

National Water-Quality Assessment Program

Source Water-Quality Assessments

**Anthropogenic Organic Compounds in Ground
Water and Finished Water of Community Water
Systems near Dayton, Ohio, 2002–04**

Scientific Investigations Report 2007–5035

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By Mary Ann Thomas

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U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
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U.S. Geological Survey
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Suggested citation:

Thomas, M.A., 2007, Anthropogenic organic compounds in ground water and finished water of community water systems near Dayton, Ohio, 2002–04: U.S. Geological Survey Scientific Investigations Report 2007–5035, 21 p.

Foreword

The U.S. Geological Survey (USGS) is committed to providing the Nation with accurate and timely scientific information that helps enhance and protect the overall quality of life and that facilitates effective management of water, biological, energy, and mineral resources (<http://www.usgs.gov/>). Information on the quality of the Nation's water resources is critical to assuring the long-term availability of water that is safe for drinking and recreation and suitable for industry, irrigation, and habitat for fish and wildlife. Population growth and increasing demands for multiple water uses make water availability, now measured in terms of quantity and quality, even more essential to the long-term sustainability of our communities and ecosystems.

The USGS implemented the National Water-Quality Assessment (NAWQA) Program in 1991 to support national, regional, and local information needs and decisions related to water-quality management and policy (<http://water.usgs.gov/nawqa>). Shaped by and coordinated with ongoing efforts of other Federal, State, and local agencies, the NAWQA Program is designed to answer: What is the condition of our Nation's streams and ground water? How are the conditions changing over time? How do natural features and human activities affect the quality of streams and ground water, and where are those effects most pronounced? By combining information on water chemistry, physical characteristics, stream habitat, and aquatic life, the NAWQA Program aims to provide science-based insights for current and emerging water issues and priorities.

From 1991 to 2001, the NAWQA Program completed interdisciplinary assessments in 51 of the Nation's major river basins and aquifer systems, referred to as Study Units (<http://water.usgs.gov/nawqa/studyu.html>). Baseline conditions were established for comparison to future assessments, and long-term monitoring was initiated in many of the basins. During the next decade, 42 of the 51 Study Units will be reassessed so that 10 years of comparable monitoring data will be available to determine trends at many of the Nation's streams and aquifers. The next 10 years of study also will fill in critical gaps in characterizing water-quality conditions, enhance understanding of factors that affect water quality, and establish links between sources of contaminants, the transport of those contaminants through the hydrologic system, and the potential effects of contaminants on humans and aquatic ecosystems.

The USGS aims to disseminate credible, timely, and relevant science information to inform practical and effective water-resource management and strategies that protect and restore water quality. We hope this NAWQA publication will provide you with insights and information to meet your needs, and will foster increased citizen awareness and involvement in the protection and restoration of our Nation's waters.

The USGS recognizes that a national assessment by a single program cannot address all water-resource issues of interest. External coordination at all levels is critical for a fully integrated understanding of watersheds and for cost-effective management, regulation, and conservation of our Nation's water resources. The NAWQA Program, therefore, depends on advice and information from other agencies—Federal, State, interstate, Tribal, and local—as well as nongovernmental organizations, industry, academia, and other stakeholder groups. Your assistance and suggestions are greatly appreciated.

Robert M. Hirsch
Associate Director for Water

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Conversion Factors, Abbreviations, and Acronyms

Multiply	By	To obtain
Length		
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
kilometer (km)	0.6214	mile (mi)
Area		
square mile (mi ²)	2.590	square kilometer (km ²)
Volume		
million gallons (Mgal)	3,785	cubic meter (m ³)
parts per billion	1.0	micrograms per liter (µg/L)

Abbreviations and Acronyms

<	Less than
>	Greater than
µg/L	micrograms per liter
AOC	Anthropogenic organic compound
BQ	Benchmark Quotient
BQmax	Ratio of the maximum concentration to a drinking-water benchmark
CWS	Community water system
E	Estimated concentration
DBP	Disinfection byproduct
HBSL	Health Based-Screening Level
MRL	Minimum Reporting Level
OAOC	Other anthropogenic organic compound
MTBE	Methyl tert-butyl ether
NAWQA	National Water-Quality Assessment
NWQL	National Water Quality Laboratory
SWQA	Source Water-Quality Assessment
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VOC	Volatile organic compound

Anthropogenic Organic Compounds in Ground Water and Finished Water of Community Water Systems near Dayton, Ohio, 2002–04

By Mary Ann Thomas

Abstract

Source water for 15 community-water-system (CWS) wells in the vicinity of Dayton, Ohio, was sampled to evaluate the occurrence of 258 anthropogenic compounds (AOCs). At least one AOC was detected in 12 of the 15 samples. Most samples contained a mixture of compounds (average of four compounds per sample). The compounds that were detected in more than 30 percent of the samples included three volatile organic compounds (VOCs) (trichloroethene, chloroform, and 1,1,1-trichloroethane) and four pesticides or pesticide breakdown products (prometon, simazine, atrazine, and deethylatrazine). In general, VOCs were detected at higher concentrations than pesticides were; among the VOCs, the maximum detected concentration was 4.8 $\mu\text{g/L}$ (for trichloroethene), whereas among the pesticides, the maximum detected concentration was 0.041 $\mu\text{g/L}$ (for atrazine).

During a later phase of the study, samples of source water from five CWS wells were compared to samples of finished water associated with each well. In general, VOC detections were higher in finished water than in source water, primarily due to the occurrence of trihalomethanes, which are compounds that can form during the treatment process. In contrast, pesticide detections were relatively similar between source- and finished-water samples.

To assess the human-health relevance of the data, concentrations of AOCs were compared to their respective human-health benchmarks. For pesticides, the maximum detected concentrations were at least 2 orders of magnitude less than the benchmark values. However, three VOCs—trichloroethene, carbon tetrachloride, and tetrachloromethane—were detected at concentrations that approach human-health benchmarks and therefore may warrant inclusion in a low-concentration, trends monitoring program.

Introduction

The U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program was designed to document the Nation's current water-quality conditions, identify water-quality trends, and describe factors that affect water-

quality conditions and trends. Beginning in 2001, the NAWQA Program has been characterizing the quality of major aquifers used as a source of supply for larger community water systems (CWSs) through a new type of study called Source Water-Quality Assessments (SWQAs). As of 2006, 15 ground-water SWQAs have been completed in NAWQA study units around the Nation (fig. 1). These studies are intended to complement drinking-water monitoring required by Federal, state, and local programs, which focus primarily on posttreatment compliance monitoring.

The compounds monitored for SWQAs are referred to as anthropogenic organic compounds (AOCs); that is, chemicals that are commonly derived from or related to human activity in industrialized societies. These include volatile organic compounds (VOCs), pesticides and pesticide breakdown products, and other anthropogenic organic compounds (OAOCs). VOCs are a subset of organic chemicals that have been produced and used in a variety of commercial, industrial, and household applications for many decades and are major components or additives to gasoline, paints, varnishes, glues, dyes, and plastics. Pesticides are used extensively throughout the United States to increase crop yields; enhance the esthetics of lawns, gardens, golf courses, and recreational areas; and protect the safety of the public from insect-associated diseases. OAOCs represent a group of compounds that are present in a wide range of products commonly used in homes, industry, and agriculture, including personal-care and domestic-use products, plant- or animal-derived biochemicals, and fumigants.

This report focuses on an SWQA completed in the vicinity of Dayton, Ohio, which is part of the White River-Great and Little Miami River Basins (WHMI) study unit (fig. 1). The Dayton area was chosen for study because a large population relies heavily on ground water from the glacial aquifer system, one of the Nation's most widespread principal aquifers (Warner and Arnold, 2005).

The report has three objectives: (1) describe the occurrence of AOCs in source water of 15 CWSs in the vicinity of Dayton, Ohio, during 2002–2003, (2) describe and compare the occurrence of selected AOCs in source water and finished water from 5 CWSs during 2004, and (3) compare detected concentrations of AOCs to benchmark concentrations to evaluate the potential relevance to human health.

