.005 mg/L. An estimated 3.6 million (7.36% of) people served by ground water systems in the 16 States were exposed to tetrachloroethylene above 0.0005 mg/L.

Approximately 0.565% of the population (345,600 people in the 16 States) was served by surface water PWSs with estimated mean concentrations greater than 0.005 mg/L. The percentage of population served by surface water PWSs with estimated mean concentrations greater than 0.0005 mg/L increased dramatically to approximately 16.2% (almost 10 million people in the 16 States).

Table 4.8-6: Stage 2 Estimated Tetrachloroethylene Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.005	0.833%	0.642% - 1.10%	411,600	317,200 - 544,500
	0.0005	7.36%	6.72% - 8.32%	3,636,800	3,319,200 - 4,112,100
Surface Water	0.005	0.565%	0.218% - 0.777%	345,600	133,500 - 475,400
	0.0005	16.2%	15.2% - 18.6%	9,875,900	9,288,800 - 11,392,400
Combined Ground & Surface Water	0.005	0.685%	0.470% - 0.873%	757,200	519,700 - 965,100
	0.0005	12.2%	11.5% - 13.7%	13,510,200	12,747,300 - 15,102,200

4.8.4.3 Estimated National Occurrence

Based on the Stage 2 estimated percent of systems (and population served by systems) exceeding each threshold, an estimated 132 PWSs serving almost 1.5 million people nationally could be exposed to tetrachloroethylene concentrations above 0.005 mg/L. About 1,053 systems serving over 26 million people nationally had estimated mean concentrations greater than 0.0005 mg/L. (See Section 1.4 for a description of how Stage 2 16-State estimates are extrapolated to national values.)

For ground water systems, an estimated 115 PWSs serving about 713,800 people nationally had mean concentrations greater than 0.005 mg/L. Approximately 925 systems serving about 6.3 million people nationally had estimated mean concentration values that exceeded 0.0005 mg/L.

Approximately 18 surface water systems serving about 719,500 people nationally were estimated to have mean concentrations of tetrachloroethylene above 0.005 mg/L. About 139 surface water systems serving almost 21 million people had estimated mean concentrations greater than 0.0005 mg/L.

Table 4.8-7: Estimated National Tetrachloroethylene Occurrence - Systems and Population Served

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.005	115	91 - 137	713,800	550,200 - 944,200
	0.0005	925	849 - 997	6,307,000	5,756,100 - 7,131,300
Surface Water	0.005	18	11 - 25	719,500	278,000 - 989,800
	0.0005	139	121 - 161	20,563,200	19,340,900 - 23,720,900
Combined Ground & Surface Water	0.005	132	108 - 154	1,458,900	1,001,400 - 1,859,300
	0.0005	1,053	974 - 1,134	26,029,600	24,559,800 - 29,096,900

4.8.5 Additional Drinking Water Occurrence Data

Several additional data sources regarding the occurrence of tetrachloroethylene in drinking water are also reviewed. Previously compiled occurrence information, from an OGWDW summary document entitled "Occurrence of Tetrachloroethylene in Drinking Water, Food, and Air" (JRB Associates, 1983), is presented in this section. This variety of studies and information are presented regarding levels of tetrachloroethylene in drinking water, with the scope of the reviewed studies ranging from national to regional. Note that none of the studies presented in the following section provide the quantitative analytical results or comprehensive coverage that would enable direct comparison to the occurrence findings estimated with the cross-section occurrence data presented in Section 4.8.4. These additional studies, however, do enable a broader assessment of the Stage 2 occurrence estimates presented for this Six-Year Review. All the following information in Section 4.8.5 is taken directly from "Occurrence of Tetrachloroethylene in Drinking Water, Food, and Air" (JRB Associates, 1983).

JRB Associates (1983) found two major types of data available that are potentially useful for describing the occurrence of tetrachloroethylene in the nation's public drinking water supplies. First, there are several Federal surveys in which a number of public water supplies from throughout the U.S. were selected for analysis of chemical contamination, including tetrachloroethylene. Second, data are available from State surveys and from State investigations of specific incidents of known or suspected contamination of a supply. For accomplishing the basic objectives of this study, namely to estimate the number of public water supplies nationally within the various source and size categories contaminated with tetrachloroethylene, the distribution of tetrachloroethylene concentrations in those supplies, and the number of individuals exposed to those concentrations, it was determined that the Federal survey data provides the most suitable data base. The State data tend to be poorly described with respect to the source and size categories of the supplies examined and the sampling and analysis methods used for determining contaminant levels. The lack of source and system size information precludes using the data for estimating levels in public water supplies of similar characteristics. The absence of details on sampling and analysis methods precludes evaluating those data for their qualitative and quantitative reliability. Also, because much of the State data are from investigations in response to incidents of known or suspected contamination (e.g., spills), they were judged to be not representative of contaminant levels in the nation's water supplies in general. Although they are not used with the Federal data for the purpose of estimating contamination levels nationally, the available State data are presented here to provide some additional perspective on tetrachloroethylene occurrence in drinking water.

Data are presented only on drinking water samples taken from a consumer's tap (i.e., distribution water samples) or on treated water samples taken at the water supply (i.e., finished water samples) because these are considered to be most representative of the water consumed by the public. No data on raw (i.e., untreated) water are presented. It is recognized that for some groundwater supplies where no treatment of the water occurs, samples identified as raw may be representative of water consumed by the users of the supply. However, it was generally not possible to differentiate between those groundwater supplies that do and those that do not treat raw water from the available survey data.

4.8.5.1 Overview and Quality Assurance Assessment of Federal Drinking Water Surveys

Five Federal drinking water surveys provide data on tetrachloroethylene: the National Organic Monitoring Survey (NOMS), the National Screening Program for Organics in Drinking Water (NSP), the 1978 Community Water Supply Survey (CWSS), the Rural Water Survey (RWS), and the Groundwater Supply Survey (GWSS). The terms used in this report are those used in the individual surveys, recognizing that they may not always correspond to strict technical definitions.

The National Organic Monitoring Survey (NOMS) was conducted to identify contaminant sources, to determine the frequency of occurrence of specific drinking water contaminants, and to provide data for the establishment of maximum contaminant levels (MCL's) for various organic compounds in drinking water (Brass et al., 1977, as cited in JRB Associates, 1983). The NOMS was conducted in three phases: March-April 1976, May-July 1976, and November 1976-January 1977. For tetrachloroethylene, qualitative results are available for Phase II and quantitative results for Phase III. Tetrachloroethylene was not analyzed for in Phase I. Finished drinking water samples from 113 communities were analyzed for 21 different compounds. Of the 113 community supplies sampled, 18 had groundwater sources, 91 had surface water sources, and 4 had a mixed groundwater/surface water source. In Phase III, only 14 groundwater supplies had data available for tetrachloroethylene.

The analytical results of the NOMS were made available in printed form by EPA's Technical Support Division, Office of Drinking Water. Additional information on the locations and source of the supplies, and on the populations served by the supplies in the NOMS were provided by Wayne Mello (1983, as cited in JRB Associates, 1983) at EPA's Technical Support Division, Office of Drinking Water. A single value for tetrachloroethylene was reported for each supply studied in the NOMS.

The National Screening Program for Organics in Drinking Water (NSP), conducted by SRI International from June 1977 to March 1981, examined both raw and finished drinking water samples from 166 water systems in 33 States for 51 organic chemical contaminants. Data are available for tetrachloroethylene on finished water samples from 12 groundwater and 106 surface water supplies.

In the Community Water Supply Survey (CWSS), carried out in 1978, 106 surface water supplies, 330 groundwater supplies, and 16 supplies with mixed sources were examined for volatile organic chemical contamination. Samples were taken of raw, finished, and distribution water. Only the latter two types of water are considered here. Data for tetrachloroethylene in finished and/or distribution samples were obtained from a total of 316 groundwater and 105 surface water supplies.

The Rural Water Survey (RWS), conducted in 1978, was carried out in response to Section 3 of the Safe Drinking Water Act, which mandated that EPA "conduct a survey of the quantity, quality, and availability of rural drinking water supplies." Drinking water samples were collected for analysis of inorganic chemicals, pesticides, and VOCs from 2,655 households throughout the United States located in areas defined in the survey as rural. Of these, a total of 855 household samples were examined for VOCs. The majority of these samples were obtained from households receiving water from private wells or small supplies serving fewer than 25 people. For tetrachloroethylene, data are available in the RWS for 207 groundwater and 45 surface water supplies serving 25 or more people.

The RWS did not obtain data on the number of persons in each household served by the supplies. However, data were obtained on the number of service connections at each supply. With the input of Dr. Bruce Brower at Cornell University, who participated in the statistical analysis of the RWS for parameters other than VOCs, the population served by each supply was estimated from the average number of persons per household (3.034) observed in the survey. A single value was reported for each household; in some cases it was necessary to average two or three households obtaining water from the same supply. Brass (1981, as cited in JRB Associates, 1983) cautions that the RWS water samples were analyzed 6 to 27 months after collection and that degradation of some VOCs may have occurred during this holding period.

The Groundwater Supply Survey (GWSS) was conducted from December 1980 to December 1981 to develop additional data on the occurrence of volatile organic chemicals in the nation's groundwater supplies (Westrick et al., 1983, as cited in JRB Associates, 1983). It was hoped that this study would stimulate State efforts toward the detection and control of groundwater contamination and the identification of potential chemical "hot spots." A total of 945 systems were sampled, of which 466 were chosen at random. The remaining 479 systems were chosen non-randomly based on information from States encouraged to identify locations believed to have a higher than normal probability of VOC contamination (e.g., locations near landfills or industrial activity). The file provided a single analytical result for each supply sampled. One sample of finished water was collected from each supply at a point near the entrance to the distribution system.

Each of the drinking water surveys was evaluated with respect to the validity of the reported occurrence data for a number of organic chemicals, including tetrachloroethylene. The evaluations were carried out by analyzing information about the procedures used for collection and analysis of samples as well as the quality control protocols used. The analyzed compounds dealt with in each study were assigned one of three possible ratings: quantitatively acceptable, qualitatively acceptable (i.e., the substance measured was tetrachloroethylene), and totally unacceptable. In the case of tetrachloroethylene, a qualitatively acceptable rating was given for data from the NOMS, NSP, CWSS, and RWS because of suspected biodegradation of the samples, which were held unrefrigerated for prolonged periods before analysis (particularly CWSS and RWS). Tetrachloroethylene values in excess of the quantitation limit reported for some samples in these studies are qualitatively valid and can be taken as minimum values, representative of samples which probably originally contained tetrachloroethylene at higher concentrations. In the case of the GWSS, all data were rated both quantitatively and qualitatively acceptable.

4.8.5.2 Groundwater – Federal Surveys

The National Organic Monitoring Survey (NOMS), the National Screening Program for Organics in Drinking Water (NSP), the Community Water Supply Survey (CWSS), the Rural Water Survey (RWS), and the Groundwater Supply Survey (GWSS) all contain data concerning the levels of tetrachloroethylene in groundwater supplies from across the country.

Tetrachloroethylene was not analyzed for in Phase I of NOMS (March to April 1976). In NOMS Phase II (May to July 1976), a qualitative assessment that tetrachloroethylene was present in 6 of the 18 groundwater supplies sampled was made on the basis of the presence of a peak on the gas chromatograph at the appropriate retention time for tetrachloroethylene. As indicated previously, a rigorous analysis of all samples was not made, and some samples with smaller tetrachloroethylene peaks may have been overlooked. Samples analyzed during Phase III of the study (November 1976 to January 1977) proved positive for two of the 14 systems for which data are available, with levels of 1.1 and 3.1 µg/L. The minimum quantifiable limit for tetrachloroethylene was 0.2 µg/L in Phase III.

Twelve groundwater supplies were tested for tetrachloroethylene contamination in the NSP. Of these 12 systems, three were found to be contaminated with tetrachloroethylene at levels of 0.1, 0.2, and 0.7 µg/L. The quantification limit for tetrachloroethylene was 0.1 µg/L.

The 1978 CWSS provided information on tetrachloroethylene levels in 316 groundwater systems. Of these systems, 18 contained detectable levels of tetrachloroethylene, with values ranging from 0.51-15.3 µg/L. The two highest values were 3.1 µg/L and 15.3 µg/L; all other values were less than 3.0 µg/L. The mean value was 2.1 µg/L with a standard deviation of 3.4 µg/L; the median value was 1.2 µg/L. The minimum quantitation limit for tetrachloroethylene in the CWSS was 0.5 µg/L.

