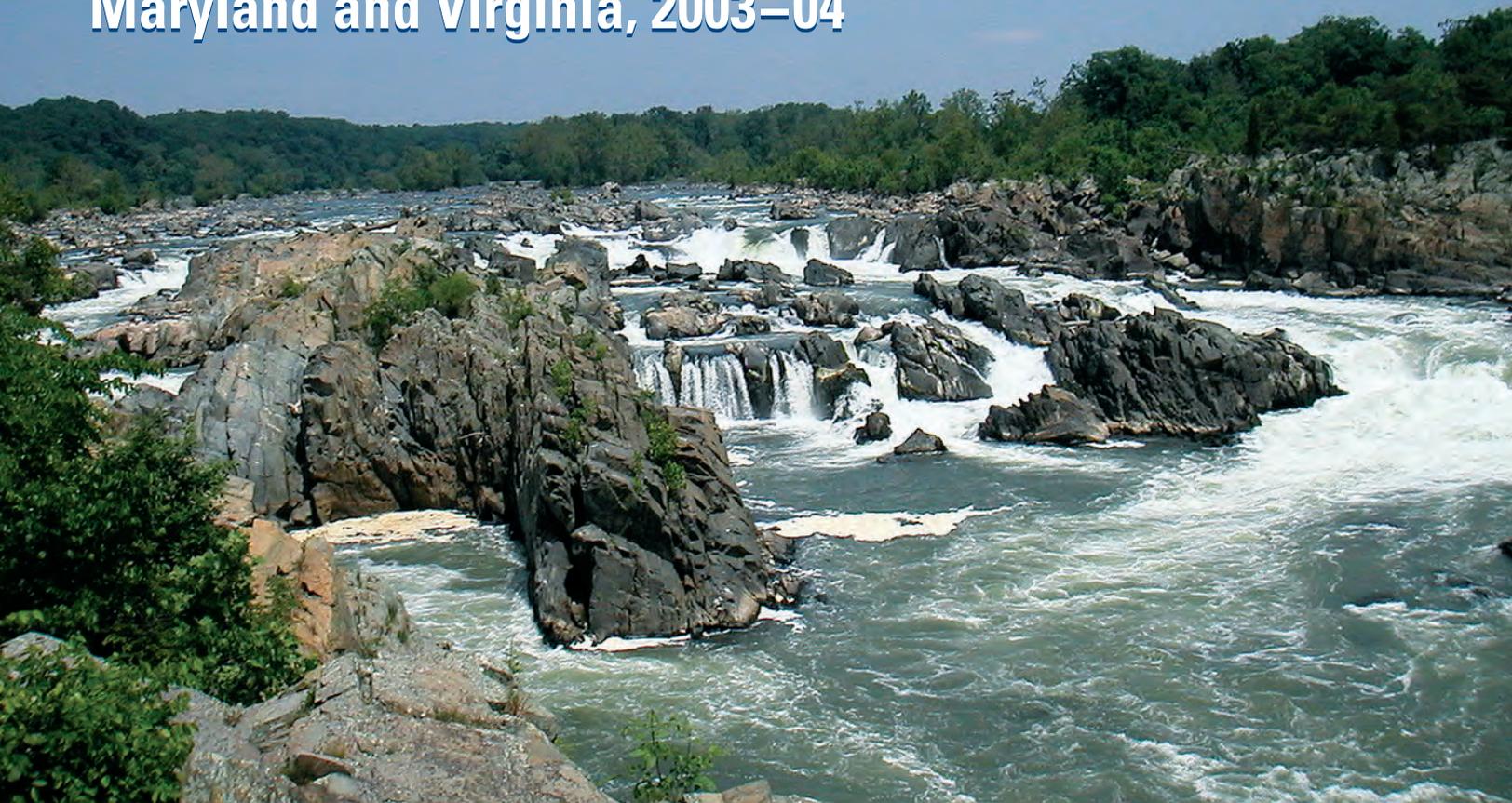


**National Water-Quality Assessment Program
Source-Water-Quality Assessments**

Anthropogenic Organic Compounds in Source and Finished Groundwater of Community Water Systems in the Piedmont Physiographic Province, Potomac River Basin, Maryland and Virginia, 2003–04



Scientific Investigations Report 2009–5064

Cover. The Great Falls of the Potomac River is located at the Fall Line, 14 miles upstream from Washington, D.C.
Photograph by U.S. Geological Survey.

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By William S.L. Banks and Betzaida Reyes

National Water-Quality Assessment Program

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Scientific Investigations Report 2009–5064

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

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Suzette Kimball, Acting Director

U.S. Geological Survey, Reston, Virginia: 2009

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Foreword

The U.S. Geological Survey (USGS) is committed to providing the Nation with reliable scientific information that helps to 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 Nation's water resources is critical to ensuring long-term availability of water that is safe for drinking and recreation and is suitable for industry, irrigation, and fish and wildlife. Population growth and increasing demands for water make the availability of that water, 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, State, and local information needs and decisions related to water-quality management and policy (<http://water.usgs.gov/nawqa>). The NAWQA Program is designed to answer: What is the quality of our Nation's streams and groundwater? How are conditions changing over time? How do natural features and human activities affect the quality of streams and groundwater, 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 and established a baseline understanding of water-quality conditions in 51 of the Nation's river basins and aquifers, referred to as Study Units (<http://water.usgs.gov/nawqa/studyu.html>).