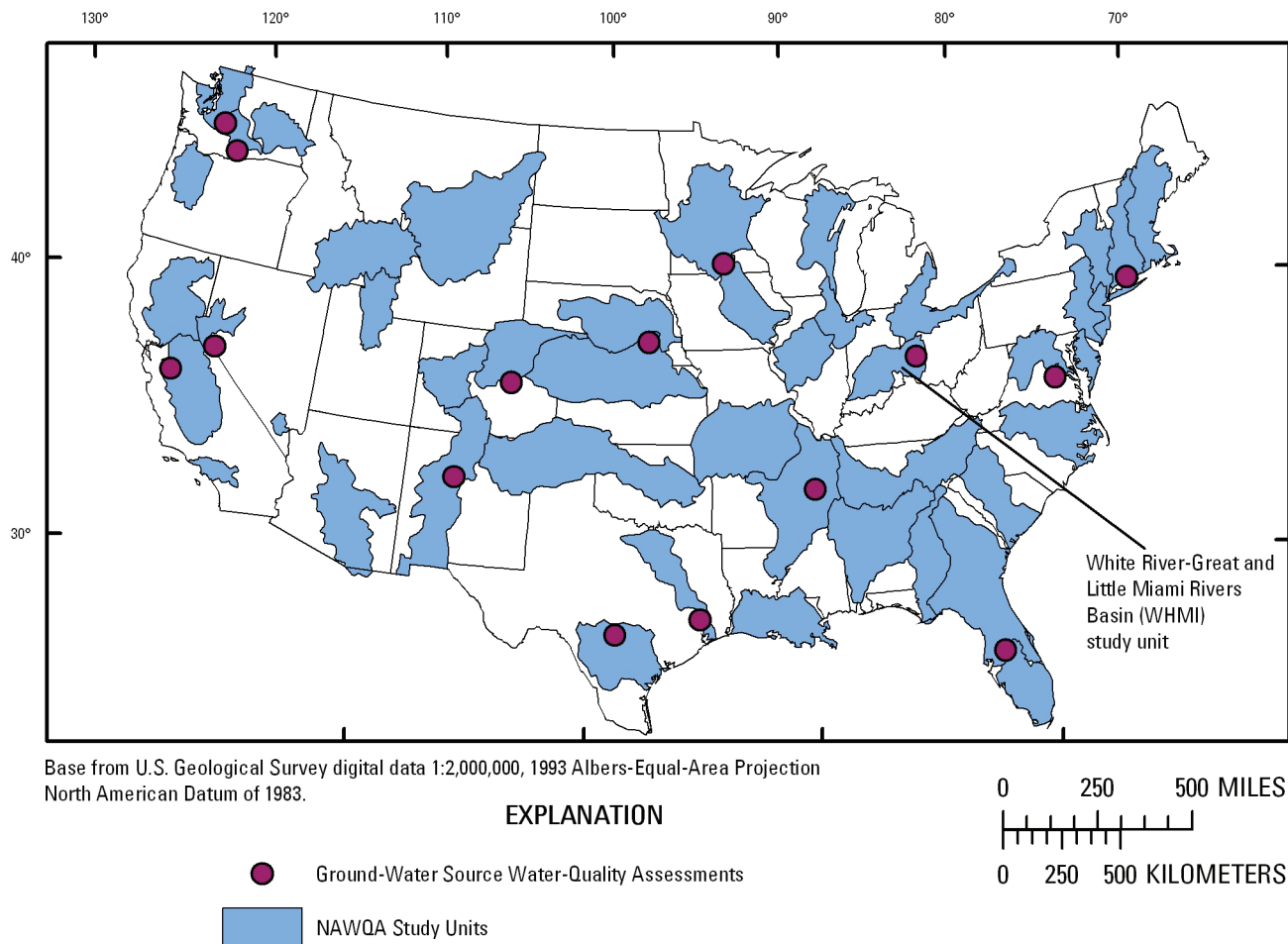


Figure 1. Location of National Water-Quality Assessment Study Units and Ground-Water Source Water-Quality Assessments.

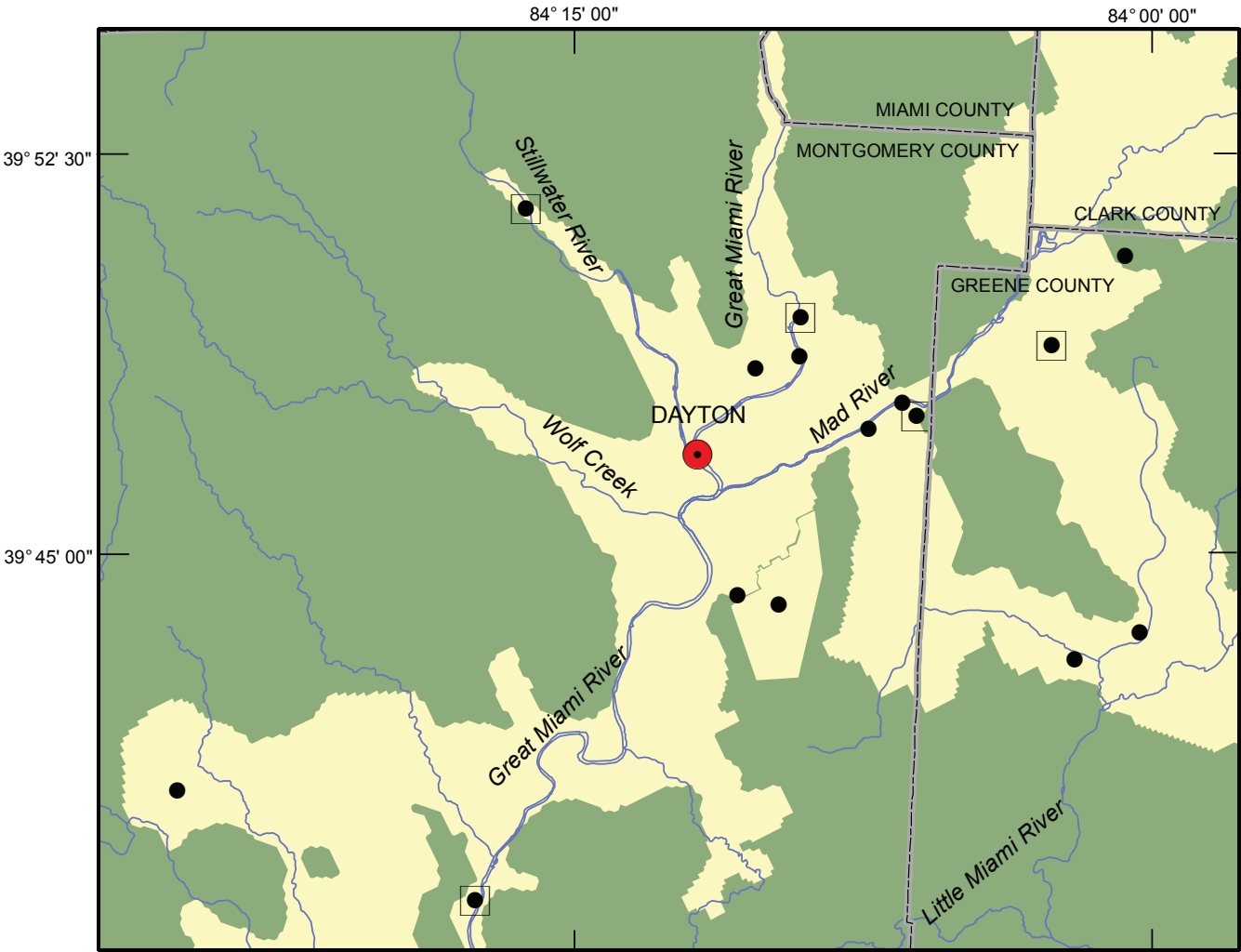
Description of Study Area

The study area is in the vicinity of Dayton, Ohio, a major industrial center for southwestern Ohio and the home of Wright-Patterson Air Force Base. The study area includes a 250-mi² area that overlies valley-fill deposits of the glacial aquifer system, locally referred to as the Buried-Valley Aquifer (fig. 2). The majority of water use in Dayton and surrounding areas is from the Buried-Valley Aquifer, which has been designated a sole-source aquifer by the U.S. Environmental Protection Agency (Debrewer and others, 2000). Along the main valley, land use is predominantly urban, commercial, or residential. Agriculture (row crops and pasture) is the predominant land use in the upper reaches of the tributary valleys (Debrewer and others, 2000; Sheets, in press).

The hydrogeology of the study area has been described by Norris and Spieker (1966), Dumouchelle (1998), Sheets and others (1998), Debrewer and others (2000), and Sheets

(in press). The climate is temperate continental, and the average annual rainfall is approximately 39 in. (Debrewer and others, 2000). The topography is flat to gently rolling. Preglacial valleys are incised in bedrock and are filled with as much as 300 ft of glacial deposits. The glacial deposits are predominantly coarse grained (fine sand to gravel) but are interspersed with layers of clay-rich till or clay (Dumouchelle, 1998). In areas where the till is laterally continuous, the glacial deposits are separated into two or more aquifers, the lower aquifer being confined or semiconfined (Norris and Spieker, 1966).