The RWS examined 207 groundwater supplies for tetrachloroethylene and found 7 to have levels above the minimum quantification limit range of 0.5-1.5 µg/L. The range of positive values was 1.0 to 8.2 µg/L. The mean of the positive values was 3.2 µg/L with a standard deviation of 2.5 µg/L; the median concentration was 2.1 µg/L. In the GWSS, 34 of the 456 randomly chosen water systems serving 25 or more individuals were contaminated with tetrachloroethylene, at concentrations ranging from 0.21-23 µg/L. The three systems with the highest values were contaminated at 2.9, 5.9, and 23 µg/L. Twenty-one of the 34 positive systems served populations in excess of 10,000 people. The average for all randomly chosen systems was 1.5 µg/L with a standard deviation of 4 µg/L; the median was 0.5 µg/L. Of the 473 nonrandom locations sampled serving 25 or more individuals, 43 were contaminated with tetrachloroethylene, at concentrations between 0.22-69 µg/L, the highest values being 20, 21, and 69 µg/L. Of the 43 positive samples, 18 were from systems serving populations in excess of 10,000 people. The average tetrachloroethylene level for the nonrandom systems was 4.7 µg/L with a standard deviation of 11 µg/L; the median value was 0.73 µg/L. The minimum quantitation limit for tetrachloroethylene was 0.2 µg/L.

4.8.5.3 Groundwater – State Data

Seven States (California, Connecticut, Delaware, Indiana, Massachusetts, New Jersey, and New York) provided the USEPA with information concerning tetrachloroethylene contamination in groundwater supplies. Analytical results for 407 samples from 16 areas in California revealed 257 positive samples with tetrachloroethylene concentrations from 0.03 to “greater than 20" µg/L. Monitoring data from 55 locations in Connecticut revealed a wide range of contamination levels. Fifteen cities were supplied with water containing no detectable tetrachloroethylene. Of the 40 systems with detectable tetrachloroethylene, 20 had levels of 2.5 µg/L or less, 13 had levels between 2.5-10 µg/L, and seven were contaminated at 10-640 µg/L. Data from Delaware indicated that of eight samples taken from finished groundwater supplies in two counties, five contained tetrachloroethylene at 0.79-7.1 µg/L. Information supplied by Indiana showed that eight samples from one system were free of detectable tetrachloroethylene contamination. Of five systems sampled in Massachusetts, four were free of detectable contamination while another had between 24-49 µg/L. Data from New Jersey showed a large variation in the concentration of measured tetrachloroethylene contamination, ranging from undetectable to 870 µg/L. Finally, of 421 samples from Nassau County, New York, 67 reported tetrachloroethylene to be present qualitatively.

4.8.5.4 Surface Water – Federal Surveys

The National Organic Monitoring Survey (NOMS), the National Screening Program for Organics in Drinking Water (NSP), the Community Water Supply Survey (CWSS), and the Rural Water Survey (RWS) all contain data concerning the levels of tetrachloroethylene in surface water supplies from across the country.

Tetrachloroethylene was not analyzed for in Phase I of NOMS. In NOMS Phase II (May to July 1976), a qualitative assessment that tetrachloroethylene was present in 40 of 91 surface water supplies sampled (and in one of the mixed source supplies using surface water ,during Phase II) was made on the basis of the presence of a peak on the gas chromatograph at the appropriate retention time for tetrachloroethylene. As indicated previously, a rigorous analysis of all samples was not made, and some samples with smaller tetrachloroethylene peaks may have been overlooked. During Phase III of NOMS (November 1976 to January 1977), analyses revealed tetrachloroethylene contamination in 7 out of a total of 87 systems. The contamination levels for these systems ranged from 0.2-0.82 µg/L. The mean concentration was 0.4 µg/L with a standard deviation of 0.2 µg/L; the median level was 0.45 µg/L. The minimum quantifiable limit for tetrachloroethylene was 0.2 µg/L in Phase III.

Surface water samples from 106 drinking water systems were analyzed for tetrachloroethylene during the National Screening Program (NSP) between June 1977 and March 1981. Of these, 16 systems contained detectable levels of tetrachloroethylene, ranging from 0.1-3.2 µg/L. Only two of these systems were contaminated at levels greater than 1.0 µg/L (1.1 and 3.2 µg/L). The average concentration among the 16 positive systems was 0.6 µg/L with a standard deviation of 0.8 µg/L; the median level was 0.4 µg/L. The quantification limit for the NSP was 0.1 µg/L.

Of the 105 surface water systems sampled during the Community Water Supply Survey (CWSS), 2 contained quantifiable levels of tetrachloroethylene. The positive values were 0.5 and 1.7 µg/L. The minimum quantitation limit for tetrachloroethylene in the CWSS was 0.5 µg/L. The RWS examined drinking water from 45 surface water supplies; none were found to have tetrachloroethylene present above the minimum quantification limit range of 0.5-5 µg/L.

4.8.5.5 Surface Water – State Data

Three States provided the USEPA with data on tetrachloroethylene from surface water sources. Of 12 cities sampled in Connecticut, 10 had tetrachloroethylene contamination, with one mean concentration higher than 10 µg/L (at 31 µg/L). Two of three locations sampled in New York had detectable tetrachloroethylene ranging from 0.49 to 2.8 µg/L. One location in California was sampled twice, revealing no detectable tetrachloroethylene.

4.8.5.6 Projected National Occurrence of Tetrachloroethylene in Public Water Supplies

As reported in the JRB Associates study, public water systems fall into two major categories with respect to water source (surface water and groundwater) and into five size categories and twelve subcategories according to the number of individuals served. The JRB Associates (1983) report presented estimates of both the number of drinking water supplies nationally within each of the source/size categories expected to have tetrachloroethylene present, and of the concentration of tetrachloroethylene expected to be present in those supplies.

The key features of the methodology used and assumptions made to develop the national estimates are summarized here. The estimates are based on the data from the Federal surveys only. The State data were not included for several reasons. Generally, these data are from a few States (e.g., California and Connecticut provide most of the data) and were not considered to be geographically representative. There was also a general lack of data on the population served by systems measured, the type of water sampled, and the methodologies used to sample, identify, and measure tetrachloroethylene. Furthermore, since much of these data were apparently obtained in response to incidents of recognized contamination problems, they may not be representative of typical conditions existing nationally. However, while these data were not used for computing the national projections, they do provide a valuable and necessary perspective for evaluating those projections, especially with respect to the projected high levels of contamination of tetrachloroethylene.

The Federal survey data from the NOMS, NSP, CWSS, RWS, and GWSS were pooled together for developing the national projections. It was assumed in combining these surveys that the resulting data base would be representative of the nation's water supplies. In the case of the GWSS data, both the random and nonrandom samples were included in the projections because a statistical test of the GWSS data showed that neither the frequency of occurrence of positive values nor the mean of the positive values for tetrachloroethylene was significantly different in the two samples.

Ideally, adequate data would be available to develop the national projections separately for each of the twelve system size categories within the groundwater and surface water groups; however, the available data were too limited for this. JRB Associates (1983) consolidated some of the size categories to have sufficient data for developing the projections. In consolidating data from various size categories, consideration was given to the potential for there being statistically significant differences in the frequency of occurrence of tetrachloroethylene as a function of system size. The consolidation of size categories therefore involved a balancing of the need to group size categories together to have an adequate data base for developing the national projections against the need to treat size categories separately in order to preserve the influence of system size as a determinant of contamination potential. The consolidation of size categories also took into account EPA's classification of systems into the five major groups as very small (25-500), small (501-3,300), medium (3,301-10,000), large (10,001-100,000), and very large (> 100,000) (Kuzmack, 1983, as cited in JRB Associates, 1983).

Once the data were consolidated, statistical models for extrapolating to the national level were tested and an appropriate model selected. In the case of tetrachloroethylene, the multinominal method was used. The frequency of contamination of groundwater and surface water systems at various concentrations was determined for each consolidated size category. For completing the national estimates, it was assumed that the frequency of contamination observed for each consolidated category was directly applicable to each of the system sizes comprising it.

In the JRB Associates (1983) report, it is noted that some of the data used in computing the national estimates are from samples held for a prolonged period of time prior to analysis, with possible biodegradation of tetrachloroethylene. Therefore, these projections of national occurrence may underestimate actual contaminant levels.

4.8.5.6.1 Groundwater Supplies

JRB Associates (1983) reported that data were available for a total of 1,457 supplies from the combined surveys. Of these, 103 supplies were reported to have tetrachloroethylene present, at concentrations ranging from 0.20 µg/L to 69 µg/L.

Based on the overall distribution of positive values and maximum possible values for those supplies in which tetrachloroethylene was not found, 0.5 µg/L was selected as the common minimum quantifiable concentration for the combined survey data. That is, quantitative projections are made of supplies at several concentration ranges ≥ 0.5 µg/L, while only a total number for supplies expected to have either no tetrachloroethylene or levels below 0.5 µg/L can be determined. Although some data indicate the presence of tetrachloroethylene in groundwater supplies at levels < 0.5 µg/L, it is not possible to determine the proportion of supplies that have tetrachloroethylene present and the proportion that are actually free of tetrachloroethylene contamination.

Of the 1,354 supplies reporting no tetrachloroethylene to be present, 1,244 were assumed to have maximum possible levels of < 0.5 µg/L based on the minimum quantifiable concentrations reported for the various surveys (857 of these had maximum levels of < 0.2 µg/L). The other 110 supplies reporting no tetrachloroethylene to be present had maximum possible levels ranging from 1.0 µg/L to 1.5 µg/L. It is assumed, based on the overall distribution of values, that tetrachloroethylene if present in these 110 supplies is so at a concentration of < 0.5 µg/L, although a rigorous, conservative argument could be made for assuming a level equal to the maximum possible value. The impact of this assumption is considerable both in terms of the national projection of groundwater systems between 0.5 and 5 µg/L and the size of the population exposed to that concentration range.

The data indicate that 68 of 1,457 supplies examined had measured values of tetrachloroethylene > 0.5 µg/L. When the twelve size categories were consolidated into the five major EPA groupings, there was an apparent general trend in the frequency of values > 0.5 µg/L as a function of size:

Very small	3.6%	(15/423)
Small	2.2%	(9/416)
Medium	8.5%	(18/213)
Large	5.6%	(20/358)
Very large	12.8%	(6/47)
Overall	4.7%	(68/1,457)

A test for statistical significance revealed that, at the $\alpha = 0.05$ level, the difference between the very small and small categories was not significant; nor was the difference between the large and very large groups. The medium category showed a statistically significant difference from the combined very small and small categories. Three consolidated categories were, therefore, selected for developing the national estimates:

Very small/small (25-3,300)
Medium (3,301-10,000)

Large/very large (> 10,000)

As noted previously, the frequency of occurrence of tetrachloroethylene at various concentrations was determined for the consolidated groups and then applied to the number of supplies nationally within each of the size categories comprising each group.

An estimated 1,557 groundwater supplies (range of 1,047-2,066), approximately 3.2% of the total groundwater supplies in the United States, are expected to have tetrachloroethylene at levels of ≥ 0.5 µg/L; the remaining 46,901 supplies have either no tetrachloroethylene or levels < 0.5 µg/L. It is estimated that 325 supplies (range of 89-560) are expected to have tetrachloroethylene levels > 5 µg/L; while only 3 supplies (range of 0-187) are expected to have levels > 30 µg/L. None are expected at levels above 70 µg/L. Most of the supplies with high tetrachloroethylene levels are expected to be in the smaller size categories. Although, as noted previously, the frequency of tetrachloroethylene occurrence increases with increasing system size, the number of systems affected nationally is greater for the small sizes because there are many more small systems in existence.

It is interesting to note the impact on the national projections of the assumption made that the 110 supplies with undetected but maximum potential values of 1.0-1.5 µg/L had < 0.5 µg/L. Had it been assumed that tetrachloroethylene was present in those supplies at their maximum possible values, the national projection of supplies with tetrachloroethylene levels > 0.5 µg/L would have increased to 6,278 (5,258-7,297) with no differences in levels > 5 µg/L. These differences in the 0.5-5 µg/L range would be found predominantly in systems serving < 10,000 people.

4.8.5.6.2 Surface Water Systems

Data are available for a total of 296 surface water supplies. Of these, 24 supplies were reported by JRB Associates (1983) to have tetrachloroethylene present at concentrations ranging from 0.1 µg/L to 3.2 µg/L.

Based on the overall distribution of positive values and maximum possible values for those supplies in which tetrachloroethylene was not found, 0.5 µg/L was selected as the common minimum quantifiable concentration for the combined survey data. That is, quantitative projections are made of supplies at several concentration ranges ≥ 0.5 µg/L, while only a total number for supplies expected to have either no tetrachloroethylene or levels below 0.5 µg/L can be determined. Although some data indicate the presence of tetrachloroethylene in surface water supplies at levels < 0.5 µg/L, it is not possible to determine the proportion that have tetrachloroethylene present and the proportion that are free of tetrachloroethylene contamination.

Of the 272 supplies reporting no tetrachloroethylene to be present, 243 had maximum possible levels of < 0.5 µg/L based on the minimum quantifiable concentrations reported for the various surveys. The other 29 supplies reporting no tetrachloroethylene to be present had maximum possible levels ranging from 1.0 µg/L to 1.5 µg/L. It is assumed, based on the overall distribution of values, that tetrachloroethylene if present in these 29 supplies is so at a concentration of < 0.5 µg/L, although a rigorous conservative argument could be made for assuming a level equal to the maximum possible value. As will be noted further below, the difference between these alternatives is considerable for the estimate of the number of surface water supplies with tetrachloroethylene at 0.5-5 µg/L; also, the impact on the estimated population exposed to tetrachloroethylene at levels of 0.5-5 µg/L in surface water supplies is very large.