National and regional assessments are ongoing in the second decade (2001–2012) of the NAWQA Program as 42 of the 51 Study Units are selectively reassessed. These assessments extend the findings in the Study Units by determining water-quality status and trends at sites that have been consistently monitored for more than a decade, and filling critical gaps in characterizing the quality of surface water and groundwater. For example, increased emphasis has been placed on assessing the quality of source water and finished water associated with many of the Nation's largest community water systems. During the second decade, NAWQA is addressing five national priority topics that build an understanding of how natural features and human activities 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. Included are studies on the fate of agricultural chemicals, effects of urbanization on stream ecosystems, bioaccumulation of mercury in stream ecosystems, effects of nutrient enrichment on aquatic ecosystems, and transport of contaminants to public-supply wells. In addition, national syntheses of information on pesticides, volatile organic compounds (VOCs), nutrients, trace elements, and aquatic ecology are continuing.

The USGS aims to disseminate credible, timely, and relevant science information to address 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 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, regional, interstate, Tribal, and local — as well as nongovernmental organizations, industry, academia, and other stakeholder groups. Your assistance and suggestions are greatly appreciated.

Matthew C. Larsen
Associate Director for Water

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Conversion Factors

Multiply	By	To obtain
square mile (mi ²)	2.590	square kilometer (km ²)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
gallon per day (gal/d)	0.003785	cubic meter per day (m ³ /d)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m ³ /s)
micrograms per liter (µg/L)	1.0	parts per billion (ppb)
pounds per year (lbs/yr)	0.0004536	metric tons per year (tons/yr)
million pounds per year (Mlbs/yr)	453.59237	metric tons per year (tons/yr)

Abbreviations and Acronyms

Symbol	Explanation
AOC	Anthropogenic organic compound
BQ	Benchmark Quotient
BQmax	Ratio of the maximum concentration to a drinking-water benchmark
CCR	Consumer confidence report
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CWS	Community water system
DBP	Disinfection by-product
DEET	N,N,-diethyl-meta-toluamide
ESA	Ethanesulfonic acid
HBSL	Health-Based Screening Level
MCL	Maximum Contaminant Level
MTBE	Methyl <i>tert</i> -butyl ether
NAWQA	National Water-Quality Assessment
NWQL	National Water-Quality Laboratory
OA	Oxanilic acid
OAOC	Other anthropogenic organic compound
QA and QC	Quality assurance and quality control
SWQA	Source-Water-Quality Assessment
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VOC	Volatile organic compound

Definitions

Term	Definition
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 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	In this report, finished water that has been blended with one or more different untreated groundwater sources.
BQ_{max}	Ratio of the maximum concentration of a contaminant to its MCL or HBSL value.
Community Water System (CWS)	A public water system with 15 or more connections and serving 25 or more year-round residents, making it subject to U.S. Environmental Protection Agency (USEPA) regulations that enforce the Safe Drinking Water Act. A CWS serves a residential population, such as a municipality, mobile home park, or nursing home.
Drinking-Water Guidelines	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 Standards	As used in this report, a threshold concentration that is legally enforceable (such as MCLs) by the USEPA or State agencies.
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.
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 U.S. Geological Survey (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 and Florida Department of Environmental Protection maximum contaminant level values and HBSL values developed collaboratively by the USGS, USEPA, New Jersey Department of Environmental Protection, and Oregon Health & Science University.
Maximum Contaminant Level (MCL)	As used in this report, 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.
Source Water	Source water is the raw (ambient) water collected at the supply well or surface-water intake prior to water treatment. Following water treatment, source water is finished water.
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.

Anthropogenic Organic Compounds in Source and Finished Groundwater of Community Water Systems in the Piedmont Physiographic Province, Potomac River Basin, Maryland and Virginia, 2003–04

By William S.L. Banks and Betzaida Reyes

Abstract

A source- and finished-water-quality assessment of groundwater was conducted in the Piedmont Physiographic Province of Maryland and Virginia in the Potomac River Basin during 2003–04 as part of the U.S. Geological Survey's National Water-Quality Assessment Program. This assessment used a two-phased approach to sampling that allowed investigators to evaluate the occurrence of more than 280 anthropogenic organic compounds (volatile organic compounds, pesticides and pesticide degradates, and other anthropogenic organic compounds). Analysis of waters from 15 of the largest community water systems in the study area were included in the assessment. Source-water samples (raw-water samples collected prior to treatment) were collected at the well head. Finished-water samples (raw water that had been treated and disinfected) were collected after treatment and prior to distribution. Phase one samples, collected in August and September 2003, focused on source water. Phase two analyzed both source and finished water, and samples were collected in August and October of 2004.

The results from phase one showed that samples collected from the source water for 15 community water systems contained 92 anthropogenic organic compounds (41 volatile organic compounds, 37 pesticides and pesticide degradates, and 14 other anthropogenic organic compounds). The 5 most frequently occurring anthropogenic organic compounds were detected in 11 of the 15 source-water samples. Deethylatrazine, a degradate of atrazine, was present in all 15 samples and metolachlor ethanesulfonic acid, a degradate of metolachlor, and chloroform were present in 13 samples. Atrazine and metolachlor were present in 12 and 11 samples, respectively. All samples contained a mixture of compounds with an average of about 14 compounds per sample.

Phase two sampling focused on 10 of the 15 community water systems that were selected for resampling on the basis of occurrence of anthropogenic organic compounds detected

most frequently during the first phase. A total of 48 different anthropogenic organic compounds were detected in samples collected from source and finished water. There were a similar number of compounds detected in finished water (41) and in source water (39). The most commonly detected group of anthropogenic organic compounds in finished water was trihalomethanes — compounds associated with the disinfection of drinking water. This group of compounds accounted for 30 percent of the detections in source water and 44 percent of the detections in finished water, and were generally found in higher concentrations in finished water. Excluding trihalomethanes, the number of total detections was about the same in source-water samples (33) as it was in finished-water samples (35).

