

Chapter 5: DDE

A chapter from:

**Regulatory Determinations Support Document for Selected Contaminants
from the Second Drinking Water Contaminant Candidate List (CCL 2)**

EPA Report 815-R-08-012

Executive Summary

1,1-Dichloro-2,2-bis(*p*-chlorophenyl)ethylene (DDE) is a primary metabolite of 1,1,1-trichloro-2,2-bis(*p*-chlorophenyl)ethane (DDT), a pesticide once used to protect crops and eliminate disease-carrying insects in the U.S., until it was banned in 1973. DDE itself has no commercial uses and is only found in the environment as a result of contamination and/or breakdown of DDT. DDT production in the United States declined from 82 million kg in 1962 to 2 million kg in 1971. In smaller quantities, DDT production for export continued as late as the 1980s.

While DDE tends to adsorb strongly to surface soil and is fairly insoluble in water, it may enter surface waters from runoff that contains soil particles contaminated with DDE. In both soil and water, DDE is subject to photodegradation, biodegradation, and volatilization.

Limited data on DDE, mostly from a National Cancer Institute (NCI) bioassay, suggest that the liver is the primary target organ in mammalian species. However, the NCI study did not evaluate a full array of noncancer endpoints. There is an RfD of 0.0005 mg/kg/day for the parent pesticide DDT based on a No-Observed-Adverse-Effect Level (NOAEL) of 0.05 mg/kg/day from a dietary subchronic study. In this study, liver lesions were identified at a Lowest-Observed-Adverse-Effects Level (LOAEL) of 0.25 mg/kg/day. Data on DDT identify effects on the nervous and hormonal systems as adverse effects that might also be seen with DDE because it is one of DDT's primary metabolites. The limited data for DDE suggest that any effects on the nervous system are less severe than those seen with DDT.

Based on animal studies, DDE is classified as “likely to be carcinogenic to humans.” This classification is based on increases in the incidence of liver tumors, including carcinomas, in two strains of mice and in hamsters after dietary exposure to DDE. For this regulatory determination, EPA calculated an oral slope factor of $1.67 \times 10^{-1} \text{ (mg/kg/day)}^{-1}$, resulting in a one-in-a-million cancer-risk health reference level (HRL) of 0.2 µg/L.

There are some indications that DDE has an adverse impact on the immune system. Considerable evidence exists that DDE can act as an endocrine disruptor. Children and adolescents may be sensitive populations for exposure to DDE due to its endocrine disruption properties.

Data on the ambient occurrence of DDE are available from the first monitoring cycle (1992-2001) of the United States Geological Survey's (USGS's) National Ambient Water Quality Association (NAWQA) program. While the USGS detected DDE in both surface and ground waters, 95 percent of the samples from the various land use settings were less than 0.006 µg/L (the USGS reporting limit). The maximum surface water concentration, 0.062 µg/L (agricultural setting), and the maximum ground water concentration, 0.008 µg/L (agricultural setting), are both less than the HRL.

To evaluate the occurrence of DDE in the nation's drinking water, EPA included it as an analyte in the First Unregulated Contaminant Monitoring Regulation (UCMR 1). Because the HRL for DDE (0.2 µg/L) is lower than the minimum reporting level (MRL) used for monitoring (0.8 µg/L), EPA used the MRL value to evaluate occurrence and exposure. The MRL is within

the 10^{-4} to the 10^{-6} cancer risk range for DDE. In evaluating the UCMR 1 data, EPA found that only 1 of the 3,874 public water systems (PWSs) sampled (approximately 0.03 percent) had a detection of DDE, affecting approximately 0.01 percent of the population served.

EPA also consulted data on DDE monitoring in ambient and drinking water from other sources, including National Urban Runoff Program, the Pesticides in Ground Water Database, and the National Pesticide Survey.

The Agency has made a determination not to regulate DDE with a national primary drinking water regulation (NPDWR). Because DDE appears to occur infrequently at levels of concern in PWSs, the Agency believes that an NPDWR does not present a meaningful opportunity for health risk reduction.

If a State finds highly localized occurrence of DDE at concentrations above the HRL, it should consider whether State-level guidance (or some other type of action) may be appropriate.

The Agency's regulatory determination for this contaminant is presented formally in the *Federal Register*.

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Abbreviations

AOAC	Association of Analytical Communities
APHA	American Public Health Association
ASTM	American Society for Testing and Materials
CAS	Chemical Abstracts Service
CCL 2	Second Contaminant Candidate List
CWS	Community Water System
DDD	1,1-dichloro-2,2-bis(p-chlorophenyl)ethane
DDE	1,1-dichloro-2,2-bis(p-chlorophenyl)ethylene or p,p-dichlorodiphenyldichloroethylene
DDT	1,1,1-trichloro-2,2-bis(p-chlorophenyl) ethane
GAC	Granular Activated Carbon
GC	Gas Chromatography
GC/ECD	Gas Chromatography with Electron Capture Detection
GC/MS	Gas Chromatography with Mass Spectrometry
HRL	Health Reference Level
LOAEL	Lowest-Observed-Adverse-Effect Level
LSE	Liquid-Solid Extraction
MDL	Method Detection Limit
MRL	Minimum Reporting Level
MTBE	Methyl Tertiary Butyl Ether
NAWQA	National Water Quality Assessment
NCI	National Cancer Institute
NOAEL	No-Observed-Adverse-Effect Level
NPDWR	National Primary Drinking Water Regulation
NPL	National Priorities List
NPS	National Pesticide Survey
NTNCWS	Non-Transient Non-Community Water System
PGWDB	Pesticides in Ground Water Database
PWS	Public Water System
RfD	Reference Dose
RL	Reporting Limit
RO	Reverse Osmosis
UCMR 1	First Unregulated Contaminant Monitoring Regulation
USGS	United States Geological Survey

5 DDE

5.1 Definition

DDE (1,1-dichloro-2,2-bis(p-chlorophenyl)ethylene), an organochlorine, is a primary metabolite of DDT (1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane) along with DDD (1,1-dichloro-2,2-bis(p-chlorophenyl)ethane). DDE, like DDT and related compounds, can exist in three isomeric forms based on the relative position of the chlorine substitution on the two chlorophenyl rings. The most prevalent isomer, 1,1-dichloro-2,2-bis(p-chlorophenyl)ethylene, is commonly known as *p,p'*-DDE. The name “DDE” usually refers to *p,p'*-DDE. *p,p'*-DDE is also given the following names: 4,4'-DDE; dichlorodiphenyl-dichloroethane, 1,1-dichloro-2,2-bis(p-chlorophenyl) ethylene, and 1,1'-(2,2-dichloroethylidene)bis(4-chlorobenzene) (ATSDR, 2002). A less common isomer, 1,1-dichloro-2-(o-chlorophenyl)-2-(p-chlorophenyl)ethylene, is known as *o,p'*-DDE or 2,4'-DDE.