The data also indicates that 11 of the 296 supplies examined had measured values of tetrachloroethylene ≥0.5 µg/L. When the twelve size categories are consolidated into the five major EPA groupings, the frequency of values > 0.5 µg/L as a function of size are:

Very small	0%	(0/20)
Small	1.7%	(1/58)
Medium	0%	(0/39)
Large	6.1%	(4/66)
Very large	5.3%	(6/113)
Overall	3.7%	(11/296)

A test for statistical significance revealed that, at the $\alpha = 0.05$ level, the very small, small, and medium groups were not different from one another and that the large and very large groups are not different; however, the combined very small, small, and medium groups and the combined large and very large groups are different. These two consolidated categories were selected for developing the national estimates:

Very small/small/medium (25-10,000)
Large/very large (> 10,000)

As noted previously, the frequency of occurrence of tetrachloroethylene at various concentrations was determined for the consolidated groups and then applied to the number of supplies nationally within each of the size categories comprising each group.

About 180 surface water supplies (range of 13-346), approximately 1.6% of the total surface water systems in the United States, are expected to have tetrachloroethylene at levels between 0.5 and 5 µg/L; the remaining 11,022 supplies have either no tetrachloroethylene or levels < 0.5 µg/L. It is estimated that no surface water supplies will have levels > 5 µg/L.

There was a notable impact on the national projections by the assumption made that the 29 supplies with undetected but maximum potential values of 1.0-1.7 µg/L had < 0.5 µg/L. Had it been assumed that tetrachloroethylene was present in these supplies at their maximum possible values, the national projections of supplies with tetrachloroethylene levels of 0.5-5 µg/L would be 1,953 (range of 1,282-2,623) supplies. However, there would still be no surface water supplies expected to have levels > 5 µg/L.

4.8.6 Conclusion

Tetrachloroethylene is a commercially important chlorinated hydrocarbon solvent and chemical intermediate in the production of chlorofluorocarbons. It is used as a dry cleaning and textile-processing solvent and for vapor degreasing in metal-cleaning operations. Production of tetrachloroethylene has decreased in recent years, although it is still widely produced and processed. Tetrachloroethylene is also a TRI chemical. Industrial releases of tetrachloroethylene have occurred since 1988 in 48 States, Puerto Rico, and the Virgin Islands. Tetrachloroethylene was an analyte for the NAWQA, NURP, and NPDES ambient occurrence studies. In the NAWQA study, tetrachloroethylene was detected in 16.6% of urban wells and 2.5% of rural wells, with median detection values of 1.1 µg/L and 0.8 µg/L, respectively. The frequency of detection of tetrachloroethylene for NURP was 5%, while the frequency of detection for NPDES was 8%. In the Stage 2 analysis of 16-State occurrence of tetrachloroethylene, 0.202% of combined ground water and surface water systems serving 0.685% of the population exceeded the MCL of 0.005 mg/L. Nationally, 132 ground water and surface water systems combined (serving approximately 1,458,900 people) are estimated to have levels greater than the MCL.

The 16-State cross-section was designed to be nationally representative based upon VOC, SOC, and IOC pollution potentials as suggested by considerations of manufacturing, agriculture, and geographic diversity factors. Nationally, tetrachloroethylene is manufactured and/or processed in 40 States and has TRI releases in 48 States. Tetrachloroethylene is manufactured and/or processed in 14 out of the 16 cross-section States and has TRI releases in all of the 16 cross-section States. The cross-section should adequately represent the occurrence of tetrachloroethylene on a national scale based upon the use, production, and release patterns of the 16-State cross-section in relation to the patterns observed for all 50 States.

4.8.7 References

Agency for Toxic Substances and Disease Registry (ATSDR). 1997. *Toxicological Profile for Tetrachloroethylene*. U.S. Department of Health and Human Services, Public Health Service. 278 pp. + Appendices. Available on the Internet at: http://www.atsdr.cdc.gov/toxprofiles/tp18.pdf.

Brass, H.J., M.A. Feige, T. Halloran, J.W. Mello, D. Munch, and R.F. Thomas. 1977. The National Organic Monitoring Survey: A sampling and analysis for purgeable organic compounds. *Drinking water quality enhancement through source protection.* R.B. Pojasek (ed.). Ann Arbor, MI: Ann Arbor Science, pp. 393-416.

Brass, H.J. 1981. Rural Water Survey organics data. Memorandum of March 17, 1981 to Hugh Hanson, Chief, Science and Technology Branch, Office of Drinking Water, and David Schnare, Office of Drinking Water , USEPA, Washington, DC.

JRB Associates. 1983. *Occurrence of Tetrachloroethylene in Drinking Water, Food and Air - DRAFT.* Draft report submitted to EPA for review June 22, 1983.

Kuzmack, A.M. 1983. Memorandum: Characterization of the water supply industry (FY82). Washington, D.C.: Office of Water, USEPA. May 16, 1983.

Lopes, T.J. and S.G. Dionne. 1998. *A Review of Semivolatile and Volatile Organic Compounds in Highway Runoff and Urban Stormwater*. U.S. Geological Survey Open-File Report 98-409. 67 pp.

Mello, Wayne. 1983. Personal communication between Wayne Mello, Technical Support Division, Office of Drinking Water, USEPA, and author of JRB Associates, 1983, March 10, 1983.

National Safety Council (NSC). 2001. *Tetrachloroethylene Chemical Backgrounder*. Itasca, IL: National Safety Council. Available on the Internet at: http://www.crossroads.nsc.org/ChemicalTemplate.cfm?chempath=chemicals&id=137, accessed July 17, 2001.

National Toxicology Program (NTP). 1991. National Toxicology Program Health and Safety Information Sheet - Tetrachloroethylene. Available on the Internet at http://ntp-db.niehs.nih.gov/NTP_Reports/NTP_Chem_H&S/NTP_Chem1/Radian127-18-4.txt.

Squillace, P.J., M.J. Moran, W.W. Lapham, C.V. Price, R.M. Clawges, and J.S. Zogorski. 1999. Volatile organic compounds in untreated ambient groundwater of the United States, 1985-1995. *Env. Sci. and Tech*. 33(23):4176-4187.

USEPA. 1994. *R.E.D. Facts: Tetrachloroethylene*. EPA Report/749-F-94-020. Washington, DC: Office of Prevention, Pesticides, and Toxic Substances. Available on the Internet at: http://www.epa.gov/opptintr/chemfact/f_perchl.txt

USEPA. 2000. *TRI Explorer: Trends*. Available on the Internet at: http://www.epa.gov/triexplorer/trends.htm, last updated May 5, 2000.

USEPA. 2001. *National Primary Drinking Water Regulations - Consumer Factsheet on: Tetrachloroethylene.* Office of Ground Water and Drinking Water, USEPA. Available on the Internet at: http://www.epa.gov/safewater/dwh/c-voc/tetrachl.html, Last updated April 12, 2001.

USEPA. 2002. *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT*. EPA Report/815-D-02-005, Office of Water, 55 pp.

Westrick, J.J., J.W. Mello, and R.F. Thomas. 1983. *The Ground Water Supply Survey summary of volatile organic contaminant occurrence data.* EPA Technical Support Division, Office of Drinking Water, Cincinnati, Ohio.

4.9 1,1,2-Trichloroethane

Table of Contents

Tables and Figures

4.9.1 Introduction, Use and Production

1,1,2-Trichloroethane (chemical formula $C_2H_3Cl_3$) is a colorless, sweet-smelling liquid. It does not burn easily, but does boil at a higher temperature than water. 1,1,2-Trichloroethane is also known as ethane trichloride, β-trichloroethane, vinyl trichloride, and 1,2,2-trichloroethane (ATSDR, 1989).

The principal use of 1,1,2-trichloroethane is as a chemical intermediate in the production of 1,1-dichloroethylene (also known as vinylidene chloride), which is in turn used to make synthetic fibers and plastic wraps (ATSDR, 1989; USEPA, 2001). 1,1,2-Trichloroethane has limited use as a solvent, where its high solvency is useful. It may also be used as a solvent for fats, oils, waxes, and resins. Information indicates that 1,1,2-trichloroethane has been sold for use in consumer products, but it is not known for which products, nor how extensive the use. A Dow Chemical spokesman, as cited in ATSDR, stated that the company had no knowledge of any consumer uses of 1,1,2-trichloroethane and that the company screens potential customers to determine how they intend to use it (ATSDR, 1989).

1,1,2-Trichloroethane is produced exclusively by Dow Chemical in Freeport, TX, and Olin Corporation in Seward, IL. No recent information on production volumes is available. Dow Chemical was formerly the sole manufacturer of 1,1,2-trichloroethane, and therefore manufacturing volumes from that time period are proprietary information and are unavailable. The only estimates of production of 1,1,2-trichloroethane are based upon the production of 1,1-dichloroethylene. In 1974, the production volume of 1,1,2-trichloroethane was estimated at 124 million pounds (USEPA, 2001), and in 1979, 412 million pounds (ATSDR, 1989).

It should be noted that ATSDR indicates that information on 1,1,2-trichloroethane is wholly inadequate and does not provide sufficient information to determine how widespread this chemical is, or what potential exists for exposure in the general population. It is emphasized that information is especially needed on the commercial uses of 1,1,2-trichloroethane and what types of consumer products, if any, contain it. That information is requisite in determining exposure to 1,1,2-trichloroethane, and for determining which groups in the population are occupationally, or generally, exposed (ATSDR, 1989).

4.9.2 Environmental Release

1,1,2-Trichloroethane is listed as a Toxics Release Inventory (TRI) chemical. Table 4.9-1 illustrates the environmental releases for 1,1,2-trichloroethane from 1988 - 1999. (1,1,2-Trichloroethane data are only available for these years.) Air emissions constitute the vast majority of the on-site releases, with a relatively steady decrease over the years. The decrease in air emissions, as well as surface water discharges, have contributed to decreases in 1,1,2-trichloroethane total on- and off-site releases over the years. Except for releases in 1989-1991, no underground injection was reported for 1,1,2-trichloroethane. Releases to land (such as spills or leaks within the boundaries of the reporting facility), except for an upturn in 1999, decreased to at or near zero from 1992-1998. Off-site releases (including metals or metal compounds transferred off-site) have also declined from large amounts recorded from 1988-1991, as releases since then have, with one exception, remained below 600 pounds. These TRI data for 1,1,2-trichloroethane were reported from 29 States, with six States reporting every year (USEPA, 2000). Twelve of the 16 cross-section States (used for analyses of 1,1,2-trichloroethane occurrence in drinking water; see Section 4.9.4) reported release of 1,1,2-trichloroethane. (For a map of the 16-State cross-section, see Figure 1.3-1.)

Table 4.9-1: Environmental Releases (in pounds) for 1,1,2-Trichloroethane in the United States, 1988-1999

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1999	198,539	925	0	123	91	199,678
1998	279,470	540	0	1	1,203	281,214
1997	296,348	621	0	0	141	297,110
1996	339,055	516	0	16	114	339,701
1995	280,352	870	0	0	113	281,335
1994	310,112	914	0	0	166	311,192
1993	315,152	2,030	0	5	592	317,779
1992	562,085	1,163	0	7	219	563,474
1991	527,866	1,382	2	256	8,580	538,086
1990	588,464	2,231	1,091	265	25,498	617,549
1989	744,618	6,395	2,090	130	75,990	829,223
1988	1,741,442	5,303	0	89	19,810	1,766,644

Source: USEPA, 2000

4.9.3 Ambient Occurrence

1,1,2-Trichloroethane was not detected in rural or urban wells in the local, State, and federal data set compiled by NAWQA. These data represent untreated ambient ground water of the conterminous United States for the years 1985-1995 (Squillace et al., 1999).

The NURP study found 1,1,2-trichloroethane in urban runoff (Lopes and Dionne, 1998). The minimum and maximum concentrations detected were 2 µg/L and 3 µg/L, respectively, with no mean value reported. The use of the land from which the samples were taken was unspecified.

4.9.3.1 Additional Ambient Occurrence Data

A summary document entitled "Estimated National Occurrence and Exposure Assessment of 1,1,2-Trichloroethane in Public Drinking Water Supplies" (Wade Miller, 1989), was previously prepared for past USEPA assessments of 1,1,2-trichloroethane. Various information was presented regarding levels of 1,1,2-trichloroethane in water other than drinking water. The following information is taken directly from "Estimated National Occurrence and Exposure Assessment of 1,1,2-Trichloroethane in Public Drinking Water Supplies" (Wade Miller, 1989).

4.9.3.1.1 Groundwater Sources

In an effort to obtain information on the occurrence of 1,1,2-TCE in water other than drinking water from ground water sources, an extensive search of the literature was conducted. In addition, knowledgeable sources within the Office of Drinking Water were contacted. No data are available on the occurrence of 1,1,2-TCE in non-drinking ground water sources.