During both phases of the study, two measurements for human-health assessment were used. The first, the Maximum Contaminant Level for drinking water, is set by the U.S. Environmental Protection Agency and represents a legally enforceable maximum concentration of a contaminant permitted in drinking water. The second, the Health-Based Screening Level, was developed by the U.S. Geological Survey, is not legally enforceable, and represents a limit for more chronic exposures. Maximum concentrations for each detected compound were compared with either the Maximum Contaminant Level or the Health-Based Screening Level when available. More than half of the compounds detected had either a Maximum Contaminant Level or a Health-Based Screening Level. A benchmark quotient was set at 10 percent (greater than or equal to 0.1) of the ratio of the detected concentration of a particular compound to its Maximum Contaminant Level, or Health-Based Screening Level. This was considered a threshold for further monitoring. During phase one, when only source water was sampled, seven compounds (chloroform, benzene, acrylonitrile, methylene chloride, atrazine, alachlor, and dieldrin) met or exceeded a benchmark quotient. No detected compounds in source or finished water exceeded a benchmark quotient during phase two.

Introduction

Anthropogenic organic compounds (AOCs) are chemicals that are associated with human activities that range from manufacturing and agriculture to domestic-use products discharged through the waste stream. Virtually all of these compounds are manmade, and many are released into the environment as a function of their use. Some AOCs are known to affect human health. Recent research has focused on the fate and transport (and in some instances, the human-health effects) of many AOCs in shallow groundwater (Barbash and Resek, 1996; Herberer, 2002; Ternes and others, 2002; and Zogorski and others, 2006). Their occurrence and distribution in source water and fate and transport through public drinking-water systems is not clearly understood. Further study would benefit the understanding of these processes. As an example, in one sampling survey investigators showed that AOCs were detected in the raw water of approximately one quarter of the nearly 1,100 public water-supply wells sampled (Herberer, 2002). Additionally, Loraine and Pettigrove (2006),

and Stackelberg and others (2004) have shown that AOCs often occur in finished water at concentrations similar to those found in source water, and that some compounds are created through the source-water disinfection process.

The U.S. Geological Survey (USGS) has designed Source-Water-Quality Assessment (SWQA) studies to characterize the water quality of major rivers and aquifers used as a source of drinking water for larger community water systems (CWSs). These studies are intended to complement the drinking-water monitoring currently performed by public water suppliers and required by Federal, State, and local programs. These programs tend to focus primarily on post-treatment compliance monitoring. The SWQA studies provide a mechanism for comparing the results obtained from both regional NAWQA monitoring and required drinking-water monitoring and can help determine whether water used for human consumption is meeting appropriate human-health guidelines (fig. 1). This study looks at three broad classes of AOCs in 15 CWSs in the Piedmont Physiographic Province of the Potomac River Basin (fig. 2) (U.S. Geological Survey, 2007a, 2007b, 2007c, and 2007d).