The notation in this document follows the usage in each source: for instance, the National Water Quality Assessment (NAWQA) program uses “*p,p'*-DDE” where the First Unregulated Contaminant Monitoring Regulation (UCMR 1) uses “4,4'-DDE.” The Chemical Abstracts Service (CAS) registry number for DDE is 72-55-9.

5.1.1 Properties and Sources

DDT is a pesticide that was once widely used to control insects on agricultural crops and insects that carried diseases such as malaria and typhus. All uses of DDT in the United States were banned on January 1, 1973 except for case-by-case emergency measures (Meister and Sine, 1999 as cited in ATSDR, 2002). However, DDT is still produced and used in other countries as an anti-malarial measure. In Mexico, production ended in 1997 and use was phased-out by 2000 under the North American Agreement on Environmental Cooperation (CEC, 2003). Unlike DDT, DDE has no commercial use and is only found in the environment as a result of contamination or breakdown of DDT. DDT that has entered the atmosphere via spraying or volatilization can travel long distances and contaminate soils and surface waters by both wet and dry deposition. In the soil, DDT biodegrades to DDE under unflooded (generally aerobic) conditions and to DDD under flooded (generally anaerobic) conditions (ATSDR, 2002). DDT is highly persistent in the environment with reported half-lives between 2 and 15 years (Extoxnet, 1994). Vapor-phase degradation of DDT as a result of reactions with hydroxyl radicals in the atmosphere can act much faster, with an estimated half life of 37 hours (ATSDR, 2002). Analytical studies suggest that degradation of the insecticide dicofol, and of impurities in dicofol, could be additional sources of DDE (Risebrough *et al.*, 1986 as cited in ATSDR, 2002). Physical and chemical properties of DDE are summarized in Exhibit 5-1.

Exhibit 5-1: Physical and Chemical Properties of DDE

Identification	
CAS number	72-55-9
Molecular Formula	C ₁₄ H ₈ Cl ₄
Physical and Chemical Properties	
Boiling Point	336 °C ¹
Melting Point	89 °C ¹
Molecular Weight	318.03 g/mol ¹
Log K _{oc}	4.70 ²
Log K _{ow}	6.51 ¹
Water Solubility	0.12 mg/L at 25 °C ¹
Vapor Pressure	6.0 x 10 ⁻⁶ mm Hg at 25 °C ¹
Henry's Law Constant	2.1 x 10 ⁻⁵ atm-m ³ /mol ¹ 2.8 x 10 ⁻³ (dimensionless), predicted ³ 4.1 x 10 ⁻⁴ (dimensionless), from literature ³
Freundlich Isotherm Constant (K)	18,000 (µg/g)(L/µg) ^{1/n} ⁴

¹ Howard and Meylan, 1997 (as cited in ATSDR, 2002)

² Sabljic, 1984 (as cited in ATSDR, 2002)

³ Speth et al., 2001

⁴ Dobbs and Cohen, 1980 (as cited in Speth et al., 2001)

5.1.2 Environmental Fate and Behavior

DDE strongly adsorbs to soil particles, especially in moist soils. As a result of strong binding to soil, DDE tends to remain on the surface layer of soil with little leaching into the lower soil layers and ground water (ATSDR, 2002). DDE is known to photodegrade and biodegrade on soil surfaces or when adsorbed to sediment (Baker and Applegate, 1970; Lichtenstein and Schultz, 1959; Miller and Zepp, 1979, all as cited in ATSDR, 2002). However, only limited data are available on degradation rates. One study found that the soil half-life of DDE ranged from 151 to 271 days in thirteen countries, while in a fourteenth country, where the soil was extremely acidic, the half-life was greater than 672 days (ATSDR, 2002).

Because DDE is fairly insoluble in water (see Exhibit 5-1), it is transported in runoff water principally by adsorption to particulate matter (ATSDR, 2002). In water, DDE may photodegrade or biodegrade. When exposed to sunlight, DDE undergoes photoisomerization. Direct photolysis of DDE results in a water half-life of about 1 day in the summer and 6 days in

the winter (ATSDR, 2002). However, as a hydrophobic organochlorine, DDE can persist for long periods of time in aquatic sediments and in the tissue of aquatic biota (USGS, 2000).

Volatilization accounts for considerable loss of this compound from soil surfaces and water. In the atmosphere, DDE can exist in vapor phase and particulate phase. In the vapor phase, DDE reacts with photochemically-produced hydroxyl radicals, with an estimated half-life of 17 hours to 2 days (ATSDR, 2002; HSDB, 2003). Attached to particles, DDE can last much longer, and can be transported long distances and deposited by wet or dry deposition. Because of long-range global transport of DDT, DDE, and related compounds, primarily from warmer regions to colder regions (ATSDR, 2002; CEC, 2003), DDE contamination could still be of concern even in countries like the U.S. where DDT has not been used in decades.

5.2 Health Effects

DDE is not produced as a commercial product. This has limited the numbers of conventional studies that have been performed to assess toxicological properties. Limited data on DDE, mostly from a National Cancer Institute (NCI) bioassay, suggest that the liver is the primary target organ in mammalian species. However, the NCI study did not evaluate a full array of noncancer endpoints. There is a reference dose (RfD) of 0.0005 mg/kg/day for the parent pesticide DDT based on a “No-Observed-Adverse-Effect Level” (NOAEL) of 0.05 mg/kg/day from a dietary subchronic study (USEPA, 1996). In this study, liver lesions were identified at a “Lowest-Observed-Adverse-Effect level” (LOAEL) of 0.25 mg/kg/day. Data on DDT identify effects on the nervous and hormonal systems as adverse effects that might also be seen with DDE because it is one of DDT’s primary metabolites. The limited data for DDE suggest that any effects on the nervous system are less severe than those seen with DDT. Endocrine effects from DDE are discussed below.