4.9.3.1.2 Surface Water Sources

The STORET water quality data base provides information on the occurrence of contaminants at ambient water stations in U.S. waterways. A summary of this information was obtained for 1,1,2-TCE in ambient waters. Ambient sites include streams, lakes, ponds, wells, reservoirs, canals, estuaries, and oceans. Since the preponderance of data were collected from surface water sources, the data are presented in this section. However, the number of samples collected from ground water wells, relative to the total number of samples collected from all ambient sites combined, is unspecified (Staples et al. 1985, as cited in Wade Miller, 1989). The limitations with these data are the same as those described for drinking water (see Section 4.9.5.6). Staples et al. (1985, as cited in Wade Miller, 1989) have summarized data from the 1980s only; that is, data from 1980 through 1983. This was done based on the number of data points and the likelihood that better quality assurance practices have been employed in more recent years. In the absence of sophisticated statistical analyses to eliminate improbable data, median values have been reported. The median value is less sensitive to extreme values, and reflects a measure of central tendency more accurately than the mean value in the presence of these extreme values (Staples et al. 1985, as cited in Wade Miller, 1989).

For a total of 1,047 observations from ambient water stations, the median concentration of 1,1,2-TCE was < 5.0 µg/L. Of the total number of observations, two percent were reported as detectable. Detection limits and other sampling information were not reported.

4.9.4 Drinking Water Occurrence Based on the 16-State Cross-Section

The analysis of 1,1,2-trichloroethane occurrence presented in the following section is based on State compliance monitoring data from the 16 cross-section States. The 16-State cross-section is the largest and most comprehensive compliance monitoring data set compiled by EPA to date. These data were evaluated relative to two concentration thresholds of interest: 0.005 mg/L; and 0.003 mg/L.

All sixteen cross-section State data sets contained occurrence data for 1,1,2-trichloroethane. These data represent approximately 174,000 analytical results from over 22,000 PWSs during the period from 1984 to 1998 (with most analytical results from 1992 to 1997). The number of sample results and PWSs vary by State, although the State data sets have been reviewed and checked to ensure adequacy of coverage and completeness. The overall modal detection limit for 1,1,2-trichloroethane in the 16 cross-section States is equal to 0.0005 mg/L. (For details regarding the 16-State cross-section, please refer to Section 1.3.5 of this report.)

4.9.4.1 Stage 1 Analysis Occurrence Findings

Table 4.9-2 illustrates the low occurrence of in drinking water for the public water systems in the 16-State cross-section relative to two thresholds: 0.005 mg/L (the current MCL), and 0.003 mg/L. Based on the 16-State cross-section data, a total of 9 (approximately 0.0404% of) ground water and surface water PWSs had analytical results exceeding the MCL. Twice as many (0.0808% of) systems had results exceeding 0.003 mg/L.

Approximately 0.0385% of ground water systems (8 systems) had any analytical results greater than the MCL. Only 1 (0.0655% of) surface water system had results greater than the MCL. About 0.0626% of ground water systems (13 systems) had results above 0.003 mg/L. A total of 5 (0.328% of) surface water systems had at least one analytical result greater than 0.003 mg/L.

Table 4.9-2: Stage 1 1,1,2-Trichloroethane Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Ground Water	0.005	0.0385%	8
	0.003	0.0626%	13
Surface Water	0.005	0.0655%	1
	0.003	0.328%	5
Combined Ground & Surface Water	0.005	0.0404%	9
	0.003	0.0808%	18

Reviewing 1,1,2-trichloroethane occurrence in the 16 cross-section States by PWS population served (Table 4.9-3) shows that approximately 6.97% of the population (almost 7.7 million people) was served by PWSs with at least one analytical result of 1,1,2-trichloroethane greater than the MCL (0.005 mg/L). Approximately 8.0 million (7.21% of) people were served by systems with an exceedance of 0.003 mg/L.

A much larger percentage of population served by surface water systems had MCL exceedances as compared to the population served by ground water systems. Approximately 0.556% of people served by ground water systems in the 16 States (about 274,900 people) were exposed to levels of 1,1,2-trichloroethane greater than 0.005 mg/L. The percentage of population served by surface water systems with exceedances of 0.005 mg/L was equal to 12.2% (approximately 7.4 million people). When evaluated relative to 0.003 mg/L, the percent of population served by ground water exposed was equal to 0.627% (309,700 people). Approximately 12.6% of the population served by surface water systems (almost 7.7 million people) was exposed to 1,1,2-trichloroethane concentrations greater than 0.003 mg/L.

Table 4.9-3: Stage 1 1,1,2-Trichloroethane Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Ground Water	0.005	0.556%	274,900
	0.003	0.627%	309,700
Surface Water	0.005	12.2%	7,415,200
	0.003	12.6%	7,652,100
Combined Ground & Surface Water	0.005	6.97%	7,690,100
	0.003	7.21%	7,961,800

4.9.4.2 Stage 2 Analysis Occurrence Findings

The Stage 2 occurrence findings, based on the cross-section data, are presented in Tables 4.9-4 and 4.9-5. The statistically generated best estimate values, as well as the ranges around the best estimate value, are presented. (For a review of the Stage 2 analytical approach, please refer to Section 1.4 of this report. For complete details regarding the Stage 2 analyses, please refer to *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT* (USEPA, 2002)).

No ground water or surface water PWSs (therefore, no population served by systems) had an estimated mean concentration of 1,1,2-trichloroethane exceeding 0.005 mg/L or 0.003 mg/L.

Table 4.9-4: Stage 2 Estimated 1,1,2-Trichloroethane Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.005	0.000%	0.000% - 0.000%	0	0 - 0
	0.003	0.000%	0.000% - 0.000%	0	0 - 0
Surface Water	0.005	0.000%	0.000% - 0.000%	0	0 - 0
	0.003	0.000%	0.000% - 0.000%	0	0 - 0
Combined Ground & Surface Water	0.005	0.000%	0.000% - 0.000%	0	0 - 0
	0.003	0.000%	0.000% - 0.000%	0	0 - 0

Table 4.9-5: Stage 2 Estimated 1,1,2-Trichloroethane Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.005	0.000%	0.000% - 0.000%	0	0 - 0
	0.003	0.000%	0.000% - 0.000%	0	0 - 0
Surface Water	0.005	0.000%	0.000% - 0.000%	0	0 - 0
	0.003	0.000%	0.000% - 0.000%	0	0 - 0

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Combined Ground & Surface Water	0.005	0.000%	0.000% - 0.000%	0	0 - 0
	0.003	0.000%	0.000% - 0.000%	0	0 - 0

4.9.4.3 Estimated National Occurrence

As illustrated in Table 4.9-6, the Stage 2 analysis estimates zero systems serving zero people nationally have estimated mean concentration values of 1,1,2-trichloroethane greater than 0.005 mg/L, or 0.003 mg/L. (See Section 1.4 for a description of how Stage 2 16-State estimates are extrapolated to national values.)

Table 4.9-6: Estimated National 1,1,2-Trichloroethane Occurrence - Systems and Population Served

Source Water Type	Threshold (mg/L)	Total Number of Systems Nationally Estimated to Exceed Threshold		Total Population Served by Systems Nationally Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.005	0	0 - 0	0	0 - 0
	0.003	0	0 - 0	0	0 - 0
Surface Water	0.005	0	0 - 0	0	0 - 0
	0.003	0	0 - 0	0	0 - 0
Combined Ground & Surface Water	0.005	0	0 - 0	0	0 - 0
	0.003	0	0 - 0	0	0 - 0

4.9.5 Additional Drinking Water Occurrence Data

Several additional data sources regarding the occurrence of 1,1,2-trichloroethane in drinking water are also reviewed. Previously compiled occurrence information, from an OGWDW summary document entitled "Estimated National Occurrence and Exposure Assessment of 1,1,2-Trichloroethane in Public Drinking Water Supplies" (Wade Miller, 1989), is presented in this section. This variety of studies and information are presented regarding levels of 1,1,2-trichloroethane in drinking water, with the scope of the reviewed studies ranging from national to regional. Note that none of the studies presented in the following section provide the quantitative analytical results or comprehensive coverage that would enable direct comparison to the occurrence findings estimated with the cross-section occurrence data presented in Section 4.9.4. These additional studies, however, do enable a broader assessment of the Stage 2 occurrence estimates presented for this Six-Year Review. All the following information in

Section 4.9.5 is taken directly from "Estimated National Occurrence and Exposure Assessment of 1,1,2-Trichloroethane in Public Drinking Water Supplies" (Wade Miller, 1989).

4.9.5.1 Groundwater Sources – National Studies

The Ground Water Supply Survey (GWSS) was conducted from December 1980 to December 1981 to develop additional data on the occurrence of volatile organic chemicals (VOCs) in the Nation's ground water supplies (Westrick et al. 1983, as cited in Wade Miller, 1989). A total of 929 finished drinking water supplies serving 25 or more individuals were sampled. Four hundred and fifty-six systems were chosen at random, while the remaining 473 systems were chosen non-randomly based on information from States encouraged to identify locations believed to have a higher than normal probability of VOC contamination (e.g., locations near landfills or industrial activity). None of the supplies sampled contained 1,1,2-TCE in excess of the minimum quantifiable concentration of 0.5 µg/L.

The National Screening Program for organics in drinking water (NSP), conducted by SRI International from June 1977 to March 1981, examined both raw and finished drinking water samples from 166 water systems in 33 States for 51 organic chemical contaminants, including 1,1,2-TCE. Analyses were made using gas chromatography with electrolytic conductivity detection. In this procedure, chlorodibromomethane and 1,1,2-TCE coelute and are not distinguishable. Reported levels should be considered "as either compound or a combination of the two with maximum concentrations as indicated." In summarizing the results of this survey for 1,1,2-TCE, SAIC has presented a worst case assessment by assuming all of the coelute to be 1,1,2-TCE. The values reported are thus taken to be maximum (potential) contamination levels in the sampled finished drinking water supplies.

The NSP data extracted from Boland (1981, as cited in Wade Miller, 1989) indicated that for ground water systems (5 samples), concentrations ranged from 0.2 to 12.0 µg/L (mean = 3.82 µg/L; median = 0.3 µg/L). The minimum quantifiable concentration for 1,1,2-TCE was 0.1 µg/L.

4.9.5.2 Groundwater Sources – Regional Studies

The State of California's Department of Health Services (DHS) analyzed samples from 2,947 drinking water wells used by large public water systems (having 200 connections) between 1984 and 1985. 1,1,2-TCE was detected in four of the wells sampled with concentrations ranging from 0.7 to 1.1 µg/L. The median concentration was 1.0 µg/L (California Department of Health Services, 1986, as cited in Wade Miller, 1989). The California DHS also reported that one drinking water well used by a small public water system (< 200 connections) tested positive twice for 1,1,2-TCE at concentrations of 3.2 µg/L and 1.1 µg/L (California Department of Health Services, unpublished, as cited in Wade Miller, 1989). In an earlier study, the State of California (1980, as cited in Wade Miller, 1989) reported that 1,1,2-TCE was detected in two of four wells (1 well sampled at 4 separate California Water Utilities), both at concentrations of 0.2 µg/L. The other two samples were reported as less than the detection limit, which was not provided.

The State of Minnesota's Department of Health (MDH) sampled 1,801 community water supply wells for VOCs between 1982 and 1985. 1,1,2-TCE was detected in one well at a median and maximum concentration of 0.3 µg/L. The minimum quantifiable concentration was 0.2 µg/L (Minnesota Department of Health, 1985, as cited in Wade Miller, 1989). One hundred and seven additional wells were tested after the 1985 MDH survey was completed, but 1,1,2-TCE was not detected in any of them (detection limit not specified) (FSTRAC, 1988, as cited in Wade Miller, 1989).

Four hundred and fifty-nine actual or potential drinking water wells in Nebraska were tested for the presence of 1,1,2-TCE. One well tested positive, with multiple samples showing concentrations ranging from 2.3 to 32.1 µg/L. The average concentration of 1,1,2-TCE was 13.7 µg/L (FSTRAC, 1988, as cited in Wade Miller, 1989).

The results of a Statewide New Jersey ground water quality survey revealed that through March 1981, two percent of the 1,118 well water samples collected contained 1,1,2-TCE at concentrations exceeding the minimum reportable quantity of 1.0 µg/L. Although the maximum concentration reported was 31.1 µg/L, no other sample exceeded a concentration of 10.0 µg/L (Tucker, 1981, as cited in Wade Miller, 1989). USEPA (1981, as cited in Wade Miller, 1989) reported that of 399 ground water samples collected in New Jersey, 203 samples had concentrations of < 1.0 µg/L, 141 samples had concentrations ranging from 1.0 to 10.0 µg/L, 55 samples had concentrations ranging from 10.0 to 1,000.0 µg/L, and one sample had a concentration > 1,000.0 µg/L.

In 1978, 372 drinking water wells in Nassau County, Long Island, New York were tested for the presence of 1,1,2-TCE. Thirteen percent of the wells tested positive, with a maximum concentration of 300.0 µg/L detected (USEPA, 1981, as cited in Wade Miller, 1989).