Under natural flow conditions, the predominant source of ground-water recharge is precipitation, and the predominant discharge areas are major streams. However, heavy pumping in the study area induces infiltration of surface water (rivers and artificial recharge lagoons) to the aquifer (Sheets, in press). For the period 1997–2001, more than 300 publicly and privately owned wells pumped water from the glacial deposits at an average rate of 500,00 m³/d (Sheets, in press).



Base from U.S. Geological Survey
Albers projection



EXPLANATION




-  Approximate extent of buried valleys (from Dumouchelle, 1998)
-  Wells sampled during Phase 1
-  Wells resampled during Phase 2

Figure 2. Location of wells sampled for the Source Water-Quality Assessment near Dayton, Ohio, 2002–04.

Ground-water quality of the Buried-Valley Aquifer in the study area was documented by Rowe and others (1999, 2004). In general, ground water is of the calcium-magnesium-bicarbonate type, and the pH is circumneutral (around 7). Redox conditions vary from oxic to anoxic. Oxic waters rarely occur at depths greater than 40 ft below the water table (Rowe and others, 1999). Anoxic waters predominate at greater depths but are also present at shallow depths. Ground-water ages in the upper 50 ft of the aquifer are generally 1 to 2 years; at greater depths, ground-water can be as old as 50 years (Rowe and others, 1999, 2004).

Most of the water produced by large CWSs is treated and blended prior to distribution to consumers. As used in this study, “source water” is the raw (ambient) water collected at the supply well prior to water treatment, “blended water” is a mixture of water from several ground-water sources, and “finished water” is the source water or blended water that is treated and ready to be delivered to consumers.

Study Methods

SWQA studies are based on nationally consistent methods for site selection, sample collection and analysis (Carter and others, 2007). Water-quality results are interpreted in a human-health context using Health-Based Screening Levels (Toccalino and others, 2006).

Well Selection

SWQA studies are targeted to urban areas where most of the water use is from a major aquifer, such as the Buried-Valley Aquifer. Additional criteria for well selection are the following: (1) wells are least one km apart to ensure that contributing areas do not overlap, (2) the wells are among the highest producing CWSs in the study area, based on annual production data for a well or well field, and (3) the wells are not under the influence of surface water.

For the Dayton area, most of highest-producing CWS wells are near rivers, and pumping induces surface-water infiltration to wells. So, the decision was made to relax the third well-selection criterion and select wells that were minimally influenced by surface-water infiltration, with the understanding that these wells would not all have high annual pumping rates. Identification of wells minimally influenced by surface water was facilitated by the use of a steady-state ground-water-flow model for the Buried-Valley Aquifer in the Dayton area that was developed by Dumouchelle (1998) and refined by Sheets (in press). Wells were deemed to be minimally influenced by surface-water infiltration if the majority of the flow lines to the well did not originate at a river or other surface water body (Rodney A. Sheets, U.S. Geological Survey, oral commun., 2004). However, it is possible that other wells from the same well fields could be under the influence of surface-water infiltration, so a sample of blended water could show the

effects of surface-water infiltration. The first criterion also was relaxed: two of the selected wells were less than 1 km apart, but they were on different sides of the Great Miami River, and it is unlikely that the contributing areas overlap.

Characteristics of the 15 selected wells are listed in table 1. The wells were 60–158 ft deep, and the open intervals were 12–50 ft long. For 14 of the 15 wells, annual average production rates during 2002 were estimated to range from 120 to 2,080 Mgal, with an average value of 980 Mgal. One of the wells was not in use during 2002, although other wells in the same well field were.

Table 1. Selected characteristics of 15 community-water-system wells sampled during Phase 1 of the Source Water-Quality Assessment near Dayton, Ohio.

Well depth, in feet	Length of open interval, in feet	Annual pumping, in millions of gallons
60	12	223
77	30	111
80	25	120
83	20	80
84	30	138
94	20	0
94	24	568
123	25	217
125	17	62
136	38	260
146	50	389
148	15	35
152	50	200
157	50	275
158	30	88

Sample Collection, Analysis, and Quality Control

The study was done in two phases. For Phase 1, source-water samples were collected from the 15 CWS wells mentioned previously. The samples were collected at the wellhead before any treatment. Established USGS protocols were followed for sample collection and preservation (Koterba and others, 1995). Samples were analyzed for 88 VOCs, 120 pesticides, and 50 OAOs (Carter and others, 2007).

For Phase 2, a subset of the wells was resampled. Five wells were selected for resampling on the basis of relatively high frequency or concentration of AOC detections during Phase 1. The finished water associated with each of the

five source-water wells also was analyzed. Finished-water samples were collected after treatment and blending but before distribution. Finished-water samples were stabilized during collection by the addition of a dechlorination agent (ascorbic acid) and, for certain contaminant groups, pH buffers. Samples were analyzed for VOCs, pesticides, and OAOCs, in addition to 19 acetamide herbicides and breakdown products (Carter and others, 2007).

During both phases of study, quality-control samples (equipment blanks, field blanks, source-solution blanks, replicates, and field spikes) were collected and analyzed in accordance with established protocols (Koterba and others, 1995; Carter and others, 2007).

Samples were analyzed at the USGS National Water Quality Laboratory in Denver, Colo., by USGS-approved analytical methods (Zaugg and others, 1995; Lindley and others, 1996; Connor and others, 1998; Furlong and others, 2001; Sandstrom and others, 2001; Zaugg and others, 2002; and Madsen and others, 2003). Analyses for the additional acetamide herbicides and breakdown products collected for Phase 2 were done at the Organic Geochemistry Research Group Laboratory in Lawrence, Kansas (Lee and Strahan, 2003).

On a national scale, all data (including source-water, finished-water, and quality-control samples) from each SWQA study were collectively reviewed each year. The goals were to evaluate variability and potential bias from systematic contamination. No systematic contamination was found for VOCs (D.A. Bender, U.S. Geological Survey, written commun., 2006) or pesticides (J.A. Hopple, U.S. Geological Survey, written commun., 2006). On the other hand, analysis of OAOC field and laboratory blank data indicated possible systematic contamination for several compounds. Of the 7 compounds detected during the study in the Dayton area, six were identified as possible contaminants because of their frequent occurrence in field blanks (J.A. Kingsbury, U.S. Geological Survey, written commun., 2006) or laboratory blanks resulting from laboratory procedures used prior to 2005 (Zaugg and Leiker, 2006). For the current study, the single OAOC that was not identified as a possible contaminant was detected in one sample at a concentration too small to be quantified. For these reasons, OAOC detections are not included in this report.

Interpretation of Results in a Human-Health Context

Historically, the USGS has assessed water-quality by comparing measured concentrations to USEPA Maximum Contaminant Levels (MCLs) for regulated compounds (U.S. Environmental Protection Agency, 2002) and drinking-water guidelines for unregulated compounds. However, MCLs and drinking-water guidelines have not been established for more than 85 percent of the compounds monitored by SWQAs. Health-Based Screening Levels (HBSLs) were developed to provide a more complete understanding of the

significance of water-quality data (Toccalino and others, 2006). HBSLs are benchmark concentrations of contaminants in water that may be of potential concern for human health, if exceeded. HBSLs supplement existing MCLs and drinking-water guidelines. For regulated compounds, the HBSL is the same as the Maximum Contaminant Level (MCL).

Benchmark Quotient (BQ) values are used as a means of comparing measured concentrations of contaminants to their respective human-health benchmarks (Toccalino and others, 2006). The BQ value is the ratio of a measured concentration of a compound to its MCL or HBSL. For a particular compound, the BQmax is the maximum BQ value for all samples in a dataset. BQmax values greater than 0.1 identify compounds that may warrant inclusion in a low-concentration, trends-monitoring program. BQmax values greater than or equal to 1.0 identify concentrations that may be of potential human-health concern (Toccalino and others, 2006).

Consumer confidence reports and source-water quality assessments.— Since 1999, the U.S. Environmental Protection Agency (USEPA) has required water suppliers to provide annual drinking-water quality reports called Consumer Confidence Reports (CCRs) to their customers (<http://www.epa.gov/safewater/ccr/ccrfact.html>). CCRs are the centerpiece of the right-to-know provisions of the 1996 Amendments to the Safe Drinking Water Act. Each CCR lists fundamental information about drinking water:

- The source of the drinking water.
- A brief summary of the susceptibility to contamination of the local drinking-water source.
- The concentrations (or range of concentrations) of any contaminants found in local drinking water, as well as their USEPA Maximum Contaminant Levels (MCLs) for comparison. MCLs are legally enforceable drinking-water standards and are the highest allowed concentrations of contaminants in drinking water.
- Phone numbers for additional sources of information.