Based on animal studies DDE is likely to be carcinogenic to humans. This classification is based on increases in the incidence of liver tumors, including carcinomas, in two strains of mice and in hamsters after dietary exposure to DDE. Some epidemiological studies suggest a possible association of the levels of DDE in serum with breast cancer. However, other studies with similar methodologies do not show any association. DDE was mutagenic in mouse lymphoma L5178Y and Chinese hamster V79 cells but negative in the Ames assay. In the 1988 IRIS, EPA calculated an oral slope factor of $0.34 \text{ (mg/kg/day)}^{-1}$ for DDE (USEPA, 1988). For this regulatory determination, EPA calculated an oral slope factor from the same data set (from the 1988 IRIS) using the EPA 1999 Cancer Guidelines (USEPA, 1999). The revised slope factor is $1.67 \times 10^{-1} \text{ (mg/kg/day)}^{-1}$ resulting in a one-in-a-million cancer-risk health reference level (HRL) of 0.2 $\mu\text{g/L}$.

There are some indications that DDE has an adverse impact on the immune system (Banerjee *et al.*, 1996 as cited in ATSDR, 2002). Oral exposures to 22 mg/kg/day for six weeks suppressed serum immunoglobulin levels and antibody titers. Inhibition of leucocytes and macrophage migration were observed at the cellular level. Considerable evidence exists that DDE can act as an endocrine disruptor since it binds to the estrogen and androgen receptors. DDE has a stronger affinity for the androgen receptor than for the estrogen receptor. It competes with testicular hormones for the androgen receptor leading to receptor-related changes in gene expression (Kelce *et al.*, 1995 as cited in ATSDR, 2002).

EPA evaluated whether health information is available regarding the potential effects on children and other sensitive populations. Children and adolescents may be sensitive populations for exposure to DDE due to its endocrine disruption properties. Some data suggest that DDE can delay puberty in males (ATSDR, 2002).

5.3 Occurrence and Exposure

5.3.1 Use and Environmental Release

DDT is a pesticide that was once widely used to control insects on agricultural crops, and insects that carried diseases such as malaria and typhus. All uses of DDT in the United States were banned on January 1, 1973 except for case-by-case emergency measures (USEPA, 1972). DDT production in the United States declined from 82 million kg in 1962 to 2 million kg in 1971. In smaller quantities, DDT production for export continued as late as the 1980s (ATSDR, 2002; HSDB, 2003).

Unlike DDT, DDE has no commercial use. It is only found in the environment as a result of contamination or breakdown of DDT. DDT that has entered the atmosphere via spraying or volatilization can contaminate soils and surface waters by both wet and dry deposition. In soil, DDT biodegrades to DDE under unflooded (generally aerobic) conditions and to DDD under flooded (generally anaerobic) conditions (ATSDR, 2002).

Among the 1,613 hazardous waste sites in the United States and its territories that have been considered as candidates for inclusion in EPA's National Priorities List (NPL), at least 441 are known to be contaminated with DDT, DDE, and/or DDD. *p,p'*-DDE was found at 219 of these sites. While not specifically targeted, *o,p'*-DDE was also present in at least four sites. Of the 441 hazardous waste sites in which DDT, DDE, or DDD was detected, the contaminants were identified in air samples at 32 sites, in surface water samples at 101 sites, in ground water samples at 247 sites, and in sediment samples at 305 sites (HazDat, 2002 as cited in ATSDR, 2002).

5.3.2 Ambient Water Occurrence

Ambient lakes, rivers, and aquifers are the source of most drinking water. Data on the occurrence of DDE in ambient surface and ground water, as well as in bed sediment and biotic tissue, are available from the NAWQA program of the United States Geological Survey (USGS). For details on this program, see the discussion of NAWQA in Chapter 2. NAWQA data have been analyzed independently by USGS and EPA. Supplementary data are available from EPA's Nationwide Urban Runoff Program.

NAWQA National Pesticide Synthesis

Surface Water and Ground Water

Under the NAWQA program, USGS monitored *p,p'*-DDE between 1992 and 2001 in representative watersheds and aquifers across the country. Reporting limits in surface water and ground water varied but did not exceed 0.006 µg/L.

In surface water (Exhibit 5-2), *p,p'*-DDE was detected at frequencies ranging from 1.68% of samples in urban settings to 3.66% in undeveloped settings, 4.84% in agricultural settings, and 6.14% in mixed land use settings. The 95th percentile concentrations were below the reporting limit in all land use settings. The highest detected concentration, 0.062 µg/L, occurred in an agricultural setting (Martin *et al.*, 2003).

Exhibit 5-2: USGS National Synthesis Summary of NAWQA Monitoring of *p,p'*-DDE in Ambient Surface Water, 1992-2001

Land Use Type	No. of Samples (and No. of Sites)	Detection Frequency	50 th Percentile (Median) Concentration	95 th Percentile Concentration	Maximum Concentration
Agricultural	1,885 (78)	4.84%	<RL	<RL	0.062 µg/L
Mixed	1,021 (47)	6.14%	<RL	<RL	0.009 µg/L
Undeveloped	60 (4)	3.66%	<RL	<RL	0.002 µg/L
Urban	900 (33)	1.68%	<RL	<RL	0.007 µg/L

Abbreviations:

RL = Reporting limit. Reporting limits for *p,p'*-DDE varied, but did not exceed 0.006 µg/L.

The USGS Pesticide National Synthesis used one year of data, generally the year with the most sampling results, to represent each site in this analysis. The sampling results were time-weighted, to eliminate bias from more frequent sampling at certain times of year. Detection Frequencies and Percentile Concentrations can be interpreted as representing annual occurrence. For instance, the detection frequency can be thought of as the percent of the year in which detections are found at a typical site in this land use category, and the 95th percentile concentration can be thought of as a concentration that is not exceeded for 95% of the year at a typical site in this land use category.