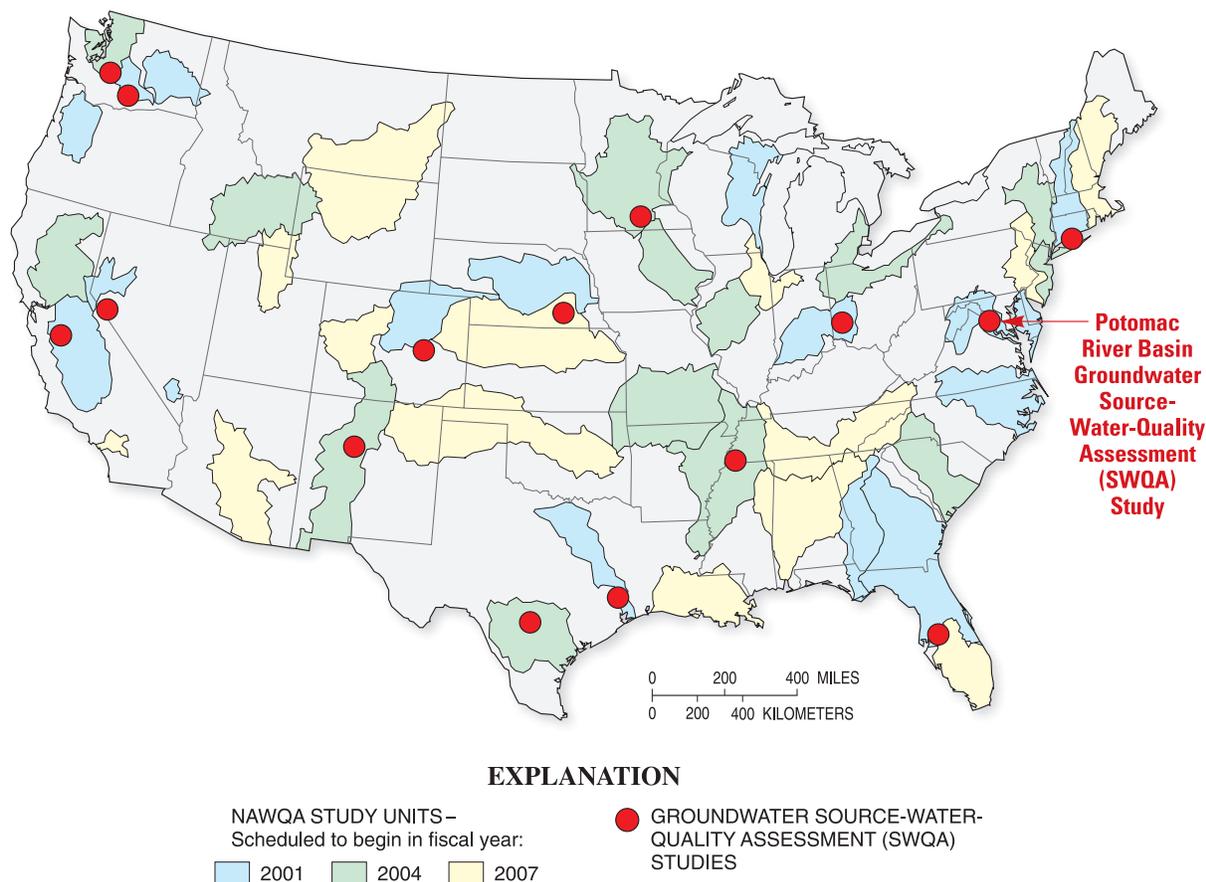


Figure 1. Location of National Water-Quality Assessment (NAWQA) Program study units and groundwater source-water-quality assessment.

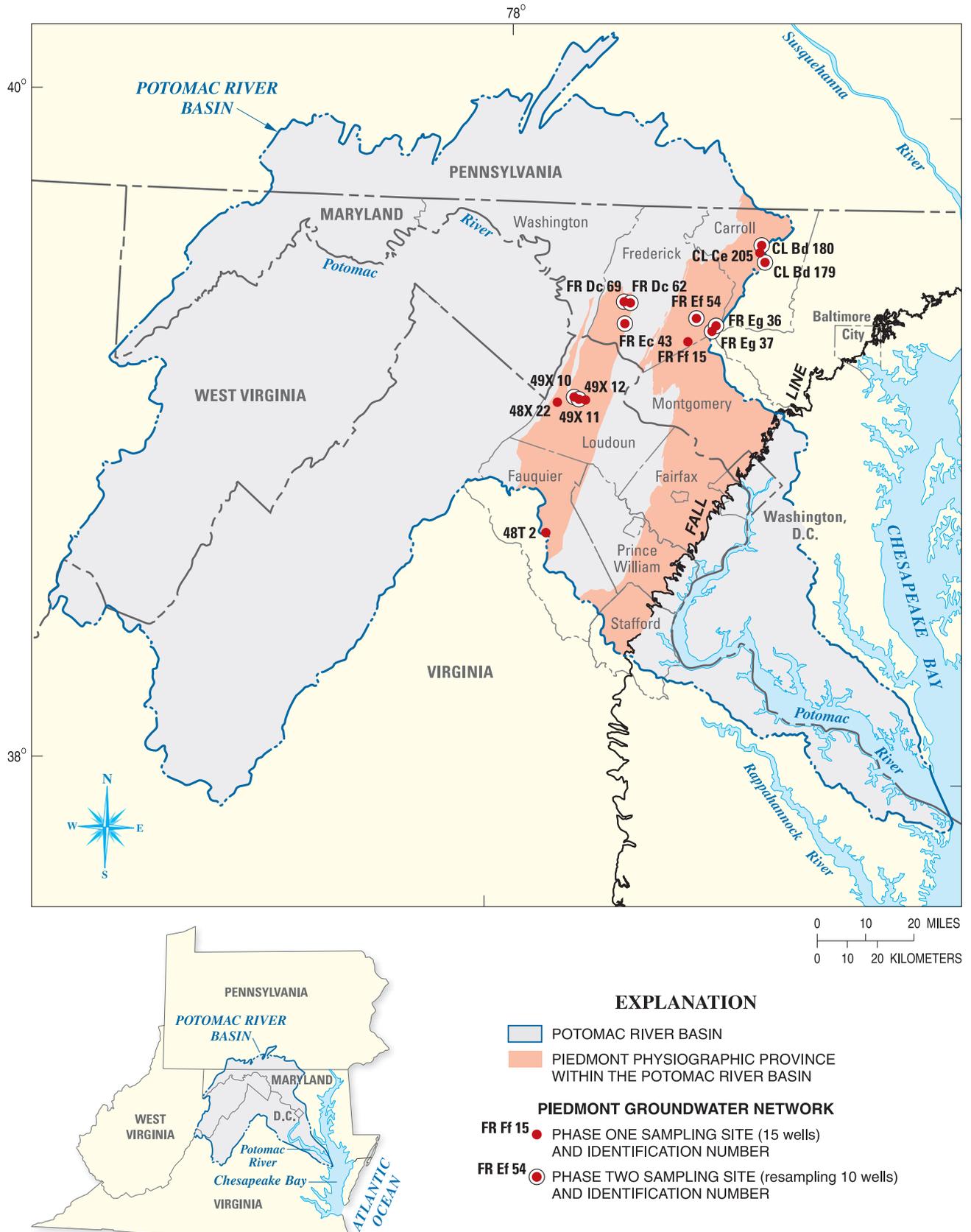


Figure 2. Location of the Potomac River Basin, Piedmont Physiographic Province, and location and names of wells in the Piedmont source-water assessment groundwater network, 2003–04.

Volatile organic compounds (VOCs) are 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, solvents, glues, dyes, and plastics. The second class of AOCs, pesticides, are chemicals used extensively throughout the United States to increase crop yields, enhance the aesthetics of lawns, gardens, golf courses, and recreational areas, and protect the public from insect-associated diseases. This class also includes herbicides and insecticides, fungicides, and some of the degradates (breakdown products) that form when pesticides are exposed to the environment. Compounds in the last class, other AOCs (OAOCs), 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.