Information in each CCR is specific to a particular water utility. Water utilities analyze finished-water samples primarily for regulated contaminants (that is, those with MCLs) using USEPA analytical methods for the purpose of compliance monitoring. In contrast, USGS Source Water-Quality Assessments (SWQAs) are not done for compliance monitoring and encompass data from multiple water utilities spatially distributed across the Nation. As part of SWQAs, both source- and finished-water samples are analyzed by USGS analytical methods, where source water is the raw (ambient) water collected at a supply well prior to water treatment, and finished water is the treated water sampled prior to its entering the distribution system. USGS analytical methods used in SWQAs typically have lower analytical reporting levels than those used in compliance monitoring; contaminant detection frequencies reported in SWQA reports may therefore be higher than detection frequencies for the same contaminants reported in CCRs. In SWQAs, concentrations of regulated and unregulated contaminants in source and finished water are compared to MCLs and Health-Based Screening Levels (HBSLs), respectively. HBSLs are estimates of benchmark concentrations of contaminants in water that may be of potential human-health concern and are consistent with USEPA Office of Water methodologies for setting non-enforceable drinking-water guideline values. HBSLs are not legally enforceable regulatory standards, and water utilities are not required to compare contaminant monitoring results to HBSLs.

Anthropogenic Organic Compounds in Ground Water During Phase 1

For Phase 1 of the SWQA study near Dayton, samples were collected from 15 CWS wells between November 2002 and January 2003. The complete dataset is available in Shindel and others (2003). Summaries of the detected AOCs are presented in figure 3 and table 2.

At least one AOC was detected in 12 of the 15 samples. Most samples had a mixture of AOCs; an average of four compounds per sample were detected. The maximum number of AOC detections in a single sample was 13.

The minimum reporting levels for detected compounds varied from 0.2 to 0.005 $\mu\text{g/L}$. For a true comparison of analytical results among different AOCs, each compound should have the same reporting level, because compounds with low reporting levels may be detected more frequently than those with higher reporting levels. However, for the purposes of this report, comparisons are made among AOCs regardless of the varied reporting levels.

Volatile Organic Compounds

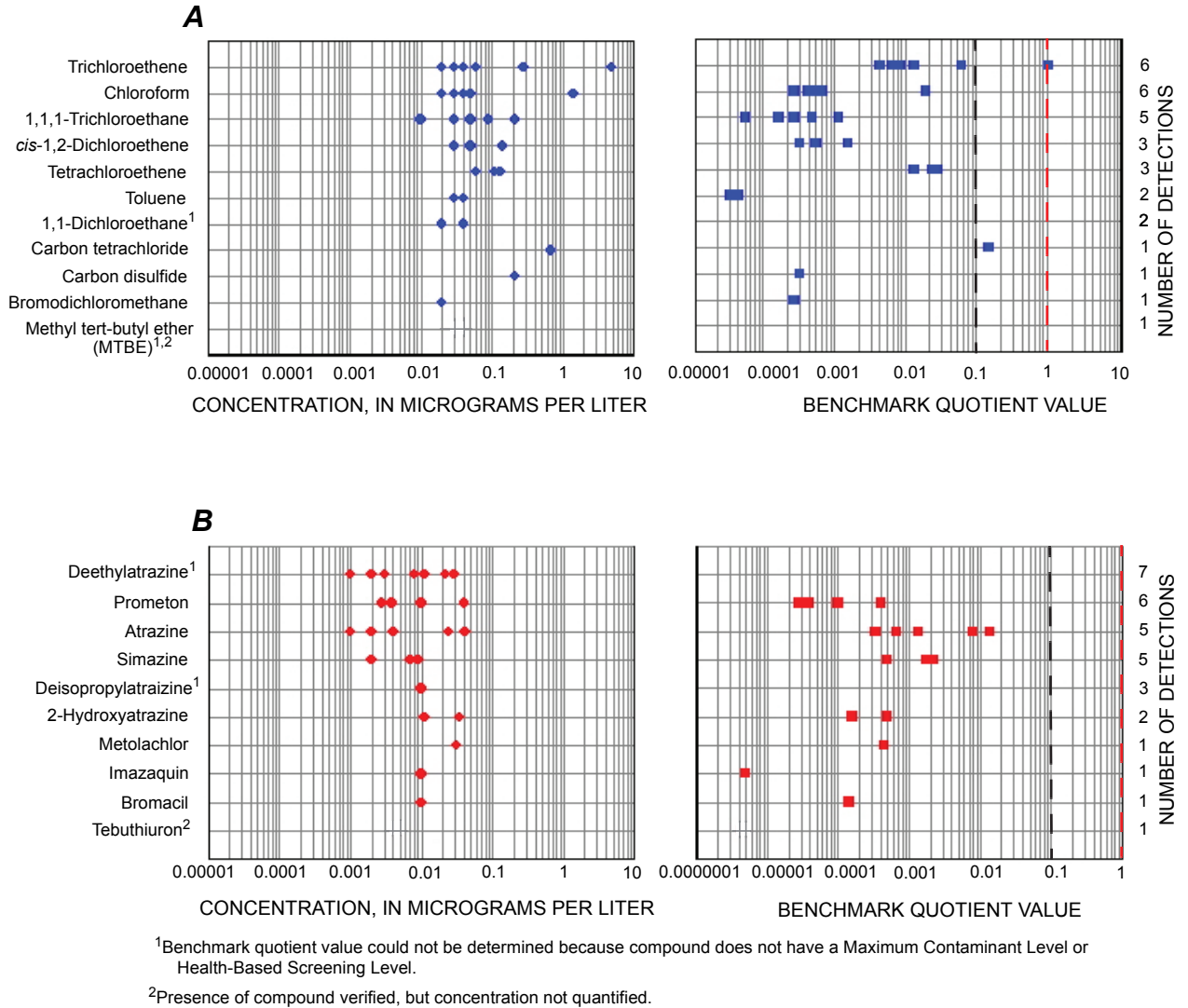
Eleven VOCs were detected in source-water samples (fig. 3A, table 2). The VOCs detected most frequently—in more than 30 percent of the samples—were trichloroethene (TCE), 1,1,1-trichloroethane, and chloroform. TCE is a solvent primarily used in dry cleaning but also used for paint and ink formulation, and rubber processing (Zogorski and others, 2006). 1,1,1-trichloroethane is a solvent used for dyeing, textile processing, cosmetics, and aerosols (Zogorski and others, 2006). Chloroform is one of four disinfection byproducts (DBPs) produced during the chlorination of drinking water and wastewater. Chloroform can enter the ground water if chlorinated water is used for irrigation or leaks from distribution lines, pools, or septic systems (Thiros, 2000). Chloroform can also be formed by dehalogenation of tetrachloromethane or from natural sources (Ivahnenco and Barbash, 2004).

The maximum VOC concentration detected was 4.8 $\mu\text{g/L}$ (for trichloroethene). Human-health benchmarks were available for nine of the VOCs detected. For seven of these compounds, concentrations were low relative to the human-health benchmarks; BQmax values were 1–5 orders of magnitude below 0.1 (table 1, fig 3A). However, two VOCs had BQmax values greater than 0.1 and therefore might warrant inclusion in a low-concentration, trends-monitoring program (Toccalino and others, 2006). Trichloroethene had a BQmax value of 0.96, and carbon tetrachloride had a BQmax value of 0.14.

Pesticides

Ten pesticide compounds were detected in the source-water samples collected during Phase 1 of the study (fig. 3B, table 2). All of the pesticide compounds detected were herbicides. Four herbicides were detected in more than 30 percent of samples: prometon, simazine, atrazine, and deethylatrazine. Prometon is an herbicide that is primarily used in nonagricultural settings—roadsides, and residential or commercial areas. Simazine has both agricultural and nonagricultural uses (U.S. Geological Survey, 1999). Atrazine is an herbicide that is widely used on corn and soybeans, and deethylatrazine is a breakdown product of atrazine. Of the 32 pesticide detections, more than half (53 percent) were derived from atrazine and its breakdown products (deethylatrazine, deisopropylatrazine, or 2-hydroxyatrazine). The high detection frequency for atrazine and its breakdown products might be related to widespread use and persistence in ground water (Kruger and others, 1995; Barbash and others, 1999).

The maximum pesticide concentration detected was 0.041 $\mu\text{g/L}$ (for atrazine). In general, pesticides were detected at lower concentrations than VOCs; the maximum pesticide concentration was 2 orders of magnitude less than the maximum VOC concentration (fig. 3A and 3B). Human-health benchmarks were available for eight of the pesticides detected, and BQmax values were 1–6 orders of magnitude below 0.1 (table 2). A human-health benchmark was not available for deethylatrazine, which was detected in almost half of the samples.