Source: Martin *et al.*, 2003

In ground water (Exhibit 5-3), *p,p'*-DDE detection frequencies ranged from 2.65% of samples in mixed land use settings (major aquifers) to 3.26% in agricultural settings, 3.96% in urban settings, and 7.46% in undeveloped settings. The 95th percentile concentrations were below the reporting limit in all land use settings. The highest detected concentration, 0.008 µg/L, was found in an agricultural setting (Kolpin and Martin, 2003).

Exhibit 5-3: USGS National Synthesis Summary of NAWQA Monitoring of *p,p'*-DDE in Ambient Ground Water, 1992-2001

Land Use Type	No. of Wells	Detection Frequency	50 th Percentile (Median) Concentration	95 th Percentile Concentration	Maximum Concentration
Agricultural	1,443	3.26%	<RL	<RL	0.008 µg/L
Mixed (Major Aquifer)	2,716	2.65%	<RL	<RL	0.006 µg/L
Undeveloped	67	7.46%	<RL	<RL	0.002 µg/L
Urban	834	3.96%	<RL	<RL	0.005 µg/L

Abbreviations:

RL = Reporting limit. Reporting limits for *p,p'*-DDE varied, but did not exceed 0.006 µg/L.

The USGS Pesticide National Synthesis considered each well a distinct site in this analysis. Each well was represented by one sample: normally the first one taken, but possibly a later sample if the first sample was not analyzed for the full range of analytes.

Percentile Concentrations were drawn from the range of detects and non-detects. The method for calculating Percentile Concentrations varied depending on how much of the data was censored at particular levels by the laboratory.

Source: Kolpin and Martin, 2003

Bed Sediments and Biotic Tissue

The NAWQA program also investigated the occurrence of select organochlorine compounds, including both *p,p'*-DDE and *o,p'*-DDE, in bed sediments and biotic tissue. Sampling was conducted at 1,310 sites from 1992 to 2001. Method detection limits for both isomers were 1 µg/kg dry weight in sediment, and 5 µg/kg wet weight in tissue. Details regarding sampling techniques and analytical methods are described by Nowell (2003). Organochlorines can be present in biotic tissues and in bed sediments of aquatic systems even when they are undetectable in the water column using conventional methods. The occurrence of a toxic compound in stream sediments is pertinent to drinking water concerns because some desorption of the compound from sediments into water, albeit at low rates, may be expected to occur through equilibrium reactions.

In bed sediment (Exhibit 5-4), *p,p'*-DDE detection frequencies range from 22% of samples in undeveloped settings to 46% in mixed land use settings, 48% in agricultural settings, and 70% in urban settings. The 95th percentile concentrations in bed sediment were found to range from 3.5 µg/kg dry weight (undeveloped settings) to 28.9 µg/kg dry weight (agricultural settings). The highest concentration, 440 µg/kg dry weight, was found in a mixed land use setting (Nowell, 2003).

Exhibit 5-4: USGS National Synthesis Summary of NAWQA Monitoring of *p,p'*-DDE in Bed Sediment, 1992-2001

Land Use Type	No. of Sites	Detection Frequency in samples	50 th Percentile (Median) Concentration	95 th Percentile Concentration	Maximum Concentration
Agricultural	282	48%	0.98 µg/kg	28.9 µg/kg	190 µg/kg
Mixed	338	46%	0.81 µg/kg	11.6 µg/kg	440 µg/kg
Undeveloped	224	22%	<RL	3.5 µg/kg	31 µg/kg
Urban	166	70%	2.15 µg/kg	23.9 µg/kg	111 µg/kg

Abbreviations:

RL = Reporting limit. Reporting limits for *p,p'*-DDE varied, but did not exceed 1 µg/kg.

For sediment, all weights are dry weights.

Most sites were sampled only once. In the case of sites sampled multiple times, USGS used a single sample (the earliest sample with complete data for key analytes) to represent each site in this analysis.

Percentile Concentrations were drawn from the range of detects and non-detects. The method for calculating Percentile Concentrations varied depending on how much of the data was censored at particular levels by the laboratory.

Source: Nowell, 2003

NAWQA data indicate that the more common isomer, *p,p'*-DDE, occurs in fish tissue at detection frequencies ranging from 44% of samples in undeveloped settings to 89% in agricultural settings, 89% in urban settings, and 93% in mixed land use settings (Exhibit 5-5). The 95th percentile concentrations in fish tissue were found to range from 128 µg/kg wet weight (undeveloped settings) to 2,180 µg/kg wet weight (agricultural settings). The highest concentration, 7,300 µg/kg wet weight, was found in an agricultural setting (Nowell, 2003).

Exhibit 5-5: USGS National Synthesis Summary of NAWQA Monitoring of *p,p'*-DDE in Whole Fish, 1992-2001

Land Use Type	No. of Sites	Detection Frequency	50 th Percentile (Median) Concentration	95 th Percentile Concentration	Maximum Concentration
Agricultural	205	89%	43.5 µg/kg	2,180 µg/kg	7,300 µg/kg
Mixed	206	93%	42 µg/kg	397 µg/kg	7,200 µg/kg
Undeveloped	162	44%	3.50 µg/kg	128 µg/kg	1,300 µg/kg
Urban	100	89%	36 µg/kg	190 µg/kg	450 µg/kg

Abbreviations:

RL = Reporting limit. Reporting limits for *p,p'*-DDE varied, but did not exceed 5 µg/kg.

For whole fish, all weights are wet weights.

Most sites were sampled only once. In the case of sites sampled multiple times, USGS used a single sample (from the first year of sampling, the earliest sample of the variety of fish most often sampled in that Study Unit) to represent each site in this analysis.

Percentile Concentrations were drawn from the range of detects and non-detects. The method for calculating Percentile Concentrations varied depending on how much of the data was censored at particular levels by the laboratory.