Purpose and Scope

This report describes the occurrence of AOCs in source water obtained from 15 of the largest CWS wells serving small and medium communities in the Piedmont Physiographic Province in Maryland and Virginia. The report also describes the occurrence of selected AOCs in samples from 10 of the same 15 CWS wells and the associated AOCs in finished water from each of the 10 selected sites. Concentrations of detected compounds are compared to the U.S. Environmental Protection Agency (USEPA) Maximum Contaminant Levels (MCLs) or USGS Health-Based Screening Levels (HBSLs) to evaluate the potential relevance of the findings to human health.

Location and Description of Study Area

The Potomac River Basin drains 14,670 mi² (square miles) within the states of Maryland, Virginia, West Virginia, Pennsylvania, and Washington, D.C. Within the basin, the Piedmont Physiographic Province is roughly oriented northeast to southwest along the Atlantic coast and is the second largest province in the study area, covering about 12 percent of the Basin in Maryland, Pennsylvania, Virginia, and Washington, D.C. The area is characterized by rolling topography and low to moderate relief underlain by crystalline, metamorphic, and igneous rocks of Precambrian to Ordovician age (Milici and others, 1963; Cardwell and others, 1968; Cleaves and others, 1968; King and Beikman, 1974; Berg 1980).

Hydrologic Setting

Groundwater in the Piedmont Physiographic Province is under water-table conditions in saprolitic material (a chemically weathered, in-place rock material overlying consolidated crystalline rock), and occurs in the joints and

fractures of the underlying crystalline rock. Water-supply wells in the Piedmont region are generally designed to intercept the fractures and joints of the crystalline bedrock below the overlying unconsolidated material. Wells are drilled by isolating the overburden and drilling into the bedrock until one or multiple zones yielding satisfactory volumes of water are encountered. Water-bearing fracture zones tend to be located in topographic low areas where multiple fractures or joints occur and where the overburden has higher hydraulic head and permeability. Nutter and Otton (1969) noted that this localization is partly because valleys in the Piedmont tend to develop along fracture zones. The interconnected nature of joints and fractures in the Piedmont Physiographic Province often obscures the source and direction of groundwater flow and thus, the ultimate source of contaminants (Cleaves and others, 1968; Nutter and Otton, 1969; Heath, 1984; and Bolton, 1998).

Groundwater Withdrawals and Distribution

About 20 percent of public water used in the study area is supplied through groundwater withdrawals, and the remaining 80 percent comes from various surface-water supplies (W.P. McPherson and J.P. Pope, USGS, written commun., 2006). The ratio of groundwater to surface water used for public supply remained consistent between 2000 and 2004 in the four counties that comprise most of the study area (Fauquier and Loudon Counties in Virginia and Carroll and Frederick Counties in Maryland) (fig. 2). Although the proportions of water used from different sources have remained fairly constant, the volume of groundwater consumed in the study area has risen dramatically. In Fauquier County, Virginia, groundwater usage more than doubled between 2000 and 2004, from 0.69 to 1.66 Mgal/d (million gallons per day). In Loudon County, Virginia (the second fastest growing county in the United States between 2000 and 2005), groundwater use increased from 0.92 to 1.38 Mgal/d, or nearly 50 percent, from 2000 through 2004 (U.S. Census Bureau, 2006). From 2000 through 2004, groundwater usage in Carroll and Frederick Counties, Maryland, increased by 20 and 5 percent, or 0.51 and 0.16 Mgal/d, respectively. This increase in resource consumption is in response to a 10-year general increase in population in the region as a result of a rapidly expanding technology industry centered in Washington, D.C. These new communities are served by over 3,600 public supply wells throughout the study area in Maryland and Virginia (the Washington, D.C. area is supplied solely by surface water from the Potomac River).

Water from CWS wells may be used for a variety of purposes, including domestic, commercial, industrial, and agricultural. These supply wells may be publicly or privately owned and operated. Water from these community wells and all CWS wells in the study area is treated before distribution by a variety of methods including disinfection using chlorine gas, coagulation and filtration, adsorption, lime softening, addition

of corrosion and pH control additives, and reverse osmosis (Participating CWS managers, written commun., 2003). The wells that were monitored as part of this SWQA represent a cross section of the variety of CWS wells in the study area.

Study Design and Methods

Study design was based on a two-phase site selection and sampling process during 2003–04 to characterize the occurrence of anthropogenic compounds that may exist in publicly supplied groundwater. In phase one, 15 of the largest CWSs in the study area were identified and the owners and operators were contacted and asked to participate in this study. Each CWS received information on the objectives of the program and was asked to grant USGS scientists permission to collect samples from one randomly selected well in their system. Selected wells were at least one km (kilometer) apart and produced between about 10 and 200 gal/min (gallons per minute) (fig. 2).

During phase one, 15 CWS wells were initially sampled before treatment (at the source) in August and September 2003 and analyzed for 284 VOCs, pesticides and pesticide degradates (in this report, the term degradate refers to any herbicide transformation product formed by biotic or abiotic processes), and OAOs. Source-water samples (water that is untreated or raw), were collected at the well head, prior to any treatment.