EXPLANATION

Benchmark quotient value

Ratio of the detected concentration of a compound to its Maximum Contaminant Level or Health-Based Screening Level

! Greater than or equal to 0.1

! The compound may warrant inclusion in a low-concentration, trends-monitoring program

! Greater than or equal to 1.0

! The concentration may be of potential human-health concern

Figure 3. Concentrations, number of detections, and benchmark quotient values for samples collected during Phase 1 from 15 source-water wells of community water systems near Dayton, Ohio. **A**, Volatile organic compounds. **B**, Pesticides.

8 Anthropogenic Organic Compounds in Community Water Systems near Dayton, Ohio, 2002–04

Table 2. Maximum concentration, detection frequency, and maximum benchmark quotient for regulated and unregulated compounds detected in samples collected during Phase 1 from 15 source-water wells of community water systems near Dayton, Ohio.

[USEPA, U.S. Environmental Protection Agency; µg/L, micrograms per liter; MCL, Maximum Contaminant Level; HBSL, Health-Based Screening Level; BQmax, maximum Benchmark Quotient = ratio of maximum compound concentration to MCL or HBSL value; E, estimated value; <, less than; M, presence of compound verified, but concentration not quantified; --, not available. A regulated compound is one for which Federal and (or) state drinking-water standards have been established; an unregulated compound is one for which no Federal and (or) state drinking-water standards exist.]

Regulated (r) or unregulated (u) compound	Chemical Abstracts Service registry number	Number of detections for source water	Detection frequency (percent)	Minimum reporting level (µg/L)	Maximum concentration for source water (µg/L)	USEPA MCL ¹ or HBSL concentration (µg/L)	BQmax for source water
Volatile organic compounds							
Trichloroethene (r)	79-01-6	6	40	0.04	4.82	5	0.96
Chloroform (r)	67-66-3	6	40	.02	1.40	³ 80	.0175
1,1,1-Trichloroethane (r)	71-55-6	5	33	.03	.21	200	.001
<i>cis</i> -1,2-Dichloroethene (r)	156-59-2	3	20	.04	.14	100	.0014
Tetrachloroethene (r)	127-18-4	3	20	.03	.13	5	.026
Toluene (r)	108-88-3	2	13	.05	E .04	1000	E .00004
1,1-Dichloroethane (u)	75-34-3	2	13	.04	E .04	--	--
Carbon tetrachloride (r)	56-23-5	1	7	.06	.68	5	.136
Carbon disulfide (u)	75-15-0	1	7	.07	.21	³ 700	.0003
Bromodichloromethane (r)	75-27-4	1	7	.05	E .02	³ 80	E .0002
Methyl tert-butyl ether (MTBE) (u)	1634-04-4	1	7	.2	M	--	--
Total number of VOC detections		31					
Pesticides							
Deethylatrazine (u)	6190-65-4	7	47	.006	E .029	--	--
Prometon (u)	1610-18-0	6	40	.01	.04	³ 100	.0004
Atrazine (r)	1912-24-9	5	33	.007	.041	3	.0137
Simazine (r)	122-34-9	5	33	.005	.009	4	.0023
Deisopropylatrazine (u)	1007-28-9	3	20	.04	E .01	--	--
2-Hydroxyatrazine (u)	2163-68-0	2	13	.008	E .035	³ 70	E .0005
Metolachlor (u)	51218-45-2	1	7	.013	.031	³ 70	.0004
Imazaquin (u)	81335-37-7	1	7	.02	E .01	³ 2,000	E .00001
Bromacil (u)	314-40-9	1	7	.03	E .01	³ 70	E .0001
Tebuthiuron (u)	34014-18-1	1	7	.02	M	³ 1,000	--
Total number of pesticide detections		32					
Total number of detections for all compounds		73					

¹U.S. Environmental Protection Agency (2003, 2004).

²MCL is for total trihalomethanes.

³Denotes HBSL (Toccalino and others, 2003).

Comparison of Ground Water and Finished Water During Phase 2

For Phase 2 of the study, 5 of the 15 CWS wells were resampled during June and July 2004. Two samples were collected at each site: (1) a sample of the source water, similar to that collected during Phase 1, and (2) a sample of the finished water associated with the source-water well. All of the finished-water samples had been blended with ground water from three to seven other CWS wells from the same well field. In addition, all samples of finished water were treated by chlorination, filtration, chemical oxidation, fluoridation, and one or more of the following: pH adjustment, ion exchange, or air stripping. The complete dataset is available in Shindel and others (2005).

It is not feasible to characterize the overall frequency of occurrence of compounds using data from Phase 2 because (1) the results are biased to the AOCs detected most frequently, and (2) not all samples were analyzed for the same compounds. Therefore, the focus of this section of the report is on comparing AOC detections in source water to the associated finished water.

Volatile Organic Compounds

A total of 14 VOCs were detected in samples collected during Phase 2 (fig. 4, table 3). In source-water samples, 8 different compounds were detected, and the total number of VOC detections was 21. The eight compounds detected in source water during Phase 2 were also detected during Phase 1.

VOCs were detected more frequently in finished water than in source water (fig. 4, table 3). For finished-water samples, 13 different compounds were detected, and the total number of detections was 37. In all, six different compounds were detected in finished water but not source water. Disinfection byproducts (DBPs) accounted for more than half (20 of the 37) of the VOC detections in finished water but less than 15 percent (3 of 21) in source water. Chloroform, bromodichloromethane, dibromochloromethane, and bromoform are DBPs that were detected in all five finished-water samples (table 3). Although chloroform can be from natural sources, the detection of associated DBPs suggests that the source of chloroform is related to the input of chlorinated water or other anthropogenic sources of chloroform (Ivahnenko and Barbash, 2004). In addition to DBPs, the other compounds that were detected in finished water but not source water were m- and p-xylene, ethylbenzene, and trans-1,2-dichloroethene.

The presence of AOCs in finished water but not source water might be related to the fact that source water is from a single well, whereas finished water is a blend of water from three to seven other wells that may have different production rates, depths, and (or) zones of contribution than the single source-water well that was sampled. Another possible explanation is that compounds were introduced as the water traveled between the points where source-water and finished-water samples were collected. Regardless of what accounts for the differences, the results indicate that monitoring VOCs in source water does not necessarily characterize the occurrence of VOCs in finished water (Metz and others, in press). Of the VOCs detected during Phase 2 sampling, half were detected in either the source water or finished water, but not both.

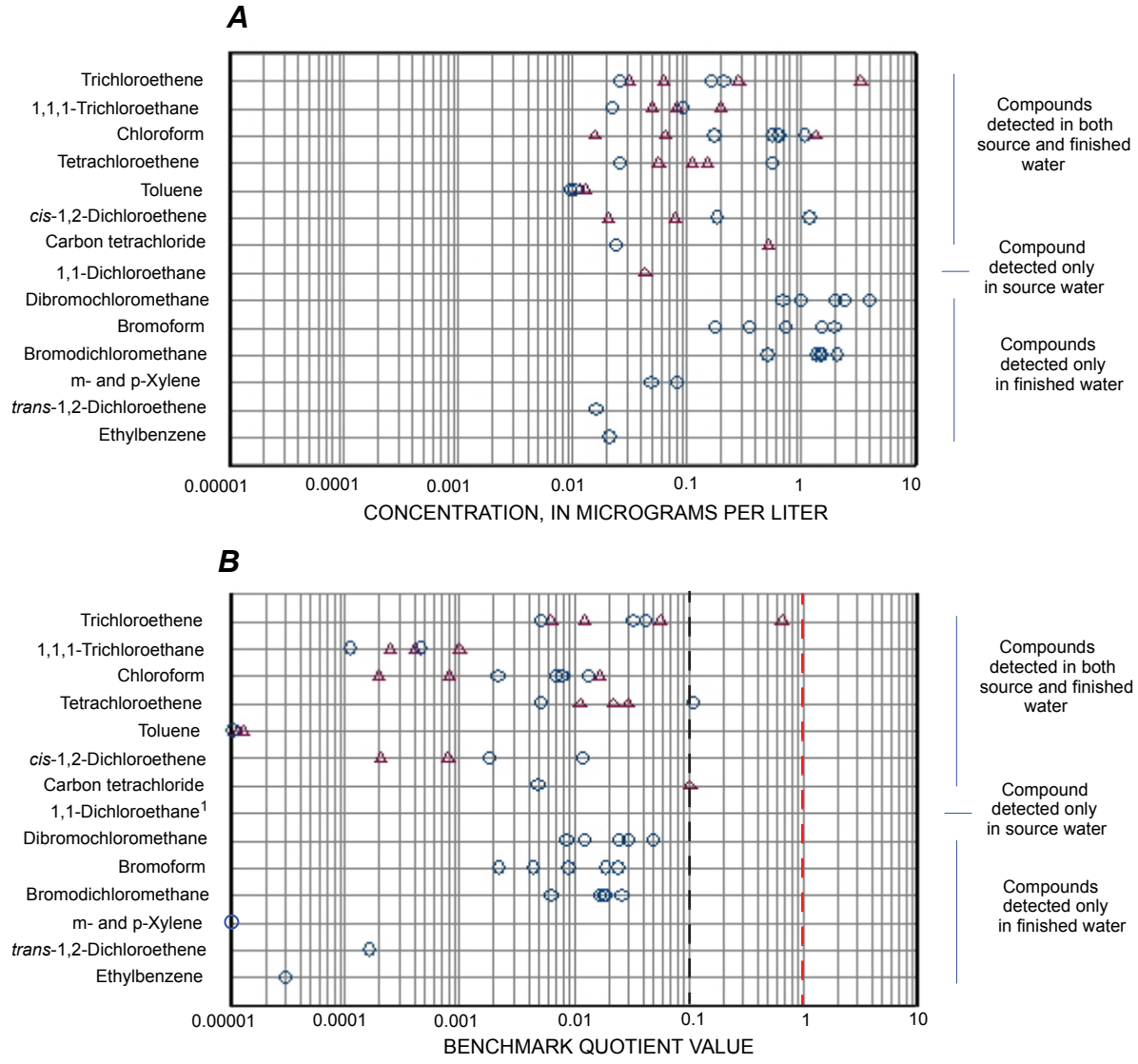
Of the 14 VOCs detected in either source or finished water, 13 had human-health benchmarks. For most (10 of 13), detected concentrations were 2–5 orders of magnitude less than human-health benchmarks. However, three VOCs had BQmax values greater than 0.1 and therefore may warrant inclusion in a low-concentration, trends-monitoring program (Toccalino and others, 2006). Trichloroethene and carbon tetrachloride had BQmax values greater than 0.1 for source water but not finished water. These are the same VOCs identified as being of potential concern for source water sampled during Phase 1. In addition, tetrachloroethene had a BQmax value greater than 0.1 for finished water but not source water.