Source: Nowell, 2003

In bed sediment (Exhibit 5-6), *o,p'*-DDE detection frequencies range from 0% of samples in undeveloped settings to 1.6% in mixed land use settings, 2.6% in agricultural settings, and 3.7% in urban settings. The 95th percentile concentrations in bed sediment were less than the reporting limit in all land use settings. The highest concentration, 26.7 µg/kg dry weight, was found in an urban setting (Nowell, 2003).

Exhibit 5-6: USGS National Synthesis Summary of NAWQA Monitoring of *o,p'*-DDE in Bed Sediment, 1992-2001

Land Use Type	No. of Sites	Detection Frequency in samples	50 th Percentile (Median) Concentration	95 th Percentile Concentration	Maximum Concentration
Agricultural	278	2.6%	<RL	<RL	4.4 µg/kg
Mixed	327	1.6%	<RL	<RL	22 µg/kg
Undeveloped	221	0.0%	<RL	<RL	<RL
Urban	164	3.7%	<RL	<RL	26.7 µg/kg

Abbreviations:

RL = Reporting limit. Reporting limits for *o,p'*-DDE varied, but did not exceed 1 µg/kg.

For sediment, all weights are dry weights.

Most sites were sampled only once. In the case of sites sampled multiple times, USGS used a single sample (the earliest sample with complete data for key analytes) to represent each site in this analysis.

Percentile Concentrations were drawn from the range of detects and non-detects. The method for calculating Percentile Concentrations varied depending on how much of the data was censored at particular levels by the laboratory.

Source: Nowell, 2003

NAWQA data indicate that the less common isomer, *o,p'*-DDE, occurs in fish tissue at detection frequencies ranging from 0.0% of samples in undeveloped settings to 3.2% in mixed land use settings, 6.4% in urban settings, and 7.0% in agricultural settings (Exhibit 5-7). The 95th percentile concentrations in fish tissue were found to range from undetectable (undeveloped and mixed land use settings) to 10 µg/kg wet weight (agricultural settings). The highest concentration, 130 µg/kg wet weight, was found in a mixed land use setting (Nowell, 2003).

Exhibit 5-7: USGS National Synthesis Summary of NAWQA Monitoring of o,p'-DDE in Whole Fish, 1992-2001

Land Use Type	No. of Sites	Detection Frequency	50 th Percentile (Median) Concentration	95 th Percentile Concentration	Maximum Concentration
Agricultural	204	7.0%	<RL	10 µg/kg	85 µg/kg
Mixed	206	3.2%	<RL	<RL	130 µg/kg
Undeveloped	162	0.0%	<RL	<RL	<RL
Urban	99	6.4%	<RL	6.9 µg/kg	22 µg/kg

Abbreviations:

RL = Reporting limit. Reporting limits for o,p'-DDE varied, but did not exceed 5 µg/kg.

For whole fish, all weights are wet weights.

Most sites were sampled only once. In the case of sites sampled multiple times, USGS used a single sample (from the first year of sampling, the earliest sample of the variety of fish most often sampled in that Study Unit) to represent each site in this analysis.

Percentile Concentrations were drawn from the range of detects and non-detects. The method for calculating Percentile Concentrations varied depending on how much of the data was censored at particular levels by the laboratory.

Source: Nowell, 2003

EPA Summary Analysis of NAWQA Data

Whereas the NAWQA program often uses the most representative data for a site to calculate summary statistics, EPA, with the cooperation of USGS, has performed a summary analysis of all Cycle 1 water monitoring data from all study units (1991-2001) for many of the Second Contaminant Candidate List (CCL 2) contaminants being considered for regulatory determination, including DDE. Detection frequencies were simply computed as the percentage of samples and sites with detections (i.e., with at least one result equal to or greater than the reporting limit). Note that reporting limits were not uniform. Sample detections can be biased by frequent sampling in areas with high (or low) occurrence. Calculating the percentage of sites with detections can reduce this bias. For more details on the data set and the EPA analysis, see Chapter 2.

The results of the EPA analysis are presented in Exhibit 5-8. Overall, DDE was detected in 5.0% of samples and at 6.4% of sites. DDE was detected more frequently and at higher concentrations (maximum of 0.062 µg/L) in surface water.

Exhibit 5-8: EPA Summary Analysis of DDE Data from NAWQA Study Units, 1992-2001

	Detection Frequency (detections are results \geq RL ¹)				Concentration Values (of detections, in $\mu\text{g/L}$)				
	Number of Samples	% Samples with Detections	Number of Sites	% Sites with Detections	Minimum	Median	95 th Percen- tile	99 th Percen- tile	Maximum
surface water	14,880	5.6%	1,907	13.8%	0.0001	0.0024	0.0168	0.026	0.062
ground water	6,079	3.3%	5,210	3.7%	0.0001	0.0014	0.0032	0.0056	0.0076
all sites	20,959	5.0%	7,117	6.4%	0.0001	0.00205	0.015	0.025	0.062

¹ RLs (Reporting Limits) for DDE varied but did not exceed 0.006 $\mu\text{g/L}$. For more information, see Chapter 2. Note that because this EPA analysis involves more data points than the USGS analyses presented above, a direct comparison is not possible.

Nationwide Urban Runoff Program

A total of 86 urban runoff samples from 15 U.S. cities, collected between 1979 and 1982 in connection with EPA's National Urban Runoff Program, were analyzed by Cole *et al.* (1984). Neither DDE nor DDD were detected in any sample. DDT was detected in 1 percent of samples, at a concentration of 0.1 $\mu\text{g/L}$. Detection limits were not reported. For background to the National Urban Runoff Program, see Chapter 2.

5.3.3 Drinking Water Occurrence

Nationally representative data on 4,4'-DDE occurrence in drinking water have been collected by large and small public water systems in accordance with EPA's First Unregulated Contaminant Monitoring Regulation (UCMR 1). For further details on the UCMR 1, see Chapter 2 and USEPA (2008).