4.9.5.3 Surface Water Sources – National Studies

The National Screening Program for Organics in Drinking Water (NSP) (see Section 4.9.5.1) also contained information on the occurrence of 1,1,2-TCE in finished drinking water from surface water sources. The NSP data extracted from Boland (1981, as cited in Wade Miller, 1989) indicated that, for surface water systems (82 samples), concentrations ranged from 0.1 to 52.0 µg/L (mean = 1.92 µg/L; median = 0.55 µg/L). The minimum quantifiable concentration for 1,1,2-TCE was 0.1 µg/L.

4.9.5.4 Surface Water Sources – Regional Studies

In an effort to obtain information from regional and State surveys on the occurrence of 1,1,2-TCE in drinking water from surface water sources, an extensive literature search was conducted. In addition, knowledgeable sources within the Office of Drinking Water were contacted. No regional survey data are available on the occurrence of 1,1,2-TCE in surface water supplies.

4.9.5.5 Unspecified Water Sources

The results of two studies which analyzed the quality of finished water at three Puerto Rico water utilities were available as data base output. Samples were collected during September of 1980 and August of 1981. None of the finished water, from any of the utilities sampled, contained detectable levels of 1,1,2-TCE. The detection limit, sampling and analytical methodology employed, and water source were unspecified (Puerto Rico, 1980 and 1981, as cited in Wade Miller, 1989).

The results of a study which analyzed the quality of finished water at ten New York water utilities were available as data base output. Samples were collected during November and December of 1980. The results of this study revealed that none of the finished water from any of the utilities sampled contained detectable levels of 1,1,2-TCE. The detection limit, sampling and analytical methodology employed, and water source were unspecified (State of New York, 1980, as cited in Wade Miller, 1989).

The results of a study which analyzed the quality of finished water at fourteen New Jersey water utilities were available as data base output. Samples were collected during July of 1980. The detection limit for

1,1,2-TCE was reported at 20.0 µg/L for this study. None of the finished water collected at any of the utilities sampled exceeded this value. The sampling and analytical methodology employed and the water source were unspecified (State of New Jersey, 1980, as cited in Wade Miller, 1989). The results of another study which analyzed the quality of finished water at twelve New Jersey water utilities were also available as data base output. Samples were collected in 1981. The results of this study revealed that none of the finished water, from any of the utilities sampled, contained detectable levels of 1,1,2-TCE. The detection limit, sampling and analytical methodology employed, and water source were unspecified (State of New Jersey, 1981, as cited in Wade Miller, 1989).

4.9.5.6 Occurrence in Groundwater and Surface Water Sources – STORET

The EPA computerized water quality data base known as STORET was devised to assist Federal and State institutions in meeting objectives of Public Law 92-500 to maintain and enhance the physical, chemical, and biological quality of the Nation's ambient waterways by providing for the collection and dissemination of basic water quality data (Staples et al., 1985, as cited in Wade Miller, 1989). Data are collected by States, EPA regional offices, and other government agencies and are maintained in the STORET system. STORET contains approximately 80 million data entries including data on drinking water from ground water and surface water sources.

Before presenting a summary of the drinking water data in STORET, it is important to note that there are significant limitations in using this data base to estimate representative concentrations of a contaminant such as 1,1,2-TCE. Data entered into STORET are gathered from an array of studies conducted for various purposes. Analyses are conducted in a number of different laboratories employing different methodologies with a range of detection limits. In many cases, detection limits are not reported, making the reliability of the data highly questionable. In cases in which the detection limits have been reported, STORET assigns the detection limit value for those observations reported as not detected. This can lead to errors in interpretation and overestimation of concentrations in a particular medium. Additionally, a few high values can inflate mean values and result in large standard deviations relative to the means (Staples et al., 1985, as cited in Wade Miller, 1989). Very high values may not be correct, as they may reflect sample contamination or analytical error and can significantly distort assessment of average concentrations. Staples et al. (1985, as cited in Wade Miller, 1989) also notes that use of data collected prior to the 1980s is not recommended since some data were obtained using less sensitive laboratory techniques than are currently available and since quality assurance procedures were not yet mandated for the data entered into the system.

With these limitations in mind, a summary of the most recently obtained data for 1,1,2-TCE is presented for drinking water from ground water sources (USEPA, 1988, as cited in Wade Miller, 1989). According to STORET, there were 16 positive observations for 1,1,2-TCE in ground water from December 1984 to March 1987, with an overall mean value of 1.97 µg/L and a range of 0.1 to 5.8 µg/L. The standard deviation for these observations was 2.06 µg/L. There were 237 samples reported as undetected and assigned detection limit values, resulting in a mean value of 0.76 µg/L, a range of 0.1 to 1.0 µg/L and a standard deviation of 0.26 µg/L. Including the undetected samples, the 10,069 observations with actual values less than the reported values, and the 3 detections that were verified but not quantified, there were a total of 10,325 observations for 1,1,2-TCE in ground water from February 1978 to November 1987, with an overall mean value of 0.42 µg/L and a range of 0.01 to 10.0 µg/L. The standard deviation for all observations was 0.35 µg/L. Detection limits and other sampling information were not reported.

The STORET data base similarly contains data on the occurrence of 1,1,2-TCE in drinking water from surface water sources (USEPA, 1988, as cited in Wade Miller, 1989). According to STORET, there were

89 observations for 1,1,2-TCE in surface water from February 1978 to July 1987, with an overall mean value of 5.51 µg/L and a range of 0.5 to 10.0 µg/L. The standard deviation for all observations was 4.44 µg/L. Detection limits and other sampling information were not reported. It is important to note that of the 89 total observations for 1,1,2-TCE, 40 observations were reported as undetected and assigned detection limit values resulting in a mean of 2.07 µg/L (range = 1.0 - 10.0 µg/L) and a standard deviation of 2.58 µg/L. The remaining 49 observations had actual values less than the reported values.

4.9.5.7 National Estimate of the Occurrence of 1,1,2-Trichloroethane and Population Exposure for Public Water Supplies

Although Federal survey data on the occurrence of 1,1,2-trichloroethane in public drinking water supplies are available, there are few detectable concentration values. Information on the occurrence of 1,1,2-TCE in public drinking water supplies is available in STORET; however, as discussed above, there are significant limitations involved with utilizing these data. The available State data are usually poorly described with respect to the source and size categories of the supplies examined and the sampling and analysis methods used for determining contaminant levels. Consequently, national estimates of occurrence and population exposure were not made for 1,1,2-TCE.

4.9.6 Conclusion

The primary use of 1,1,2-trichloroethane is as a chemical intermediate in the production of 1,1-dichloroethylene. It is also used as a solvent, and it is unknown whether or not it may be present in any consumer products. Virtually no production data about 1,1,2-trichloroethane is available due to proprietary concerns of Dow Chemical. 1,1,2-Trichloroethane is also a TRI chemical. Industrial releases of 1,1,2-trichloroethane have occurred in 29 States since 1988. 1,1,2-Trichloroethane was an analyte for the NURP ambient occurrence studies. In the NURP study, 1,1,2-trichloroethane was detected at a maximum concentration of 3 µg/L and a minimum concentration of 2 µg/L, with no median value reported. In the Stage 2 analysis of 16-State occurrence of 1,1,2-trichloroethane, zero percent of combined ground water and surface water systems serving zero percent of the population exceeded the MCL of 0.005 mg/L. Nationally, zero ground water and surface water systems combined (serving approximately zero people) are estimated to have levels greater than the MCL.

The 16-State cross-section was designed to be nationally representative based upon VOC, SOC, and IOC pollution potentials as suggested by considerations of manufacturing, agriculture, and geographic diversity factors. All production information for 1,1,2-trichloroethane is unavailable for comparison due to proprietary restrictions. Nationally, 29 States have reported TRI releases of 1,1,2-trichloroethane, including 12 of the 16 cross-section States. The cross-section should adequately represent the occurrence of 1,1,2-trichloroethane on a national scale based upon the use, production, and release patterns of the 16-State cross-section in relation to the patterns observed for all 50 States.

4.9.7 References

Agency for Toxic Substances and Disease Registry (ATSDR). 1989. *Toxicological Profile for 1,1,2-Trichloroethane*. U.S. Department of Health and Human Services, Public Health Service. 108 pp. + Appendices. Available on the Internet at http://atsdr1.atsdr.cdc.gov/toxprofiles/tp148.pdf

Boland, P.A. 1981. *National Screening Program for Organics in Drinking Water.* Prepared by SRI International, Menlo Park, California, for Office of Drinking Water, USEPA, Washington, DC. EPA Contract No. 68-01-4666.

California Department of Health Services. 1986. *Final Report on a Monitoring Program for Organic Chemical Contamination of Large Public Water Systems in California.* Summary Version. Sacramento, CA.

California Department of Health Services. Unpublished. *Final Report on a Monitoring Program for Organic Chemical Contamination of Small Public Water Systems in California*. Summary Version. Sacramento, CA.

FSTRAC. 1988. Federal/State Toxicological and Regulatory Alliance Committee. FSTRAC Survey Results - April 1988. Survey results obtained from Ralph Langemeier, Chief of Drinking Water Branch, USEPA, Region VII.

Lopes, T.J. and S.G. Dionne. 1998. *A Review of Semivolatile and Volatile Organic Compounds in Highway Runoff and Urban Stormwater*. U.S. Geological Survey Open-File Report 98-409. 67 pp.

Minnesota Department of Health. 1985. *Volatile Organic Survey of Community Water Supplies*. Report to the Legislative Commission on Minnesota Resources. Minneapolis, MN.

Puerto Rico. 1980. *Results of Puerto Rico Water Supply Study for 1,1,2-Trichloroethane*. Data obtained from Arthur Perler, Branch Chief, Science and Technology Branch, Office of Drinking Water, USEPA, Washington, D.C.

Puerto Rico. 1981. *Results of Puerto Rico Water Supply Study for 1,1,2-Trichloroethane*. Data obtained from Arthur Perler, Branch Chief, Science and Technology Branch, Office of Drinking Water, USEPA, Washington, D.C.

Squillace, P.J., M.J. Moran, W.W. Lapham, C.V. Price, R.M. Clawges, and J.S. Zogorski. 1999. Volatile organic compounds in untreated ambient groundwater of the United States, 1985-1995. *Env. Sci. and Tech*. 33(23):4176-4187.

Staples, C.A., A.F. Werner, and T.J. Hoogheem. 1985. Assessment of Priority Pollutant Concentrations in the United States Using STORET Data Base. *Environmental Toxicology and Chemistry*, 4:131-142.

State of California. 1980. Memorandum: Analysis of California Department of Health Services Well Water Samples for 1,1,2-Trichloroethane. Data obtained from Arthur Perler, Branch Chief, Science and Technology Branch, Office of Drinking Water, USEPA, Washington, D.C. 1/30/80.

State of New Jersey. 1980. *Results of New Jersey Water Supply Sampling for 1,1,2-Trichloroethane*. Report date 9/24/80. Data obtained from Arthur Perler, Branch Chief, Science and Technology Branch, Office of Drinking Water, USEPA, Washington, D.C.

State of New Jersey. 1981. *Results of New Jersey Water Supply Sampling for 1,1,2-Trichloroethane*. Report date 10/8/81. Data obtained from Arthur Perler, Branch Chief, Science and Technology Branch, Office of Drinking Water, USEPA, Washington, D.C.

State of New York. 1980. *Results of New York Water Supply Sampling for 1,1,2-Trichloroethane*. Report date 2/26/81. Data obtained from Arthur Perler, Branch Chief, Science and Technology Branch, Office of Drinking Water, USEPA, Washington, D.C.

Tucker, R.K. 1981. *Groundwater Quality in New Jersey: An Investigation of Toxic Contaminants*. State of New Jersey Department of Environmental Protection. Office of Cancer and Toxic Substances Research, Trenton, NJ.

USEPA. 1981. USEPA. *An Exposure and Risk Assessment for Trichloroethanes*. Final Draft Report. Office of Water Regulations and Standards, Office of Water, Washington, D.C. (Revised July 1982).

USEPA. 1988. Computer Printout of STORET Water Quality Data Base. Retrieval conducted March 23, 1988 by Science Applications International Corporation. Data available through Office of Water Regulations and Standards, Washington, D.C.

USEPA. 2000. *TRI Explorer: Trends*. Available on the Internet at: http://www.epa.gov/triexplorer/trends.htm, last updated May 5, 2000.

USEPA. 2001. *National Primary Drinking Water Regulations - Consumer Factsheet on: 1,1,2-Trichloroethane.* Office of Ground Water and Drinking Water, USEPA. Available on the Internet at http://www.epa.gov/safewater/dwh/c-voc/112-tric.html (Last updated 04/12/2001)

USEPA. 2002. *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT.* EPA Report/815-D-02-005, Office of Water, 55 pp.

Wade Miller Associates, Inc. 1989. *Estimated National Occurrence and Exposure Assessment of 1,1,2-Trichloroethane in Public Drinking Water Supplies*. Prepared for and submitted to EPA on September 29, 1989.