Pesticides

A total of 22 individual pesticides were detected. Most of the pesticides (18 of 22) were detected in both source and finished water at similar concentrations (table 3 and fig. 5). But overall, finished water had more pesticide detections (55) than source water did (45).

In all, 9 of the 10 pesticides detected during Phase 1 were also detected during Phase 2. However, during Phase 2, samples were analyzed for 19 additional pesticides or pesticide breakdown products that were not analyzed for during Phase 1. For example, metolachlor ESA and metolachlor OA were detected in every sample of source and finished water during Phase 2 but were not sampled for during Phase 1.

Concentrations of detected pesticides in source water and finished water were similar and ranged from 0.008 to 0.77 µg/L in the source water and from E0.004 to 0.8 µg/L in finished water (fig. 5). Human-health benchmarks were available for 11 of the 22 pesticides, and BQmax values for those compounds were 1–5 orders of magnitude less than 0.1 (fig. 5).



¹Benchmark quotient value could not be determined because compound does not have a Maximum Contaminant Level or Health-Based Screening Level

EXPLANATION

Benchmark quotient value

Ratio of the detected concentration of a compound to its Maximum Contaminant Level or Health-Based Screening Level

Greater than or equal to 0.1

The compound may warrant inclusion in a low-concentration, trends-monitoring program

Greater than or equal to 1.0

The concentration may be of potential human-health concern

△ Source water (raw)

○ Finished water (treated and blended)

Figure 4. Comparison of volatile organic compounds in samples collected during Phase 2 from five source-water wells and the associated finished water of community supply systems near Dayton, Ohio. **A**, Concentrations. **B**, Benchmark quotient values.

Table 3. Maximum concentration, detection frequency, and maximum benchmark quotient for regulated and unregulated compounds detected in samples collected during Phase 2 from five source-water wells and the associated finished water of community water systems near Dayton, Ohio.

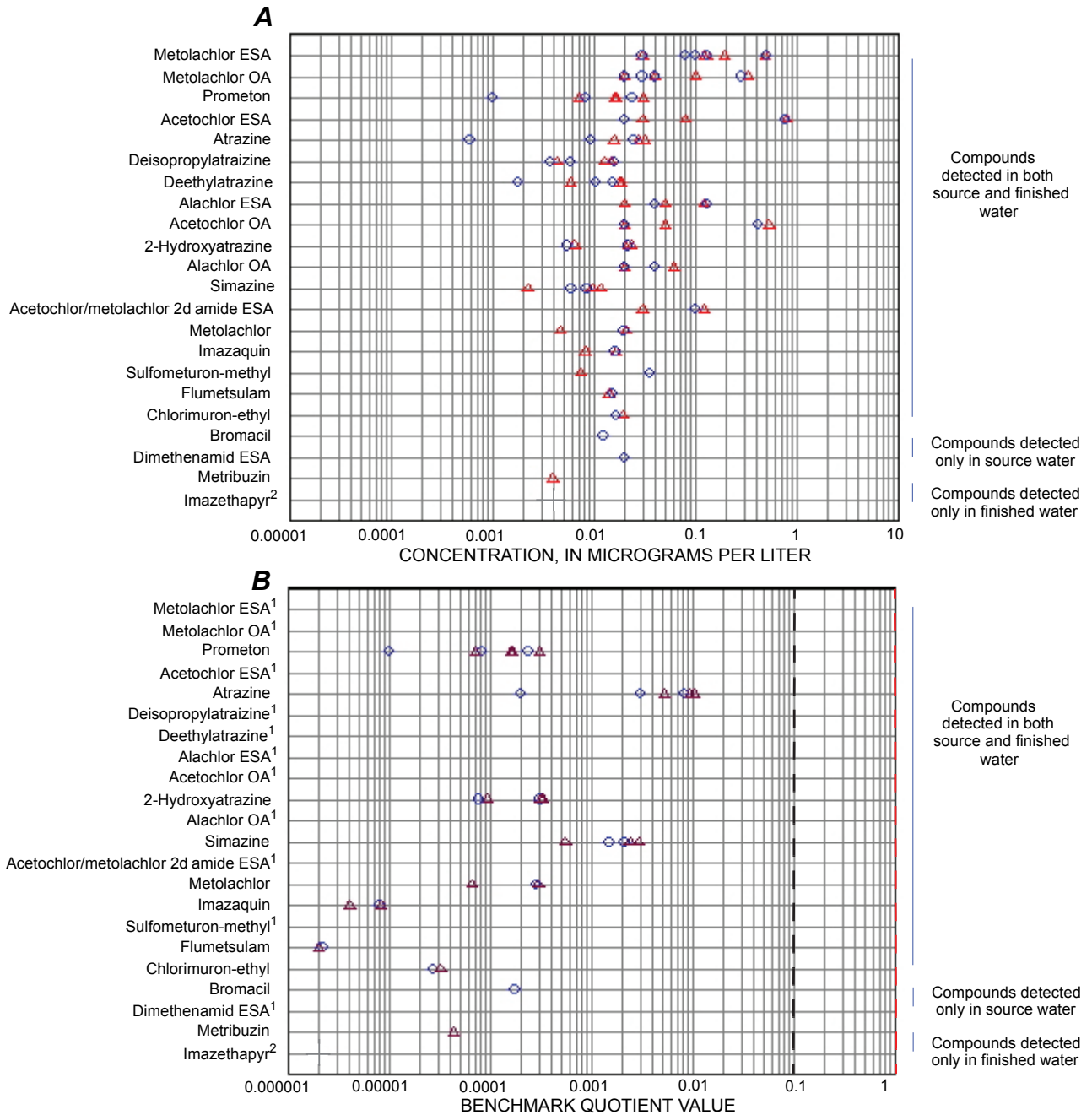
[USEPA, U.S. Environmental Protection Agency; µg/L, micrograms per liter; MCL, Maximum Contamination Level; HBSL, Health-Based Screening Level; BQmax, maximum Benchmark Quotient = ratio of maximum detected compound concentration to MCL or HBSL value; concentration; E, estimated value; <, less than; M, presence of compound verified, but concentration not quantified; --, not available. A regulated compound is one for which Federal and (or) State drinking-water standards have been established; an unregulated is one for which Federal and (or) State drinking water standards have not been established; ESA, ethane sulfonic acid; OA, oxamalic acid]