UCMR 1

UCMR 1 monitoring was conducted primarily between 2001 and 2003, though some results were not collected and reported until as late as 2006. As a List 1 contaminant, 4,4'-DDE was scheduled to be monitored by all large community water systems (CWSs) and non-transient non-community water systems (NTNCWSs) and a statistically representative sample of small CWSs and NTNCWSs. The data presented in this report reflect UCMR 1 analytical samples submitted and quality-checked under the regulation as of March 2006. 4,4'-DDE data were collected and submitted by 797 (99.6 percent) of the 800 small systems selected for the small system sample and 3,077 (99.3 percent) of the 3,100 large systems defined as eligible for the UCMR 1 large system census. 4,4'-DDE data have been analyzed at the level of simple detections (at or above the minimum reporting level, \geq MRL, or \geq 0.8 $\mu\text{g/L}$). Since the HRL of 0.2 $\mu\text{g/L}$ is less than the MRL, the data are not analyzed at the level of the HRL or half the HRL.

EPA set the MRL for UCMR 1 contaminants based on the capability of analytical methods, not anticipated health levels. For many UCMR 1 contaminants, including DDE, the MRL was determined by multiplying by 10 the least sensitive method's minimum detection limit, or, when available, multiplying by 5 the least sensitive method's estimated detection limit (USEPA, 2000). MRLs were set approximately an order of magnitude higher than detection limits to ensure consistency, accuracy, and reproducibility of results. The MRL for DDE is within the risk range of 10^{-6} to 10^{-4} used by EPA to evaluate carcinogens (see Section 2.1.1).

Results of the analysis are presented in Exhibits 5-9 and 5-10. No detections of 4,4'-DDE were found in any samples from small systems. DDE was detected at a single large system; this ground water system represented 0.03% of large public water systems (PWSs) and 0.01% of the population served by them (approximately 18,000 people). The concentration of the single detection was 3 $\mu\text{g/L}$.

Exhibit 5-9: Summary UCMR 1 Occurrence Statistics for 4,4'-DDE in Small Systems (Based on Statistically Representative National Sample of Small Systems)

Frequency Factors	UCMR Data - Small Systems		National System & Population Numbers ¹
Total Number of Samples	3,251		--
Percent of Samples with Detections	0.00%		--
99 th Percentile Concentration (all samples)	< MRL		--
Health Reference Level (HRL)	0.2 µg/L		--
Minimum Reporting Level (MRL)	0.8 µg/L		--
Maximum Concentration of Detections	< MRL		--
99 th Percentile Concentration of Detections	< MRL		--
Median Concentration of Detections	< MRL		--
Total Number of PWSs	797		60,414
Number of GW PWSs	590		56,072
Number of SW PWSs	207		4,342
Total Population	2,760,570		45,414,590
Population of GW PWSs	1,939,815		36,224,336
Population of SW PWSs	820,755		9,190,254
Occurrence by System	Number	Percentage	National Extrapolation²
PWSs (GW & SW) with Detections (≥ MRL)	0	0.00%	0
Occurrence by Population Served			
Population Served by PWSs with Detections	0	0.00%	0

1. Total PWS and population numbers are from EPA September 2004 Drinking Water Baseline Handbook, 4th edition.

2. National extrapolations are generated separately for each population-served size stratum and then added to yield the national estimate of GW PWSs with detections (and population served) and SW PWSs with detections (and population served). For intermediate calculations at the level of individual strata, see EPA's UCMR 1 Occurrence Report, entitled "The Analysis of Occurrence Data from the First Unregulated Contaminant Monitoring Regulation (UCMR 1) in Support of Regulatory Determinations for the Second Drinking Water Contaminant Candidate List."

Abbreviations:

PWS = Public Water Systems; GW = Ground Water; SW = Surface Water; N/A = Not Applicable; Total Number of Samples = the total number of samples on record for the contaminant; 99th Percentile Concentration = the concentration in the 99th percentile sample (out of either all samples or just samples with detections); Median Concentration of Detections = the concentration in the median sample (out of samples with detections); Total Number of PWSs = the total number of PWSs for which sampling results are available; Total Population Served = the total population served by PWSs for which sampling results are available; PWSs with detections, PWSs > ½ HRL, or PWSs > HRL = PWSs with at least one sampling result greater than or equal to the MRL, exceeding the ½ HRL benchmark, or exceeding the HRL benchmark, respectively; Population Served by PWSs with detections, by PWSs > ½ HRL, or by PWSs > HRL = population served by PWSs with at least one sampling result greater than or equal to the MRL, exceeding the ½ HRL benchmark, or exceeding the HRL benchmark, respectively.

Notes:

-Small systems are those that serve 10,000 persons or fewer.

-Only results at or above the MRL were reported as detections. Concentrations below the MRL are considered non-detects.

Exhibit 5-10: Summary UCMR 1 Occurrence Statistics for 4,4'-DDE in Large Systems (Based on the Census of Large Systems)

Frequency Factors	UCMR Data - Large Systems	
Total Number of Samples	30,546	
Percent of Samples with Detections	0.003%	
99 th Percentile Concentration (all samples)	< MRL	
Health Reference Level (HRL)	0.2 µg/L	
Minimum Reporting Level (MRL)	0.8 µg/L	
Maximum Concentration of Detections	3 µg/L	
99 th Percentile Concentration of Detections	3 µg/L	
Median Concentration of Detections	3 µg/L	
Total Number of PWSs	3,077	
Number of GW PWSs	1,381	
Number of SW PWSs	1,696	
Total Population	223,502,113	
Population of GW PWSs	53,415,745	
Population of SW PWSs	170,086,368	
Occurrence by System	Number	Percentage
PWSs (GW & SW) with Detections (≥ MRL)	1	0.03%
GW PWSs with Detections	1	0.07%
SW PWSs with Detections	0	0.00%
Occurrence by Population Served		
Population Served by PWSs with Detections	17,670	0.01%
Pop. Served by GW PWSs with Detections	17,670	0.03%
Pop. Served by SW PWSs with Detections	0	0.00%

Abbreviations:

PWS = Public Water Systems; GW = Ground Water; SW = Surface Water; N/A = Not Applicable; Total Number of Samples = the total number of samples on record for the contaminant; 99th Percentile Concentration = the concentration in the 99th percentile sample (out of either all samples or just samples with detections); Median Concentration of Detections = the concentration in the median sample (out of samples with detections); Total Number of PWSs = the total number of PWSs for which sampling results are available; Total Population Served = the total population served by PWSs for which sampling results are available; PWSs with detections, PWSs > ½ HRL, or PWSs > HRL = PWSs with at least one sampling result greater than or equal to the MRL, exceeding the ½ HRL benchmark, or exceeding the HRL benchmark, respectively; Population Served by PWSs with detections, by PWSs > ½ HRL, or by PWSs > HRL = population served by PWSs with at least one sampling result greater than or equal to the MRL, exceeding the ½ HRL benchmark, or exceeding the HRL benchmark, respectively.