Westrick, J.J., J.W. Mello, and R.F. Thomas. 1983. *The Ground Water Supply Survey summary of volatile organic contaminant occurrence data.* EPA Technical Support Division, Office of Drinking Water, Cincinnati, Ohio.

4.10 Trichloroethylene

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Tables and Figures

4.10.1 Introduction, Use and Production

Trichloroethylene (chemical formula C_2HCl_3) is a nonflammable, colorless liquid at room temperature that has a somewhat sweet odor, and a sweet, burning taste. It is also known as acetylene trichloride, 1-chloro-2,2-dichloroethylene, 1,1-dichloro-2-chloroethylene, ethylene trichloride, trichloride, TCE, 1,1,2-trichloroethylene, and trichloroethene. Trichloroethylene is also known as Triclene, Vitran, and by other trade names in industry (ATSDR, 1997).

The end use pattern of trichloroethylene in the U.S. in 1987 was estimated as follows: vapor degreasing of fabricated metal parts, 80%; chemical intermediates, 5%; miscellaneous uses, 5%; and exports, 10% (Spectrum Laboratories, 2001). Trichloroethylene is an excellent extraction solvent for greases, oils, fats, waxes, and tars and is used by the textile processing industry to scour cotton, wool, and other fabrics. As a general solvent, or as a component of solvent blends, trichloroethylene is used with adhesives, lubricants, paints, varnishes, paint strippers, pesticides, and cold metal cleaners (ATSDR, 1997).

Trichloroethylene is used as a chemical intermediate for the production of polyvinyl chloride, pharmaceuticals, polychlorinated aliphatics, flame retardant chemicals, and insecticides. Trichloroethylene is used as a refrigerant for low-temperature heat transfer, and in the aerospace industry for flushing liquid oxygen. Some consumer products that contain trichloroethylene are typewriter correction fluids, paint removers and strippers, adhesives, spot removers, and rug cleaning fluids (ATSDR, 1997).

Use of trichloroethylene has declined due to its toxicity (NTP, 2001). It had been used as a general and obstetrical anesthetic; a grain fumigant; a skin, wound, and surgical disinfectant; pet food additive, and extractant of spice oleoresins in food and of caffeine for the purpose of making decaffeinated coffee. These uses were banned by the U.S. Food and Drug Administration in 1977 (ATSDR, 1997).

The only U.S. manufacturers of trichloroethylene are Dow Chemical in Freeport, TX, and PPG Industries in Lake Charles, LA, with a combined annual production capacity of 320 million pounds. Because there are currently only two manufacturers, recent production data is not available. In previous years, production volumes of trichloroethylene have been reported as follows: 1978, 299 million pounds; 1979, 319 million pounds; 1980, 266 million pounds; 1981, 258 million pounds; and 1982, 200 million pounds. U.S. demand for trichloroethylene was estimated at 235 million pounds in 1983, 180 million pounds in 1985, and 170 million pounds in 1986 (ATSDR, 1997).

Table 4.10-1 shows the number of facilities in each State that manufacture and process trichloroethylene, the intended uses of the product, and the range of maximum amounts derived from the Toxics Release Inventory (TRI) of EPA (ATSDR, 1997).

Table 4.10-1: Facilities that Manufacture or Process Trichloroethylene

State[a]	Number of facilities	Range of maximum amounts on site in thousands of pounds[b]	Activities and uses[c]
AL	12	1-1,000	2,3,7,8,12,13
AR	11	1-1,000	8,9,11,12,13
AZ	4	1-10	12,13
CA	5	1-10,000	1,5,8,10,11,13
CO	1	10-100	12
CT	15	1-100	11,12,13

State[a]	Number of facilities	Range of maximum amounts on site in thousands of pounds[b]	Activities and uses[c]
DE	1	100-1,000	13
FL	14	0-100	11,12,13
GA	12	1-1,000	8,12,13
IA	5	1-10	12,13
IL	99	0-100,000	1,4,8,9,10,11,12,13
IN	50	0-10,000	7,8,10,11,12,13
KS	12	0-1,000	8,10,11,12,13
KY	17	1-50,000	1,3,7,10,12,13
LA	11	1-10,000	1,3,4,5,6,7,8,12,13
MA	36	0-1,000	8,10,11,12,13
MD	4	1-100	2,3,12,13
ME	2	10-100	13
MI	41	1-1,000	2,3,8,10,11,12,13
MN	28	0-100	11,12,13
MO	28	0-1,000	2,3,8,10,12,13
MS	6	1-1,000	12,13
NC	19	0-100	10,11,12,13
NE	10	1-100	11,12,13
NH	4	1-100	11,13
NJ	11	1-1,000	8,12,13
NY	55	0-1,000	3,7,10,11,12,13
OH	55	0-1,000	8,10,11,12,13
OK	5	1-100	2,3,13
OR	7	0-1,000	11,12,13
PA	54	1-1,000	3,8,10,11,12,13
PR	1	10-100	13
RI	5	0-100	8,12,13
SC	12	1-1,000	7,12,13
SD	2	10-100	13
TN	14	1-1,000	2,3,7,11,12,13
TX	34	1-50,000	1,3,4,5,6,7,8,10,12,13
VA	12	1-1,000	12,13
VT	3	1-100	11,13
WA	9	0-100	12,13
WI	42	0-1,000	8,10,11,12,13

[a] Post office State abbreviations used
[b] Data in TRI are maximum amounts on site at each facility
[c] Activities/Uses include:

1. Produce
2. Import
3. For on-site use/processing
4. For sale/distribution
5. As a byproduct
6. As an impurity
7. As a reactant
8. As a formulation component
9. As a product component
10. For repackaging only
11. As a chemical processing aid
12. As a manufacturing aid
13. Ancillary or other uses

Source: ATSDR, 1997 compilation of TRI93 1995 data

4.10.2 Environmental Release

Trichloroethylene is listed as a Toxics Release Inventory (TRI) chemical. Table 4.10-2 illustrates the environmental releases for trichloroethylene from 1988 - 1999. (Trichloroethylene data are only available for these years.) Air emissions constitute the vast majority of the on-site releases, with a steady decrease over the years. The decrease in air emissions, as well as surface water discharges and off-site releases (including metals or metal compounds transferred off-site), have contributed to decreases in trichloroethylene total on- and off-site releases in the years covered by the TRI data. Underground injection and releases to land (such as spills or leaks within the boundaries of the reporting facility) have fluctuated over the years, but usually do not make a very significant contribution to overall releases. These TRI data for trichloroethylene were reported from 46 States and Puerto Rico. (No data were reported from Wyoming, North Dakota, Hawaii, or Alaska). Of the 46 States, 37 reported every year

(USEPA, 2000). All of 16 cross-section States (used for analyses of trichloroethylene occurrence in drinking water; see Section 4.10.4) reported TRI data for trichloroethylene. (For a map of the 16-State cross-section, see Figure 1.3-1.)

Table 4.10-2: Environmental Releases (in pounds) for Trichloroethylene in the United States, 1988-1999

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1999	10,510,064	1,043	0	138,522	115,587	10,765,216
1998	13,137,700	867	588	800	98,774	13,238,729
1997	18,143,968	563	986	3,975	182,423	18,331,915
1996	21,880,624	541	1,291	9,740	89,527	21,981,723
1995	26,265,512	1,477	550	3,577	74,145	26,345,261
1994	30,945,977	1,671	288	4,070	96,312	31,048,318
1993	31,007,030	5,220	460	8,212	233,561	31,254,483
1992	30,838,983	8,606	466	20,726	248,714	31,117,495
1991	36,356,277	12,784	800	62,991	115,973	36,548,825
1990	40,028,932	14,285	805	12,554	753,864	40,810,440
1989	49,798,528	15,849	390	8,686	1,250,933	51,074,386
1988	55,943,736	13,801	390	21,186	1,466,469	57,445,582

Source: USEPA, 2000

4.10.3 Ambient Occurrence

Trichloroethylene was detected in 47 out of 405 wells (11.6%) in urban areas of the local, State, and federal data set compiled by NAWQA. The minimum and maximum concentrations detected were 0.2 µg/L and 80 µg/L, respectively. The median value of detection concentrations was 0.9 µg/L. Trichloroethylene was also detected in 41 of the 2,542 wells (1.6%) with analysis in rural areas. The minimum and maximum concentrations detected were 0.2 µg/L and 63 µg/L, respectively. The median value of detection concentrations was 0.6 µg/L. These data (urban and rural) represent untreated ambient ground water of the conterminous United States for the years 1985-1995 (Squillace et al., 1999).

Trichloroethylene was also an analyte in the NURP study. The NURP study found trichloroethylene in urban runoff (Lopes and Dionne, 1998). The minimum and maximum concentrations detected were 0.3 µg/L and 10 µg/L, respectively, with no mean value reported. The use of the land from which the samples were taken was unspecified.

4.10.3.1 Additional Ambient Occurrence Data

A summary document entitled "Sources, Emission and Exposure for Trichloroethylene (TCE) and Related Chemicals" (USEPA, 2001), was previously prepared for past USEPA assessments of trichloroethylene. Various studies and information are presented regarding levels of TCE in water, both ambient and drinking. These studies are summarized in Section 4.10.5.

4.10.4 Drinking Water Occurrence Based on the 16-State Cross-Section

The analysis of trichloroethylene occurrence presented in the following section is based on State compliance monitoring data from the 16 cross-section States. The 16-State cross-section is the largest and most comprehensive compliance monitoring data set compiled by EPA to date. These data were evaluated relative to several concentration thresholds of interest: 0.005 mg/L; 0.0025 mg/L; and 0.0005 mg/L.

All sixteen cross-section State data sets contained occurrence data for trichloroethylene. These data represent more than 201,000 analytical results from approximately 23,000 PWSs during the period from 1984 to 1998 (with most analytical results from 1992 to 1997). The number of sample results and PWSs vary by State, although the State data sets have been reviewed and checked to ensure adequacy of coverage and completeness. The overall modal detection limit for trichloroethylene in the 16 cross-section States is equal to 0.0005 mg/L. (For details regarding the 16-State cross-section, please refer to Section 1.3.5 of this report.)

4.10.4.1 Stage 1 Analysis Occurrence Findings

Table 4.10-3 illustrates the occurrence of trichloroethylene in drinking water for the public water systems in the 16-State cross-section relative to three thresholds: 0.005 mg/L (the current MCL), 0.0025 mg/L, and 0.0005 mg/L (the modal MRL). A total of 149 (approximately 0.647% of) ground water and surface water PWSs had analytical results exceeding the MCL; 1.02% (234 systems) of systems in the 16 States had results exceeding 0.0025 mg/L; and 2.24% of systems (516 systems) had results exceeding 0.0005 mg/L.

Approximately 0.596% (128 systems) of ground water systems had any analytical results greater than the MCL. About 0.951% (204 systems) of ground water systems had results above 0.0025 mg/L. The percentage of ground water systems with at least one result greater than 0.0005 mg/L was equal to 2.12% (455 systems).

Approximately 21 (1.33% of) surface water systems had results greater than the MCL. A total of 30 (1.91% of) surface water systems had at least one analytical result greater than 0.0025 mg/L. Sixty-one (3.88% of) surface water systems had results exceeding 0.0005 mg/L.

Table 4.10-3: Stage 1 Trichloroethylene Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Ground Water	0.005	0.596%	128
	0.0025	0.951%	204
	0.0005	2.12%	455
Surface Water	0.005	1.33%	21
	0.0025	1.91%	30
	0.0005	3.88%	61

Source Water Type	Threshold (mg/L)	Percent of Systems Exceeding Threshold	Number of Systems Exceeding Threshold
Combined Ground & Surface Water	0.005	0.647%	149
	0.0025	1.02%	234
	0.0005	2.24%	516

Reviewing trichloroethylene occurrence by PWS population served (Table 4.10-4) shows that approximately 13.3% of the population served in the 16 States (almost 15 million people) was served by PWSs with at least one analytical result of trichloroethylene greater than the MCL (0.005 mg/L). Over 17 million (15.6% of) people in the 16 States were served by systems with an exceedance of 0.0025 mg/L. A total of about 25.6 million (23.1% of) people were served by systems with at least one analytical result greater than 0.0005 mg/L.

The percentage of 16-State population served by ground water systems with analytical results greater than the MCL was equal to 8.01% (almost 4 million people). When evaluated relative to 0.0025 mg/L or 0.0005 mg/L, the percent of population exposed was equal to 11.2% (over 5.5 million people) and 18.6% (approximately 9.2 million people), respectively.

The percentage of 16-State population served by surface water systems with exceedances of 0.005 mg/L was equal to 17.5% (approximately 10.7 million people). Approximately 19.2% of the population served by surface water systems (about 11.7 million people) was exposed to trichloroethylene concentrations greater than 0.0025 mg/L. When evaluated relative to 0.0005 mg/L, the percent of population exposed was equal to 26.8% (over 16 million people).