During the second phase of the study, 10 of the original 15 wells were selected for resampling on the basis of occurrence of AOCs detected most frequently during the first phase (during the 2003 sampling) (fig. 2). Source-water samples were collected from each of the 10 public supply wells along with samples of the associated finished water (treated source water that is ready to be delivered to consumers) prior to entry to transport pipelines. All systems were chlorinated, however; other treatments prior to delivery were not documented. Each of the 10 source-water samples collected during phase two were associated with either a blended or non-blended finished-water sample. Seven source-water samples were associated with non-blended finished water and three were associated with blended finished water. At sites where blending occurred, the finished water was the product of mixing sampled source water with water from one or more additional groundwater sources. All samples for finished water were collected approximately 1 hour after the source-water sample was collected. The suite of constituents for each well varied on the basis of phase one results. During phase two, samples of both source water and the associated finished water from 10 wells were analyzed for VOCs, 6 wells were analyzed for pesticides, and 2 wells were analyzed for OAOs.

Samples were collected using established USGS protocols described in Koterba and others (1995), and on-line at <http://pubs.usgs.gov/of/1995/ofr-95-399/>. Water samples were filtered at the time of collection to remove suspended particulate matter. Organic chemicals were sorbed onto a

polystyrene-divinylbenzene resin using a disposable solid-phase cartridge. All samples were shipped overnight to the USGS National Water-Quality Laboratory (NWQL) in Denver, Colorado for analysis. Upon arrival in Denver, samples were eluted and compounds were analyzed by capillary-column gas chromatography/mass spectrometry. Analytical methods are documented in 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).

Finished-water samples were treated with a dechlorination reagent (ascorbic acid) to remove free chlorine typically introduced as part of the treatment process. Free chlorine has been shown to be a potential interference in the analysis of some organic compounds. pH buffers were added to finished-water samples during sample collection to stabilize them prior to shipment and analyses. Current research indicates that the addition of these reagents in a laboratory setting does not interfere with analytical performance (Mark Sandstrom, USGS NWQL, oral commun., 2004).

Quality Assurance and Quality Control

Quality-assurance and quality-control (QA and QC) samples were periodically collected during sampling events using the procedures described above. Samples included blanks, replicates, and spikes. Blanks can be used to detect contamination that may be introduced during sampling, shipping, and (or) the analytical process. Replicate samples measure variance within sampling groups and are used to control sample collection, processing, and analysis. Sample spikes are used to detect bias caused by analyte degradation or interference from the sampling media. In keeping with the NAWQA Program's scope and scale, QA and QC efforts for each project were focused at the national level. Thus, many individual NAWQA studies did not collect a sufficient number of QA and QC samples to adequately assess individual studies without being combined with other QA and QC samples from other SWQA studies. These samples were, however, aggregated nationally and are reviewed annually to assess systemic contamination from either sample-collection equipment or sampling procedures and sample handling or shipping protocol. Any recurrent detection (more than 10 percent of ambient concentrations) of one or more analytes in QA and QC samples indicates that there is a potential for bias for those compounds resulting from one or more of the aforementioned sources. All samples that were collected and analyzed for the uncontrolled analytes are therefore considered suspect. Environmental sample data for the affected analytes were removed from the database and were not used in any comparative or quantitative analysis (Greg Delzer, USGS, written commun., 2007).

Eight compounds were potentially biased nationwide and were subsequently eliminated from the national project data inventory. For this study, a sufficiently robust set of QA and QC samples were collected so that only those

compounds that showed systemic contamination at the project and national levels were eliminated. Specifically, five of the eight compounds were found to be biased in more than 5 percent of the source solution and field blanks nationally, and in blank samples collected at the project level. This pattern may indicate that contamination comes from point sources such as sampling equipment, field personnel (insect repellents and fragrances), field environment (dust), and (or) sample handling procedures or sample containers rather than from environmental, nonpoint sources. The five compounds excluded from the data inventory were the common insect repellent N,N diethyl-meta-toluamide (DEET), and all the phenol-based compounds such as phenol, para-nonylphenol, benzophenone, and bisphenol A. These compounds were not included in the current study.

Anthropogenic Organic Compounds in Source Water

Each source-water sample was analyzed for up to 284 AOCs, with a total of 92 AOCs detected among the 15 wells (not every compound was analyzed at each site): 41 VOCs,

37 pesticides and pesticide degradates, and 14 OAOCs. All samples contained a mixture of compounds. Two samples contained over 30 compounds, another only 4, and all 15 samples averaged about 14 AOCs per sample (table 1). The majority of concentrations for all AOCs detected in source water were generally low and ranged from 0.005 (estimated) µg/L (micrograms per liter) for the fungicide propiconazole to 13.5 µg/L for chloroform, a naturally occurring chemical and a by-product of disinfecting water through the use of chlorine (table 1). Two common industrial solvents, methyl ethyl ketone and tetrahydrofuran, were detected at concentrations of 330 and 1,020 µg/L, respectively, and were higher than concentrations found for other AOCs.

The five most frequently occurring AOCs were detected in 11 (or 73 percent) of the 15 source waters sampled during phase one. Deethylatrazine (an atrazine degradate) was the only compound present in all 15 samples. Similarly, metolachlor ethanesulfonic acid (metolachlor ESA), a degradate of the herbicide metolachlor, and chloroform, a VOC, were present in 13 of 15 wells, or 87 percent of the samples. Atrazine and metolachlor were present in 12 (80 percent), and 11 (73 percent), respectively, of the 15 wells sampled.