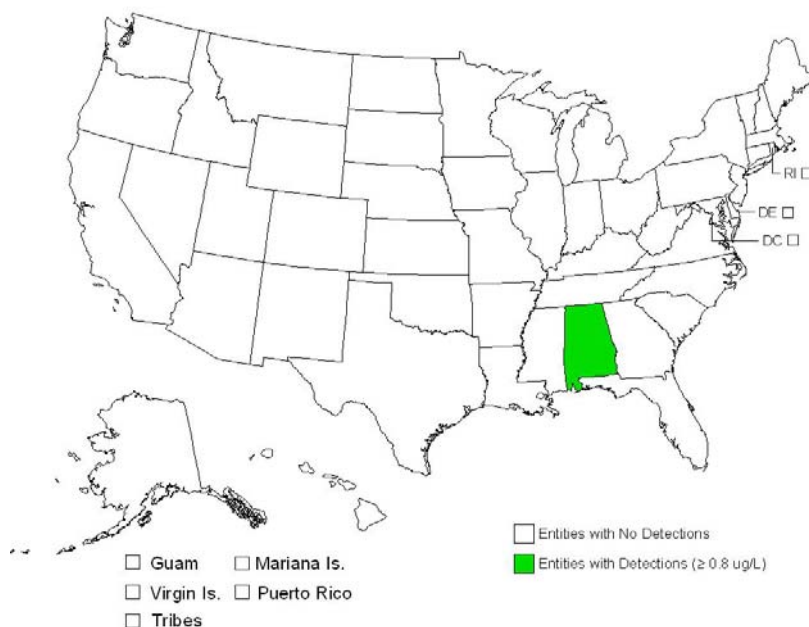
Notes:

-Large systems are those that serve more than 10,000 persons.

-Only results at or above the MRL were reported as detections. Concentrations below the MRL are considered non-detects.

DDE was only detected in one sample in all of the UCMR 1 sampling. This single detection was in a ground water sample taken in the State of Alabama (see Exhibit 5-11). Since only one system detected the contaminant, no further spatial analysis of this contaminant is presented.

Exhibit 5-11: Geographic Distribution of 4,4'-DDE in UCMR 1 Monitoring – States With at Least One Detection At or Above the MRL ($\geq 0.8 \mu\text{g/L}$)



Summary Analysis of Combined Large and Small System UCMR 1 Data

The UCMR 1 data indicate that approximately 0.03 percent (or 1) of the 3,874 PWSs sampled had a detection of DDE at the MRL of $0.8 \mu\text{g/L}$, affecting approximately 0.01 percent of the population served (or 18,000 people from 226 million).

Pesticides in Ground Water Database (PGWDB)

The Pesticides in Ground Water Database (PGWDB) is a compilation of data from ground water studies conducted by federal, State, and local governments, the pesticide industry, and other institutions between 1971 and 1991 (USEPA, 1992). Most of the data are from drinking water wells. Since PGWDB data come from multiple sources, they should be interpreted with caution. Results might be biased high, because areas with suspected contamination are likely to have been sampled more frequently than pristine areas. For further background on the PGWDB, see Chapter 2.

According to the data compiled in the PGWDB, DDE was detected in 34 of 2,918 wells (1.17 percent). The parent compound DDT was detected in 108 of 3,115 wells (3.47 percent), and the related compound DDD was detected in 35 of 2,647 wells (1.32 percent). DDE was found in 6 out of 17 States where monitoring was conducted. DDT was also found in 6 out of 17 States. DDD was found in 4 out of 17 States. DDE concentrations ranged from 0.010 to 0.090 µg/L in California, from 0.19 to 0.28 µg/L in Indiana, from 0.002 to 0.54 µg/L in Maine, and from 0.01 to 0.3 µg/L in South Carolina; one Connecticut well and one New Jersey well each had a concentration of 0.001 µg/L. The HRL of 0.2 µg/L was exceeded by DDE concentrations in three States: Indiana (maximum concentration of 0.28 µg/L), Maine (maximum concentration of 0.54 µg/L), and South Carolina (maximum concentration of 0.3 µg/L). The highest DDT and DDD concentrations were 3.3 µg/L and 1.040 µg/L, respectively (USEPA, 1992).

National Pesticide Survey (NPS)

EPA collected samples from approximately 1,300 CWS wells and rural drinking water wells between 1988 and 1990 for the National Pesticide Survey (NPS). The survey was designed to provide a statistically reliable estimate of pesticide occurrence in the nation's drinking water wells. For details about the NPS, see Chapter 2.

With a minimum reporting limit of 0.060 µg/L, DDE was not detected in the survey. DDT (with a reporting limit of 0.15 µg/L) and DDD (with a reporting limit of 0.13 µg/L) were also not detected (USEPA, 1990).

5.4 Technology Assessment

5.4.1 Analytical Methods

EPA evaluated the availability of analytical methods for all of the unregulated contaminants considered for UCMR 1, promulgated in 1999 (64 FR 50556). Sources for these methods include publications by EPA and by voluntary consensus standard organizations such as the American Society for Testing and Materials (ASTM), the Association of Analytical Communities (AOAC), and the American Public Health Association (APHA).