Table 4.10-4: Stage 1 Trichloroethylene Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Exceeding Threshold	Total Population Served by Systems Exceeding Threshold
Ground Water	0.005	8.01%	3,971,100
	0.0025	11.2%	5,539,500
	0.0005	18.6%	9,219,500
Surface Water	0.005	17.5%	10,710,100
	0.0025	19.2%	11,713,300
	0.0005	26.8%	16,357,500
Combined Ground & Surface Water	0.005	13.3%	14,681,200
	0.0025	15.6%	17,252,900
	0.0005	23.1%	25,577,000

4.10.4.2 Stage 2 Analysis Occurrence Findings

The Stage 2 occurrence findings, based on the cross-section data, are presented in Tables 4.10-5 and 4.10-6. The statistically generated best estimate values, as well as the ranges around the best estimate value, are presented. (For a review of the Stage 2 analytical approach, please refer to Section 1.4 of this report. For complete details regarding the Stage 2 analyses, please refer to *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT* (USEPA, 2002)).

A combined total of 54 (0.236% of) ground water and surface water PWSs in the 16 States had an estimated mean concentration of trichloroethylene exceeding 0.005 mg/L, while 103 (0.445% of) systems in the 16 States had an estimated mean concentration exceeding 0.0025 mg/L and 299 (1.30% of) systems had an estimated mean concentration exceeding 0.0005 mg/L.

About 47 (0.221% of) ground water PWSs in the 16 States were estimated to have a mean concentration greater than 0.005 mg/L. Additionally, 90 (0.420% of) ground water PWSs were estimated to exceed a mean concentration of 0.0025 mg/L and 272 (1.27% of) systems were estimated to exceed a mean concentration of 0.0005 mg/L. For surface water PWSs in the 16 States, 7 (0.450%), 13 (0.795%), and 27 (1.71%) had estimated mean concentrations exceeding 0.005 mg/L, 0.0025 mg/L, and 0.0005 mg/L, respectively.

Table 4.10-5: Stage 2 Estimated Trichloroethylene Occurrence Based on 16-State Cross-Section - Systems

Source Water Type	Threshold (mg/L)	Percent of Systems Estimated to Exceed Threshold		Number of Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.005	0.221%	0.186% - 0.256%	47	40 - 55
	0.0025	0.420%	0.368% - 0.466%	90	79 - 100
	0.0005	1.27%	1.17% - 1.39%	272	252 - 299
Surface Water	0.005	0.450%	0.381% - 0.572%	7	6 - 9
	0.0025	0.795%	0.699% - 0.953%	13	11 - 15
	0.0005	1.71%	1.46% - 2.03%	27	23 - 32
Combined Ground & Surface Water	0.005	0.236%	0.204% - 0.274%	54	47 - 63
	0.0025	0.445%	0.399% - 0.491%	103	92 - 113
	0.0005	1.30%	1.21% - 1.42%	299	279 - 326

Reviewing trichloroethylene occurrence by PWS population served (Table 4.10-6) shows that approximately 8.19% of population served by all PWSs in the 16 States (an estimate of over 9 million people) were potentially exposed to trichloroethylene levels above 0.005 mg/L. For all PWSs in the 16 States, an estimated 9.17% of population served (an estimate of over 10 million people served in the 16

States) was exposed to levels above 0.0025 mg/L, and 12.5% (an estimated 13.8 million people in the 16-State cross-section) was exposed to levels above 0.0005 mg/L.

When the population exposed for ground water systems was evaluated relative to thresholds of 0.005 mg/L, 0.0025 mg/L, and 0.0005 mg/L, the percentages of population exposed were equal to 1.94% (an estimated 962,700 people), 3.30% (an estimate of over 1.6 million people), and 7.90% (an estimated 3.9 million people), respectively.

The percentage of population served by surface water systems in the 16 States with levels above 0.005 mg/L was 13.3% (an estimated 8 million people), while the population served with levels above 0.0025 mg/L and 0.0005 mg/L was 13.9% (an estimated 8.5 million people) and 16.2% (an estimate of almost 9.9 million people), respectively.

Table 4.10-6: Stage 2 Estimated Trichloroethylene Occurrence Based on 16-State Cross-Section - Population

Source Water Type	Threshold (mg/L)	Percent of Population Served by Systems Estimated to Exceed Threshold		Total Population Served by Systems in the 16 States Estimated to Exceed Threshold	
		Best Estimate	Range	Best Estimate	Range
Ground Water	0.005	1.94%	1.56% - 2.33%	962,700	772,500 - 1,153,500
	0.0025	3.30%	2.91% - 3.82%	1,634,100	1,442,900 - 1,890,800
	0.0005	7.90%	7.26% - 8.69%	3,914,900	3,597,800 - 4,305,300
Surface Water	0.005	13.3%	13.0% - 13.7%	8,097,000	7,950,500 - 8,377,900
	0.0025	13.9%	13.8% - 14.5%	8,512,300	8,408,400 - 8,823,700
	0.0005	16.2%	15.0% - 18.6%	9,886,200	9,165,600 - 11,351,700
Combined Ground & Surface Water	0.005	8.19%	7.98% - 8.41%	9,062,500	8,828,000 - 9,302,500
	0.0025	9.17%	8.95% - 9.53%	10,147,600	9,894,300 - 10,535,900
	0.0005	12.5%	11.7% - 13.8%	13,804,500	12,952,800 - 15,242,500

4.10.4.3 Estimated National Occurrence

Based on the Stage 2 estimated percent of systems (and population served by systems) exceeding each threshold, an estimated 154 PWSs nationally, serving over 17 million people, could be exposed to trichloroethylene concentrations above 0.005 mg/L. About 290 systems, serving almost 20 million people nationally, had estimated mean concentrations greater than 0.0025 mg/L. Approximately 844 systems, serving about 26.6 million people nationally, were estimated to have mean trichloroethylene concentrations greater than 0.0005 mg/L. (See Section 1.4 for a description of how Stage 2 16-State estimates are extrapolated to national values.)

For ground water systems, an estimated 131 PWSs, serving about 1.7 million people nationally, had mean concentrations greater than 0.005 mg/L. Approximately 250 systems, serving over 2.8 million people nationally, had estimated mean concentration values that exceeded 0.0025 mg/L. About 754 ground water systems, serving almost 6.8 million people, had estimated mean concentrations greater than 0.0005 mg/L.

Although fewer surface water systems than ground water systems nationally had estimated mean concentration values greater than the thresholds, a much larger population was served by surface water systems with threshold exceedances because surface water systems tend to serve much larger populations. Approximately 25 surface water systems, serving almost 17 million people, were estimated to have mean concentrations of trichloroethylene above 0.005 mg/L. About 44 surface water systems, serving almost 18 million people, had estimated mean concentrations greater than 0.0025 mg/L. An estimated 95 surface water systems, serving approximately 20.6 million people, had mean concentrations greater than 0.0005 mg/L.

Table 4.10-7: Estimated National Trichloroethylene Occurrence - Systems and Population Served

Source Water Type	**Threshold (mg/L)**	**Total Number of Systems Nationally Estimated to Exceed Threshold**		**Total Population Served by Systems Nationally Estimated to Exceed Threshold**	
		Best Estimate	**Range**	**Best Estimate**	**Range**
Ground Water	0.005	131	111 - 152	1,664,800	1,335,800 - 1,994,700
	0.0025	250	219 - 277	2,825,800	2,495,100 - 3,269,600
	0.0005	754	698 - 828	6,769,700	6,221,300 - 7,444,900
Surface Water	0.005	25	21 - 32	16,883,500	16,577,900 - 17,469,200
	0.0025	44	39 - 53	17,749,300	17,532,900 - 18,398,700
	0.0005	95	82 - 114	20,614,200	19,111,700 - 23,670,000
Combined Ground & Surface Water	0.005	154	133 - 178	17,451,800	17,000,200 - 17,914,000
	0.0025	290	260 - 319	19,541,400	19,053,600 - 20,289,000
	0.0005	844	788 - 920	26,583,400	24,943,300 - 29,352,500

4.10.5 Additional Drinking Water Occurrence Data

Several additional data sources regarding the occurrence of trichloroethylene in drinking water are also reviewed. Previously compiled occurrence information, from an OGWDW summary document entitled "Sources, Emission and Exposure for Trichloroethylene (TCE) and Related Chemicals" (USEPA, 2001), is presented in this section. This variety of studies and information are presented regarding levels of trichloroethylene in drinking water, with the scope of the reviewed studies ranging from national to regional. Note that none of the studies presented in the following section provide the quantitative analytical results or comprehensive coverage that would enable direct comparison to the occurrence findings estimated with the cross-section occurrence data presented in Section 4.10.4. These additional studies, however, do enable a broader assessment of the Stage 2 occurrence estimates presented for this Six-Year Review. All the following information in Section 4.10.5 is taken directly from "Sources, Emission and Exposure for Trichloroethylene (TCE) and Related Chemicals" (USEPA, 2001).

4.10.5.1 Levels of Trichloroethylene (TCE) in Various Water Sources

According to IARC (1995, as cited in USEPA, 2001), the reported median concentrations of TCE in 1983-84 were 0.5 µg/L in industrial effluents and 0.1 µg/L in ambient water. ATSDR (1997, as cited in USEPA, 2001) has reported that TCE is the most frequently reported organic contaminant in groundwater and the one present in the highest concentration in a summary of ground water analyses reported in 1982. It has been estimated that somewhere between 9 and 34 percent of the drinking water supply sources tested in the U.S. may have some trichloroethylene contamination. This estimate is based on available Federal and State surveys (ATSDR, 1997, as cited in USEPA, 2001). Results from an analysis of the EPA STORET Data Base (1980-1982) showed that TCE was detected in 28 percent of 9,295 surface water reporting stations nationwide (ATSDR, 1997, as cited in USEPA, 2001).

More recently, the USEPA Office of Ground Water and Drinking Water reposed that most water supplies are in compliance with the maximum contaminant level (maximum contaminant level (MCL), 5 µg/L), and that only 407 samples out of many thousands taken from community and other water supplies throughout the country over the past 11 years (1987-1997) have exceeded the MCL limit for TCE (USEPA, 1998, as cited in USEPA, 2001).

TCE concentrations in ground water have been measured extensively in California. The data were derived from a survey of large water utilities (i.e. utilities with more than 200 service connections). The survey was conducted by the California Department of Health Services (DHS, 1986, as cited in USEPA, 2001). From January 1984 through December 1985, wells in 819 water systems were sampled for organic chemical contamination. The water systems use a total of 5,550 wells, 2,947 of which were sampled. TCE was found in 187 wells, at concentrations up to 440 µg/L, with a median concentration of 3.0 µg/L. Generally, the most contaminated wells and the wells with the highest concentrations were found in the heavily urbanized areas of the State. Los Angeles County registered the greatest number of contaminated wells (149).

4.10.5.2 Human Exposure and Population Estimates

4.10.5.2.1 General U.S. Population

Because of the pervasiveness of TCE in the environment, most people are exposed to it through ingestion of drinking water, inhalation of ambient air, or ingestion of food (ATSDR, 1997, as cited in USEPA, 2001). Contamination of drinking water with TCE varies according to location and with the drinking water source (whether source is surface water or groundwater). TCE readily volatilizes from water and inhalation of indoor air may be a major route of exposure in homes with contaminated water supply (ATSDR, 1997, as cited in USEPA, 2001).

The California survey of large water utilities in 1984 found a median concentration of 3.0 µg/L (DHS, 1986). Using this value and a 2 L/day water consumption rate yields an estimate of 6 µg/day. This is consistent with ATSDR (ATSDR, 1997, as cited in USEPA, 2001) which reported an average daily water intake for the general population of 2 to 20 µg/day.

The use of ambient air data to estimate inhalation exposure does not account for possible differences between contaminant levels in indoor vs. outdoor air. TCE readily volatilizes from water and indoor inhalation exposure may be comparable or greater than ingestion exposures in homes where the water supply contains TCE (ATSDR, 1997; Andelman, et al., 1985; Giardino, et al., 1992; Andelman et al., 1986a; Andelman et al., 1986b, as cited in USEPA, 2001). For example, in two homes using well water with TCE levels averaging 22 to 128 µg/L, the TCE levels in bathroom air ranged from <0.5 to 40 mg/m^3 when the shower was run less than 30 minutes (Andelman et al., 1985, as cited in USEPA, 2001). In one study, the transfer of TCE from shower water to air had a mean efficiency of 61% (independent of water temperature); it was concluded that a 10-minute shower in TCE-contaminated water could result in a daily inhalation exposure comparable to that expected from drinking TCE-contaminated tap water (ATSDR, 1997, as cited in USEPA, 2001). TCE in bathing water can also cause dermal exposure. A modeling study has suggested that a significant fraction of the total dose associated with exposure to volatile organics in drinking water results from dermal absorption (Brown, et al., 1984, as cited in USEPA, 2001).