Different AOCs have different minimum reporting levels. For the purposes of this report, comparisons of AOCs are

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 (see <http://www.epa.gov/safewater/ccr/whereyoulive.html>, accessed May 18, 2009). CCRs are the centerpiece of the right-to-know provisions of the 1996 Amendments to the Safe Drinking Water Act. Each CCR provides consumers with fundamental information about their drinking water including (1) the source of the drinking water, (2) a brief summary of the susceptibility to contamination of the local drinking-water source, (3) the concentrations (or range of concentrations) of any contaminants found in local drinking water, as well as their USEPA **Maximum Contaminant Levels (MCLs)**, which are legally enforceable drinking-water standards and are the highest allowed concentrations of contaminants in drinking water, for comparison, and (4) phone numbers for additional sources of information.

Information in CCRs 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, Source-Water-Quality Assessments (SWQAs) performed by the USGS are not conducted 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 using USGS analytical methods, where source water is the raw (ambient) water collected at the surface-water intake or supply well prior to water treatment, and finished water is the treated water sampled prior to 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.

Table 1. Maximum concentration, detection frequency, and maximum benchmark quotient for regulated and unregulated compounds detected in source water from 15 community water-supply wells in the Piedmont Physiographic Province, Potomac River Basin, Maryland and Virginia, 2003.

[**HBSL**, **Health-Based Screening Level**; MCL, Maximum Contamination Level; BQmax, Benchmark Quotient = ratio of maximum compound concentration to MCL or **HBSL** value; E, estimated value; µg/L, micrograms per liter; MRL, Minimum Reporting Level; --, not available; VOC, volatile organic compound; OAO, other anthropogenic organic compounds; **Bold type** under compound heading indicates “unregulated,” a compound that has no Federal and (or) State drinking-water standard; ESA, ethanesulfonic acid; OA, oxamic acid.]

Compound (Regulated or unregulated)	Chemical Abstracts Service Registry Number	Number of samples collected	Number of samples with detections	Frequency of detection (percent)	MRL (µg/L)	Maximum detected concentration (µg/L)	MCL or HBSL ¹ concentration (µg/L)	BQMax ²
Volatile Organic Compounds								
Chloroform	67-66-3	15	13	87	0.024	13.5	³⁸⁰	0.2
Methyl <i>tert</i>-butyl ether	1634-04-4	15	10	67	0.1	1.88	--	--
Toluene	108-88-3	15	6	40	0.02	0.224	1,000	0.0002
1,1,1-Trichloroethane	71-55-6	15	3	20	0.032	0.122	200	0.0006
<i>tert</i>-Amyl Methyl Ether	994-05-8	15	3	20	0.04	0.281	--	--
Tetrachloroethene	127-18-4	15	3	20	0.03	E 0.050	5	0.01
1,1-Dichloroethane	75-34-3	15	2	13	0.035	0.238	--	--
1,1-Dichloroethene	75-35-4	15	2	13	0.024	0.115	7	0.02
Benzene	71-43-2	15	2	13	0.021	0.631	5	0.1
Bromodichloromethane	75-27-4	15	2	13	0.028	E 0.058	³⁸⁰	0.0007
Trichloroethene	79-01-6	15	2	13	0.038	0.112	5	0.02
Trichlorofluoromethane	75-69-4	15	2	13	0.08	E 0.065	^{62,000}	0.00003
1,2-Dichloroethane	107-06-2	15	1	7	0.13	E 0.113	5	0.02
1,2-Dichloropropane	78-87-5	15	1	7	0.029	E 0.092	5	0.02
1-Ethyl-2-methylbenzene	611-14-3	15	1	7	0.06	0.666	--	--
1,2,3,4-Tetramethylbenzene	488-23-3	15	1	7	0.14	0.921	--	--
1,2,3,5-Tetramethylbenzene	527-53-7	15	1	7	0.18	1.480	--	--
1,2,3-Trimethylbenzene	526-73-8	15	1	7	0.09	1.510	--	--
1,2,4-Trimethylbenzene	95-63-6	15	1	7	0.056	2.370	--	--
1,3,5-Trimethylbenzene	108-67-8	15	1	7	0.044	0.942	--	--
Acetone	67-64-1	15	1	7	6	7.990	^{6,000}	0.001
Acrylonitrile	107-13-1	15	1	7	0.8	E 0.504	^{10.06}	8.4
Bromoform	75-25-2	15	1	7	0.1	E 0.037	³⁸⁰	0.0005
Carbon disulfide	75-15-0	15	1	7	0.038	12.700	⁶⁷⁰⁰	0.02
Carbon Tetrachloride	56-23-5	15	1	7	0.06	E 0.017	5	0.003
<i>cis</i> -1,2-Dichloroethene	156-59-2	15	1	7	0.024	0.700	70	0.01

Table 1. Maximum concentration, detection frequency, and maximum benchmark quotient for regulated and unregulated compounds detected in source water from 15 community water-supply wells in the Piedmont Physiographic Province, Potomac River Basin, Maryland and Virginia, 2003.—Continued

[**HBSL**, Health-Based Screening Level; MCL, Maximum Contamination Level; BQmax, Benchmark Quotient = ratio of maximum compound concentration to MCL or HBSL value; E, estimated value; µg/L, micrograms per liter; MRL, Minimum Reporting Level; --, not available; VOC, volatile organic compound; OAO, other anthropogenic organic compounds; **Bold type** under compound heading indicates “unregulated,” a compound that has no Federal and (or) State drinking-water standard; ESA, ethanesulfonic acid; OA, oxamic acid.]