Regulated (r) or unregulated (u) compound	Chemical Abstracts Service registry number	Number of samples collected	Number of detections			Maximum concentration (µg/L)			BQmax	
			Source water	Finished water	Minimum reporting limit (µg/L)	Source water	Finished water	USEPA MCL ¹ or HBSL (µg/L)		
Volatile organic compounds										
Trichloroethene (r)	79-01-6	10	4	3	0.04	3.29	0.21	5	0.658	0.042
1,1,1-Trichloroethane (r)	71-55-6	10	4	2	.03	.2	.09	200	.001	.0004
Chloroform (r)	67-66-3	10	3	5	.02	1.33	1.09	380	.0167	.0136
Tetrachloroethene (r)	127-18-4	10	3	3	.06	.15	.56	5	.030	.112
Toluene (r)	108-88-3	10	3	2	.05	E:01	E:01	1000	E:00001	E:00001
cis-1,2-Dichloroethene (r)	156-59-2	10	2	2	.02	.08	1.20	100	.0008	.0120
Carbon tetrachloride (r)	56-23-5	10	1	1	.06	.52	E:02	5	.104	E:004
1,1-Dichloroethane (u)	75-34-3	10	1	0	.04	.04	--	--	--	--
Dibromochloromethane (r)	124-48-1	10	0	5	.1	--	4	380	--	.05
Bromoform (r)	75-25-2	10	0	5	.10	--	1.98	380	--	.025
Bromodichloromethane (r)	75-27-4	10	0	5	.03	--	2.12	380	--	.026
m- and p-Xylene (r)	108-38-3 106-42-3	10	0	2	.06	--	E:08	⁴ 10,000	--	E:00001
trans-1,2-Dichloroethene (r)	150-60-5	10	0	1	.03	--	E:02	100	--	E:0002
Ethylbenzene (r)	100-41-4	10	0	1	.03	--	E:02	700	--	E:00003
Total number of VOC detections			21	37						
Pesticides										
Metolachlor ESA (u)	17118-09-5	10	5	5	.02	.5	.48	--	--	--
Metolachlor OA (u)	152019-73-3	10	5	5	.02	.28	.33	--	--	--
Prometon (u)	1610-18-0	9	4	4	.5	.02	.03	³ 100	.0002	.0003
Acetochlor ESA (u)	187022-11-3	10	3	4	.02	.77	.8	--	--	--
Atrazine (r)	1912-24-9	10	3	3	.009	.025	.032	3	.0083	.0107
Deisopropylatrazine (u)	1007-28-9	10	3	3	.01	.01	.01	--	--	--

Table 3. Maximum concentration, detection frequency, and maximum benchmark quotient for regulated and unregulated compounds detected in samples collected during Phase 2 from five source-water wells and the associated finished water of community water systems near Dayton, Ohio.—Continued

Regulated (r) or unregulated (u) compound	Chemical Abstracts Service registry number	Number of samples collected	Number of detections		Maximum concentration (µg/L)		USEPA MCL ¹ or HBSL (µg/L)	BQ _{max}
			Source water	Finished water	Source water	Finished water		
Pesticides—Continued								
Deethylatrazine (u)	6190-65-4	10	3	3	0.006	0.015	0.018	--
Alachlor ESA (u)	142363-53-9	10	3	4	.02	.13	.12	--
Acetochlor OA (u)	184992-44-4	10	2	4	.02	.41	.53	--
2-Hydroxyatrazine (u)	2163-68-0	10	2	4	.008	.022	.023	0.0003
Alachlor OA (u)	171262-17-2	10	2	2	.02	.04	.06	--
Simazine (r)	122-34-9	8	2	3	.005	.008	.012	.002
Acetochlor/metolachlor 2 nd amide ESA (u)	-	10	1	2	.02	.10	.12	--
Metolachlor (u)	51218-45-2	9	1	2	.013	.020	.021	.0003
Imazaquin (u)	81335-37-7	10	1	2	.02	E.02	.02	E.00001
Sulfometuron-methyl (u)	74222-97-2	10	1	1	.009	.035	E.007	--
Flumetsulam (u)	98967-40-9	10	1	1	.01	E.02	.01	<0.00001
Chlorimuron-ethyl (u)	90982-32-4	10	1	1	.010	E.016	.019	E.00003
Bromacil (u)	314-40-9	10	1	0	.03	E.01	--	E.00014
Dimethenamid ESA (u)	205939-58-8	10	1	0	.02	.02	--	--
Metribuzin (u)	21087-64-9	8	0	1	.006	--	E.004	E.00004
Imazethapyr (u)	81335-77-5	10	0	1	.02	--	M	--
Total number of pesticide detections			45	54				
Total number of detections for all compounds			68	92				

¹U.S. Environmental Protection Agency (2003, 2004).²MCL is for total trihalomethanes.³Denotes HBSL (Toccalino and others, 2003).⁴MCL is for the sum of concentrations of mixed isomers of xylene.



¹Benchmark quotient value could not be determined because compound does not have a Maximum Contaminant Level or Health-Based Screening Level.
²Presence of compound verified, but concentration not quantified.

EXPLANATION

Benchmark quotient value

Ratio of the detected concentration of a compound to its Maximum Contaminant Level or Health-Based Screening Level

Greater than or equal to 0.1

The compound may warrant inclusion in a low-concentration, trends-monitoring program

Greater than or equal to 1.0

The concentration may be a potential human-health concern

○ Source water (raw)

△ Finished water (blended and treated)

Figure 5. Comparison of pesticides in samples collected during Phase 2 from five source-water wells and the associated finished water of community water systems near Dayton, Ohio. **A**, Concentrations. **B**, Benchmark quotient values.

Summary

The U.S. Geological Survey National Water-Quality Assessment Program is assessing the quality of major aquifers used as a source of supply for community water systems (CWSs) in urban areas. These studies, called Source Water-Quality Assessments (SWQAs), are being done at several locations around the Nation, and this report focuses on a SWQA completed in valley-fill deposits of the glacial aquifer system near Dayton, Ohio.

The study was done in two phases. Phase 1 was completed during November–January 2002–03. The goal was to characterize the occurrence of 258 anthropogenic organic compounds (AOCs) in the source water from 15 CWS wells. In those samples, 11 volatile organic compounds (VOCs) and 10 pesticides were detected. At least one AOC was detected in 12 of the 15 samples. Most samples contained a mixture of compounds (average of four compounds per sample). The maximum number of AOC detections in a single sample was 13.

The VOCs detected in more than 30 percent of the samples were trichloroethene (a common dry-cleaning solvent), chloroform (a possible disinfection byproduct), and 1,1,1-trichloroethane (a solvent). The pesticides that were detected in more than 30 percent of the samples were prometon (an herbicide primarily used in nonagricultural settings), simazine (an herbicide with agricultural and nonagricultural uses), atrazine (an herbicide commonly used on corn and soybeans), and deethylatrazine (a breakdown product of atrazine). Of the 32 pesticide detections, more than half were atrazine or one of its breakdown products (deethylatrazine, deisopropylatrazine, or 2-hydroxyatrazine).

The goal of the second phase of the study was to compare AOC detections in source (raw) water with the associated finished (blended and treated) water. Five of the 15 CWS wells along with their associated finished water were resampled during June and July 2004.

In general, pesticides were detected in both source and finished water at similar concentrations. In contrast, VOCs were detected more frequently in finished-water than source-water samples. Increased detection of VOCs in finished water might be due to the creation of disinfection byproducts (DBPs) during chlorination. Other possible explanations are that compounds could have been introduced (1) during blending with water from other wells or (2) at some point in the water system, between locations where samples of source and finished water were collected.

Human-health benchmarks were available for 13 of the detected VOCs. Three VOCs (trichloroethene, carbon tetrachloride, and tetrachloroethene) were detected at concentrations approaching human-health benchmarks, and therefore may warrant inclusion in a low-concentration, trends-monitoring program. Of the 11 pesticides with human-health benchmarks, all were detected at concentrations at least 2 orders of magnitude less than their human-health benchmark values.

Acknowledgments

The author is grateful to the public and private organizations that furnished information used in this study and for permitting the collection of samples for water-quality analyses. The author acknowledges the valuable assistance of USGS employees Tom Schumann and John Tertuliani (for sample collection and data compilation) and Jessica Hopple and Greg Delzer (for guidance on the structure, content, and wording of selected sections of the report).

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Glossary

A

Anthropogenic As used in this report, derived from or related to human activities.

B

Benchmark Quotient (BQ) Ratio of the concentration of a contaminant to its Maximum Contaminant Level (MCL) value for a regulated compound or to its Health Based-Screening Level (HBSL) value for an unregulated compound. BQs greater than 1.0 identify concentrations of potential human-health concern. BQs greater than 0.1 identify compounds that may warrant inclusion in a low-concentration, trends-monitoring program.

Blended Water As used in this report, finished water that has been blended with one or more different ground-water sources. Finished water blended with surface water was not sampled as part of this study.

BQmax Ratio of the maximum concentration of a contaminant to its MCL or HBSL value.