Pharmacokinetic modeling can be used to gain further understanding of general population exposure. Clewell et al. (1995, as cited in USEPA, 2001) developed a physiologically based pharmacokinetic model for TCE that can be used to estimate the long-term average ingested dose that would result in a measured blood concentration, assuming no other TCE exposure. This dose can be converted to a TCE water concentration assuming an ingestion rate such as 2 L/day. This model was applied to the range of TCE levels in blood as measured in NHANES 111. The TCE environmental concentrations modeled from blood levels exceeded the range of measured values for air and water: modeled mean concentration in drinking water was 59.5 µg/L (measured range was trace to 50 µg/L) and the modeled mean air concentration was 4.2 µg/m^3 (measured range was for 0.01 to 3.9 µg/m^3) . This implies that neither inhalation nor water ingestion dominate exposure; rather both contribute to the total exposure. Exposure estimates derived from blood cannot distinguish among exposure routes and sources. It is generally believed that TCE exposure occurs primarily via water consumption and air inhalation, but it is impossible to use the blood data to directly estimate how much of the total exposure is attributable to each. A wide range of combinations of exposures from air and water could have produced the measured blood levels. As noted earlier, most water supplies have TCE levels under the MCL of 5 µg/L. The modeling suggests that exposure at the MCL would correspond to a very low blood level. This implies that the TCE exposure via the air and other nonwater pathways may generally be more important than water ingestion.

4.10.5.2.2 Extent of General Population Exposure

Because of the pervasiveness of TCE in the environment. most people are likely to have some exposure via one or more of the following pathways: ingestion of drinking water, inhalation of ambient air, or ingestion of food (ATSDR, 1997, as cited in USEPA, 2001). As noted earlier, the NHANES survey suggests that about 10% of the population has detectable levels of TCE in their blood. The exposures in these individuals may be higher than those in others in the general population, as a result of a number of factors. Some members of the general population may have increased TCE exposure via their drinking water. The extent of TCE exposure via drinking water is difficult to estimate; but the following discussion provide some perspective on this issue.

TCE is the most frequently reported organic contaminant in ground water (ATSDR, 1997, as cited in USEPA, 2001). Ninety-three percent of the public water systems in the United States obtain water from groundwater (USEPA, 1995, as cited in USEPA, 2001), and between 9% and 34% of the drinking water supply sources tested in the United States may have some TCE contamination (ATSDR, 1997, as cited in USEPA, 2001). Although commonly detected in water supplies, the levels are generally low, since, as discussed earlier, MCL violations for TCE in public water supplies are relatively rare for any extended period (USEPA, 1998, as cited in USEPA, 2001). Private wells, however, are often not closely monitored, and, if located near TCE disposal/contamination sites where leaching occurs, may have undetected contamination levels. About 10% of Americans (27 million people) obtain water from sources other than public water systems, primarily private wells (USEPA, 1995, as cited in USEPA, 2001). TCE is a common contaminant at Superfund sites. It has been identified in at least 861 of the 1,428 hazardous waste sites proposed for inclusion on the EPA National Priorities List (NPL) (ATSDR, 1997, as cited in USEPA, 2001). Studies have shown that many people live near these sites: 41 million people live less than 4 miles from one or more of the nation's NPL sites, and, on average, 3,325 people live within 1 mile of any given NPL site (ATSDR, 1996, as cited in USEPA, 2001). Thus, although exact estimates cannot be made, many people are probably exposed to TCE via drinking water from private wells. It is not known how often such exposures would be above the MCL.

4.10.6 Conclusion

Trichloroethylene is primarily used for vapor degreasing of fabricated metal parts. It is also used as a chemical intermediate and as a product for export. The use of trichloroethylene has also declined due to its toxicity. Recent statistics regarding production are not available, but according to TRI data, trichloroethylene is widely manufactured and processed in substantial amounts. Trichloroethylene is also a TRI chemical. Industrial releases of trichloroethylene have occurred since 1988 in 46 States and Puerto Rico. Trichloroethylene was an analyte for the NAWQA and NURP ambient occurrence studies. In the NAWQA study, trichloroethylene was detected in 11.6% of urban wells and 1.6% of rural wells, with median detection values of 0.9 µg/L and 0.6 µg/L, respectively. In the Stage 2 analysis of 16-State occurrence of trichloroethylene, 0.236% of combined ground water and surface water systems serving 8.19% of the population exceeded the MCL of 0.005 mg/L. Nationally, 154 ground water and surface water systems combined (serving approximately 17,451,800 people) are estimated to have levels greater than the MCL.

The 16-State cross-section was designed to be nationally representative based upon VOC, SOC, and IOC pollution potentials as suggested by considerations of manufacturing, agriculture, and geographic diversity factors. Nationally, trichloroethylene is manufactured and/or processed in 40 States and has TRI releases in 46 States. Trichloroethylene is manufactured and/or processed in 14 out of the 16 cross-section States and has TRI releases in all of the 16 cross-section States. The cross-section should adequately represent the occurrence of trichloroethylene on a national scale based upon the use, production, and release patterns of the 16-State cross-section in relation to the patterns observed for all 50 States.

4.10.7 References

Agency for Toxic Substances and Disease Registry (ATSDR). 1996. Biennial Report to Congress (1991 and 1992). Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, ATSDR. Internet site: www.dhhs.gov.

Agency for Toxic Substances and Disease Registry (ATSDR). 1997. *Toxicological Profile for Trichloroethylene*. U.S. Department of Health and Human Services, Public Health Service. 298 pp. + Appendices. Available on the Internet at http://www.atsdr.cdc.gov/toxprofiles/tp19.pdf

Andelman, J.B. 1985. Human exposure to volatile halogenated organic chemicals in indoor and outdoor air. *Environ Health Perspect* 62:313-318.

Andelman, J., A. Couch, W.W. Thurston. 1986a. Inhalation exposures in indoor air to trichloroethylene from shower water. Chapter 16. *Environmental epidemiology.* Kopfler, F.C. and G.C. Craun (eds.). Chelsea, MI: Lewis Publishers.

Andelman, J.B., S.M. Meyers, L.C. Wilder. 1986b. Volatilization of organic chemicals from indoor uses of water. *Chemicals in the environment.* Lester, J.N., R. Perry, and R.M. Sterritt (eds.). London: Selper Ltd.

Brown, H.S., D.R. Bishop, C.A. Rowan. 1984. The role of skin absorption as a route of exposure for volatile organic compounds in drinking water . *Am. J. Publ. Health* 74(5): 479-484.

Clewell, H.J., P.R. Gentry, J.M. Gearhart et al. 1995. Considering pharmacokinetic and mechanistic information in cancer risk assessments for environmental contaminants: examples with vinyl chloride and trichloroethylene. *Chemosphere.* 31(1): 2561-2578.

DHS. 1986. Organic chemical contamination of large public water systems in California. Sacramento, CA: California Department of Health Services.

Giardino, N.J., E. Gumerman, N.A. Esmen, et al. 1992. *Shower volatilization exposures in homes using tap water contaminated with TCE.* J. Exposure Analysis Environ Epidemiol (Suppl. 1): 147-158.

International Agency for Research on Cancer (IARC). 1995. *IARC monographs on the evaluation of carcinogenic risks to humans: dry cleaning, some chlorinated solvents and other industrial chemicals.* Vol.63. Lyon, France: IARC.

Lopes, T.J. and S.G. Dionne. 1998. *A Review of Semivolatile and Volatile Organic Compounds in Highway Runoff and Urban Stormwater*. U.S. Geological Survey Open-File Report 98-409. 67 pp.

National Toxicology Program (NTP). 2001. *National Toxicology Program Health and Safety Information Sheet - Trichloroethylene.* Available on the Internet at http://ntp-server.niehs.nih.gov/htdocs/CHEM_H&S/NTP_Chem7/Radian79-01-6.html, accessed July 23, 2001.

Spectrum Laboratories. 2001. *Chemical Fact Sheet - Trichloroethylene.* Available on the Internet at http://www.speclab.com/compound/c79016.htm, accessed July 23, 2001.

Squillace, P.J., M.J. Moran, W.W. Lapham, C.V. Price, R.M. Clawges, and J.S. Zogorski. 1999. Volatile organic compounds in untreated ambient groundwater of the United States, 1985-1995. *Env. Sci. and Tech*. 33(23):4176-4187.

USEPA. 1995. *The National Public Water Systems Supervision Program. The FY 1994 Compliance Report.* EPA 812-R-94-001. Washington, DC: Office of Water, USEPA.

USEPA. 1998. EPA data file. Office of Groundwater and Drinking Water. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 2000. *TRI Explorer: Trends*. Available on the Internet at: http://www.epa.gov/triexplorer/trends.htm, last updated May 5, 2000.

USEPA. 2001. *Sources, Emissions and Exposure for Trichloroethylene (TCE) and Related Chemicals.* Office of Research and Development, USEPA. March 2001.

USEPA. 2002. *Occurrence Estimation Methodology and Occurrence Findings for Six-Year Review of National Primary Drinking Water Regulations - DRAFT*. EPA Report/815-D-02-005, Office of Water, 55 pp.

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Abbreviations and Acronyms

>MRL - analytical results greater than the Minimum Reporting Limit (or Level)
1,1,2-TCE - 1,1,2-trichloroethane

ai - active ingredient
AMC - annualized mean concentration
ARP - Acetochlor Monitoring Partnership
ARP-GWMP - Acetochlor Monitoring Partnership Ground water Monitoring Program
ATSDR - Agency for Toxic Substances and Disease Registry
AWT - Advanced Wastewater Treatment
AWWA - American Water Works Association

CA - Census of Agriculture
CAS - Chemical Abstract Service
CASRN - Chemical Abstract Service Registry Number
CDC - Centers for Disease Control and Prevention
CERCLA - Comprehensive Environmental Response, Compensation & Liability Act
CMR - Chemical Monitoring Reform
CWS - Community Water System
CWSS - Community Water Supply Survey

DBCP - 1,2-Dibromo-3-chloropropane
DCE - dichloroethylene
DCP - dichloropropane
DEHP - di(2-ethylhexyl)phthalate
DHS - Department of Health Services, California

EFED - Environmental Fate and Effects Division
EPA - Environmental Protection Agency
EPCRA - Emergency Planning and Community Right-to-Know Act

FIFRA - Federal Insecticide, Fungicide, and Rodenticide Act
FR - Federal Register
FRDS - Federal Reporting Data Systems
FSTRAC - Federal/State Toxicological and Regulatory Alliance Committee

g/mol - grams per mole
GW - ground water
GWSS - Groundwater Supply Survey

HAL - Health Advisory Level
HSDB - Hazardous Substances Data Bank

IARC - International Agency for Research on Cancer
IOC - inorganic compound

LLMV - lower limit of method validation
LOD - level of detection

MCL - Maximum Contaminant Level
MCLG - Maximum Contaminant Level Goal
MDA - Minnesota Department of Agriculture
MDH - Minnesota Department of Health
MDL - Method Detection Limit
mg/L - milligrams per liter
MRL - Minimum Reporting Level

NAWQA - National Water Quality Assessment Program
NAWQA - National Alachlor Water Well Survey
NCFAP - National Center for Food and Agricultural Policy
NHANES - National Health and Nutrition Examination Survey
NIRS - National Inorganics and Radionuclides Survey
NLM - National Library of Medicine
NOMS - National Organic Monitoring Survey
NORS - National Organics Reconnaissance Survey
NPS - National Pesticide Survey
NPDES - National Pollution Discharge Elimination System
NPDWR - National Primary Drinking Water Regulations
NPL - National Priorities List
NSC - National Safety Council
NSDWR - National Secondary Drinking Water Regulation
NSP - National Screening Program for organics in drinking water
NTNCWS - Non-Transient Non-Community Water System
NTP - National Toxicology Program
NURP - National Urban Runoff Program

ODS - ozone depleting substance
ODW - Office of Drinking Water
OGWDW - Office of Ground Water and Drinking Water
OL - Optimum Level
OPP - Office of Pesticide Programs
OSHA - Occupational Safety and Health Administration

PCBs - polychlorinated biphenyls
PEL - permissible exposure limit
PGWDB - Pesticides in Ground Water Data Base
pH - the negative log of the concentration of H^+ ions
PLUARG - Pollution from Land Use Activities Reference Group
PPG - Pittsburgh Paint and Glass Industries
PVC - polyvinyl chloride
PWS - Public Water System
PWSID - Public Water System Identifier

QA - quality assurance
QC - quality control

RCRA - Resource Conservation and Recovery Act
RED - Reregistration Eligibility Decision
RWS - Rural Water Survey

RY	- Reporting Year
SAIC	- Science Applications International Corporation
SARA Title III	- Superfund Amendments and Reauthorization Act
SDWA	- Safe Drinking Water Act
SDWIS/FED	- Safe Drinking Water Information System/Federal version
SMCL	- Secondary Maximum Contaminant Level
SMSA	- standard metropolitan statistical areas
SOC	- synthetic organic compound
SRI	- formerly the Stanford Research Institute
STORET	- STOrage and RETrieval
SW	- surface water
TCE	- trichloroethylene
TDI	- toluene diisocyanate
TRI	- Toxics Release Inventory
TSD	- Technical Support Division (ODW)
TWMC	- time weighted mean concentration
USEPA	- United States Environmental Protection Agency
USGS	- United States Geological Survey
USITC	- United States International Trade Commission
USPHS	- United States Public Health Service
VOC	- volatile organic compound
WHO	- World Health Organization
µg/L	- micrograms per liter