DDE is a UCMR 1 List 1 contaminant that can be detected in drinking water by EPA Methods 508, 508.1 and 525.2. These methods were approved for the monitoring of DDE in 1999 (64 FR 50556). EPA Method 508 relies on liquid-liquid extraction followed by gas chromatography with electron capture detection (GC/ECD). EPA Method 508.1 relies on liquid-solid extraction (LSE) followed by GC/ECD. Like Method 508.1, Method 525.2 relies on LSE, but for detection it uses capillary column gas chromatography with mass spectrometry (GC/MS). Brief summaries of all three methods are provided below. Full descriptions can be found in EPA's *Methods for the Determination of Organic Compounds in Drinking Water, Supplement 3* (USEPA, 1995a). Additional methods approved for DDE include ASTM Method D5812-96 (ASTM, 1996; 1998) and AOAC 990.06 (AOAC, 1998).

The method detection limit (MDL) and the average recovery for each analytical method that can be used for the analysis of DDE in water are included in the method descriptions below.¹

EPA Method 508

In EPA Method 508 (Revision 3.1), “*Determination of Chlorinated Pesticides in Water by Gas Chromatography with an Electron Capture Detector*,” a measured volume of a water sample is solvent-extracted with methylene chloride by shaking in a separatory funnel or mechanical bumping in a bottle. The methylene chloride extract is isolated, dried, and concentrated after solvent substitution with methyl tertiary butyl ether (MTBE). The concentrated extract is then analyzed by capillary column GC/ ECD (USEPA 1995b).

The MDL for DDE in reagent water is 0.0025 µg/L and the average recovery is 127 percent (USEPA, 1995b).

EPA Method 508.1

In EPA Method 508.1 (Revision 2.0), “*Determination of Chlorinated Pesticides, Herbicides, and Organohalides by Liquid-Solid Extraction and Electron Capture Chromatography*,” the analytes are extracted by LSE (i.e., passing a water sample through a preconditioned disk or cartridge containing a solid matrix coated with a chemically bonded C₁₈ organic phase). The analytes are eluted from the LSE disk or cartridge with small amounts of ethyl acetate and methylene chloride. The analytes are then concentrated by evaporation of some of the solvent. The concentrated extract is analyzed by injecting micro-liter amounts of the eluate into a high resolution fused silica capillary column of a GC/ECD system (USEPA, 1995c).

The MDL for DDE is 0.003 µg/L in reagent water, while the average recovery ranges from 80 to 96.5 percent depending on the spike concentration used (USEPA, 1995c).

EPA Method 525.2

EPA Method 525.2 (Revision 2.0), “*Determination of Organic Compounds in Drinking Water by Liquid-Solid Extraction and Capillary Column Gas Chromatography/Mass Spectrometry*,” also uses the LSE method as described above. Compounds eluting from the gas chromatography (GC) column are characterized by comparing their measured mass spectra and retention times to reference mass spectra and retention times (USEPA, 1995d).

¹ MDL is a statistical estimate of the minimum concentration of a substance that can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero, i.e., greater than the background signal. The calculation of the MDL is based upon the precision of a series of replicate measurements of the analyte at low concentration. The MDL incorporates estimates of the accuracy of the determination. The MDL is not a concentration that can typically be measured by the method on a routine basis. Detection limits may vary between analysts and laboratories under various laboratory conditions.

The average recovery is the fraction or percent concentration of a target analyte determined relative to the true or expected concentration from a sample containing a known amount of the target analyte. (This can result in apparent recovery values greater than 100 percent.)

The MDL for DDE in reagent water ranges from 0.054 to 0.075 µg/L depending on the method option used. The recovery for DDE is reported as 104 percent (USEPA, 1995d).

5.4.2 Treatment Technologies

Treatment technology status does not influence the determination of whether or not a contaminant should be regulated. However, treatment technologies must be readily available before a contaminant can be regulated with a national primary drinking water regulation (NPDWR). There is no evidence that DDE is substantially removed by conventional treatments, such as coagulation/flocculation, sedimentation, and inert media filtration. Potential treatment technologies include activated carbon and reverse osmosis.

Granular activated carbon (GAC) treatment removes contaminants via the physical and chemical process of sorption, by which the contaminants attach to the carbon surface as water passes through the carbon bed. Activated carbon has a large sorption capacity for many water impurities, including synthetic organic chemicals, taste- and odor-causing compounds, and some species of mercury.

Adsorption capacity is typically represented by the Freundlich isotherm constant, with higher Freundlich (K) values indicating greater sorption potential. Activated carbon is considered to be cost-effective for removing a particular contaminant if the Freundlich (K) value of the contaminant is above 200 µg/g (L/µg)^{1/n} (Speth *et al.*, 2001). Dobbs and Cohen (1980 as cited in Speth *et al.*, 2001) determined that the Freundlich (K) value for DDE is 18,000 µg/g (L/µg)^{1/n}, which suggests that GAC is a promising treatment option.

Reverse osmosis (RO) is similar to other membrane processes, such as ultrafiltration and nanofiltration, in that water passes through a semi-permeable membrane. However, in the case of RO, the membrane is non-porous. RO involves the use of applied hydraulic pressure to oppose the osmotic pressure across the membrane, forcing the water from the concentrated-solution side to the dilute-solution side. The water dissolves into the membrane, diffuses across, then dissolves out into the permeate. Most inorganic and many organic contaminants are rejected by the membrane and will be retained in the concentrate.

USEPA (2001) reports that the organochlorine class of pesticides can be removed with 99.9 to 100 percent efficiency using a cellulose acetate membrane and 100 percent efficiency using a thin-film composite membrane. These results indicate that RO is a promising option for removal of DDE in drinking water.

5.5 Regulatory Determination

The Agency has made a determination not to regulate DDE with a NPDWR. Because DDE appears to occur infrequently at levels of concern in PWSs, the Agency believes that an NPDWR does not present a meaningful opportunity for health risk reduction. DDE was detected in only one of the PWSs monitored under the UCMR 1 at a level greater than the MRL (0.8 µg/L). The MRL is greater than the HRL of 0.2 µg/L but represents a concentration that is within the 10⁻⁴ to the 10⁻⁶ cancer risk range targeted by the Agency. In addition, ambient water

data from the USGS indicate that the maximum concentrations detected in surface and ground water were less than the HRL.

If a State finds highly localized occurrence of DDE at concentrations above the HRL, it should consider whether State-level guidance (or some other type of action) may be appropriate.

The Agency's regulatory determination for this contaminant is presented formally in the *Federal Register*.

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