C

Community Water System (CWS) A public water system with 15 or more connections and serving 25 or more year-round residents and thus subject to USEPA regulations enforcing the Safe Drinking Water Act. A CWS serves a residential population, such as a municipality, mobile home park, or nursing home. This report discusses community water systems that use ground water.

Concentration of Potential Human-Health Concern As used in this report: (1) for a regulated compound with a U.S. Environmental Protection Agency (USEPA) drinking-water standard, a concentration greater than the Maximum Contaminant Level; and (2) for an unregulated compound, a concentration greater than the Health-Based Screening Level.

D

Drinking-Water Guideline As used in this report, a threshold concentration that has no regulatory status but is issued in an advisory capacity by the USEPA or state agencies.

Drinking-Water Standard As used in this report, a threshold concentration that is legally enforceable (such as MCLs) by the USEPA or state agencies.

E**F**

Finished Water Water is “finished” when it has passed through all the processes in a water-treatment plant and is ready to be delivered to consumers.

G**H**

Health-Based Screening Level (HBSL) Benchmark concentrations of contaminants in water that may be of potential concern for human health, if exceeded. HBSLs are non-enforceable benchmarks that were developed by the USGS in collaboration with the USEPA and others using USEPA methodologies for establishing drinking-water guidelines and the most current, USEPA peer-reviewed, publicly available human-health toxicity information.

Human-Health Benchmarks As used in this report, these include USEPA MCL values and HBSL values developed collaboratively by the U.S. Geological Survey, USEPA, New Jersey Department of Environmental Protection, and Oregon Health & Science University.

I**J****K****L****M**

Maximum Contaminant Level (MCL) A USEPA drinking-water standard that is legally enforceable and that sets the maximum permissible level of a contaminant in water that is delivered to any user of a public water system at which no known or anticipated adverse effect on the health of persons occurs and which allows an adequate margin of safety.

N**O****P****Q****R**

Regulated Compound As used in this report, a compound for which a Federal and (or) state drinking-water standard has been established.

S

Source Water Source water is the raw (ambient) water collected at the supply well or surface-water intake prior to the treatment process used to produce finished water.

T**U**

Unregulated Compound As used in this report, a compound for which no Federal and (or) state drinking-water standard has been established. Note that a compound that is unregulated under the Safe Drinking Water Act may be regulated in other contexts and under other statutes.

V**W****X****Y****Z**

18 Anthropogenic Organic Compounds in Community Water Systems near Dayton, Ohio, 2002–04

Appendix 1. Comparison of anthropogenic organic compounds detected in source- and associated finished-water samples during Phase 2 of the Source Water-Quality Assessment near Dayton, Ohio.

[E; estimated value; ND; no detection; µg/L, micrograms per liter; ESA, ethane sulfonic acid; OA, oxanilic acid]

Well identifier	Detected anthropogenic organic compound (regulated (r) or unregulated (u))	Source water (µg/L)	Finished water (µg/L)	Well identifier	Detected anthropogenic organic compound (regulated (r) or unregulated (u))	Source water (µg/L)	Finished water (µg/L)
Volatile organic compounds				Pesticides			
1	Trichloroethene (r)	ND	0.17	1	Metolachlor ESA (u)	0.1	0.13
2	Trichloroethene (r)	E 0.03	ND	2	Metolachlor ESA (u)	.5	.48
3	Trichloroethene (r)	E .06	E .03	3	Metolachlor ESA (u)	.08	.12
4	Trichloroethene (r)	3.29	.21	4	Metolachlor ESA (u)	.03	.03
5	Trichloroethene (r)	.28	ND	5	Metolachlor ESA (u)	.13	.19
1	1,1,1-Trichloroethane (r)	E .08	E .09	1	Metolachlor OA (u)	.03	.04
3	1,1,1-Trichloroethane (r)	E .05	E .02	2	Metolachlor OA (u)	.28	.33
4	1,1,1-Trichloroethane (r)	.20	ND	3	Metolachlor OA (u)	.03	.04
5	1,1,1-Trichloroethane (r)	E .05	ND	4	Metolachlor OA (u)	.02	.02
1	Chloroform (r)	E .02	.63	5	Metolachlor OA (u)	.04	.1
2	Chloroform (r)	ND	1.09	1	Prometon (u)	M	.01
3	Chloroform (r)	ND	.18	2	Prometon (u)	.01	.02
4	Chloroform (r)	1.33	.56	4	Prometon (u)	.01	.02
5	Chloroform (r)	E .07	.65	5	Prometon (u)	.02	.03
1	Tetrachloroethene (r)	ND	.56	1	Acetochlor ESA (u)	.02	.03
3	Tetrachloroethene (r)	.15	E .06	2	Acetochlor ESA (u)	.77	.8
4	Tetrachloroethene (r)	E .06	E .03	3	Acetochlor ESA (u)	.02	.03
5	Tetrachloroethene (r)	.11	ND	5	Acetochlor ESA (u)	ND	.08
1	Toluene (r)	E .01	ND	1	Atrazine (r)	E .001	.016
2	Toluene (r)	E .01	E .01	2	Atrazine (r)	.025	.032
4	Toluene (r)	E .01	E .01	5	Atrazine (r)	.009	.027
1	cis-1,2-Dichloroethene (r)	E .02	.19	1	Deisopropylatrazine (u)	M	M
2	cis-1,2-Dichloroethene (r)	E .08	1.20	2	Deisopropylatrazine (u)	E .02	E .01
4	Carbon tetrachloride (r)	.52	E .02	5	Deisopropylatrazine (u)	E .01	E .01
3	1,1-Dichloroethane (u)	E .04	ND	1	Deethylatrazine (u)	E .002	.006
1	Dibromochloromethane (r)	ND	4.0	2	Deethylatrazine (u)	E .015	.018
2	Dibromochloromethane (r)	ND	1.00	5	Deethylatrazine (u)	E .010	.018
3	Dibromochloromethane (r)	ND	.7	2	Alachlor ESA (u)	.13	.12
4	Dibromochloromethane (r)	ND	2.4	3	Alachlor ESA (u)	.04	.02
5	Dibromochloromethane (r)	ND	2.0	4	Alachlor ESA (u)	ND	.02
1	Bromoform (r)	ND	1.98	5	Alachlor ESA (u)	.04	.05
2	Bromoform (r)	ND	.18	2	Acetochlor OA (u)	.41	.53
3	Bromoform (r)	ND	.35	3	Acetochlor OA (u)	.02	.02
4	Bromoform (r)	ND	1.53	5	Acetochlor OA (u)	ND	.05
5	Bromoform (r)	ND	.73	1	2-Hydroxyatrazine (u)	ND	.023
1	Bromodichloromethane (r)	ND	2.12	2	2-Hydroxyatrazine (u)	E .022	.022
2	Bromodichloromethane (r)	ND	1.49	3	2-Hydroxyatrazine (u)	ND	.006
3	Bromodichloromethane (r)	ND	.51	5	2-Hydroxyatrazine (u)	E .005	.016
4	Bromodichloromethane (r)	ND	1.36	2	Alachlor OA (u)	.04	.06
5	Bromodichloromethane (r)	ND	1.53	3	Alachlor OA (u)	.02	ND
4	m- and p-Xylene (r)	ND	E .05	4	Alachlor OA (u)	ND	.02
5	m- and p-Xylene (r)	ND	E .08	1	Simazine (r)	ND	.002
1	trans-1,2-Dichloroethene (r)	ND	E .02	2	Simazine (r)	.008	.009
5	Ethylbenzene (r)	ND	E .02	5	Simazine (r)	.006	.012

Appendix 1. Comparison of anthropogenic organic compounds detected in source- and associated finished-water samples during Phase 2 of the Source Water-Quality Assessment near Dayton, Ohio.—Continued

[E; estimated value; ND; no detection; µg/L, micrograms per liter; ESA, ethane sulfonic acid; OA, oxanilic acid]

Well identifier	Detected anthropogenic organic compound (regulated (r) or unregulated (u))	Source water (µg/L)	Finished water (µg/L)
Pesticides—Continued			
2	Acetochlor/Metolachlor 2 nd amide ESA (u)	0.1	0.12
5	Acetochlor/Metolachlor 2 nd amide ESA (u)	ND	.03
1	Metolachlor (u)	ND	E .005
2	Metolachlor (u)	.020	.021
2	Imazaquin (u)	E .020	.020
5	Imazaquin (u)	ND	.008
5	Sulfometuron-methyl (u)	.035	.007
2	Flumetsulam (u)	E .02	.01
2	Chlorimuron-ethyl (u)	E .016	.019
4	Bromacil (u)	E .01	ND
2	Dimethenamid ESA (u)	.02	ND
2	Metribuzin (u)	ND	E .004
1	Imazethapyr (u)	ND	M