Compound (Regulated or unregulated)	Chemical Abstracts Service Registry Number	Number of samples collected	Number of samples with detections	Frequency of detection (percent)	MRL (µg/L)	Maximum detected concentration (µg/L)	MCL or HBSL ¹ concentration (µg/L)	BQMax ²	
Dichlorodifluoromethane	75-71-8	15	1	7	0.18	E 0.145	61,000	0.0001	
Diisopropyl ether	108-20-3	15	1	7	0.1	0.159	--	--	
Ethylbenzene	100-41-4	15	1	7	0.03	0.517	700	0.0007	
Isopropylbenzene	98-82-8	15	1	7	0.038	E 0.074	6700	0.0001	
<i>m</i> - and <i>p</i> -Xylene	m=108-38-3 p=106-42-3	15	1	7	0.06	3.280	410,000	0.0003	
Methyl ethyl ketone	78-93-3	15	1	7	2	330	64,000	0.08	
Methyl isobutyl ketone	108-10-1	15	1	7	0.37	E 0.766	--	--	
Methylene chloride	75-09-2	15	1	7	0.06	0.994	5	0.2	
Naphthalene	91-20-3	15	1	7	0.52	0.956	6100	0.01	
<i>n</i> -Butylbenzene	104-51-8	15	1	7	0.14	E 0.069	--	--	
<i>n</i> -Propylbenzene	103-65-1	15	1	7	0.042	0.108	--	--	
<i>o</i> -Xylene	95-47-6	15	1	7	0.038	2.840	410,000	0.0003	
<i>p</i> -Isopropyltoluene	99-87-6	15	1	7	0.08	E 0.063	--	--	
<i>sec</i> -Butylbenzene	135-98-8	15	1	7	0.06	E 0.065	--	--	
Tetrahydrofuran	109-99-9	15	1	7	1.2	1020	--	--	
Total number of VOC detections			79						
Pesticides									
Deethylatrazine	6190-65-4	15	15	100	0.014	E 0.276	--	--	
Metolachlor ESA	--	15	13	87	0.05	2.720	--	--	
Atrazine	1912-24-9	15	12	80	0.007	0.439	3	0.1	
Metolachlor	51218-45-2	15	11	73	0.006	3.580	700	0.005	
Alachlor ESA	--	15	7	47	0.05	0.640	--	--	
Metolachlor OA	--	15	7	47	0.05	2.960	--	--	
Simazine	122-34-9	15	5	33	0.005	0.114	4	0.03	
2-Hydroxyatrazine	2163-68-0	13	4	31	0.032	E 0.032	670	0.0005	
Prometon	1610-18-0	15	4	27	0.01	E 0.011	6100	0.0001	
Carbofuran	1563-66-2	13	3	23	0.016	0.006	40	0.0002	

Table 1. Maximum concentration, detection frequency, and maximum benchmark quotient for regulated and unregulated compounds detected in source water from 15 community water-supply wells in the Piedmont Physiographic Province, Potomac River Basin, Maryland and Virginia, 2003.—Continued

[**HBSL**, Health-Based Screening Level; MCL, Maximum Contamination Level; BQmax, Benchmark Quotient = ratio of maximum compound concentration to MCL or HBSL value; E, estimated value; µg/L, micrograms per liter; MRL, Minimum Reporting Level; -, not available; VOC, volatile organic compound; OAOC, other anthropogenic organic compounds; **Bold type** under compound heading indicates “unregulated,” a compound that has no Federal and (or) State drinking-water standard; ESA, ethanesulfonic acid; OA, oxamic acid.]

Compound (Regulated or unregulated)	Chemical Abstracts Service Registry Number	Number of samples collected	Number of samples with detections	Frequency of detection (percent)	MRL (µg/L)	Maximum detected concentration (µg/L)	MCL or HBSL ¹ concentration (µg/L)	BQMax ²
Other Anthropogenic Organic Compounds								
4-octylphenol, diethoxylate	26636-32-8	15	2	13	1	E 0.120	--	--
4-octylphenol, monoethoxylate	26636-32-8	15	2	13	1	E 0.590	--	--
1-Methylnaphthalene	90-12-0	15	1	7	0.5	E 0.12	--	--
2-Methylnaphthalene	91-57-6	15	1	7	0.5	E 0.23	630	0.008
4-Cumylphenol	599-64-4	15	1	7	1	E 0.18	--	--
Acetophenone	98-86-2	15	1	7	0.5	E 0.15	6700	0.0002
Anthracene	120-12-7	15	1	7	0.5	E 0.024	62,000	0.00001
Anthraquinone	84-65-1	15	1	7	0.5	E 0.11	--	--
Carbazole	86-74-8	15	1	7	0.5	E 0.081	--	--
Fluoranthene	206-44-0	15	1	7	0.5	E 0.036	6300	0.0001
p-Cresol	106-44-5	15	1	7	1	E 0.1	--	--
Phenanthrene	85-01-8	15	1	7	0.5	E 0.015	--	--
Pyrene	129-00-0	15	1	7	0.5	E 0.018	6200	0.0001
Triphenyl phosphate	115-86-6	15	1	7	0.5	E 0.095	--	--
Total number of OAOC detections			16					

¹ The HBSL is a range that is based on United States Environmental Protection Agency's (USEPA) risk-specific dose at a 10⁻⁶ to 10⁻⁴ cancer risk level. The lowest value of this range was used in this assessment (Toocalino and others, 2004).

² BQmax for unregulated compounds calculated using HBSL concentration at the low end of the the HBSL range, and was rounded to one significant figure.

³ 1998 Final Rule for Disinfectants and Disinfection By-Products: The total for trihalomethanes is 80 micrograms per liter.

⁴ MCL is for the sum of concentrations for mixed isomers of xylene.

⁵ The concentration of any two or more of the three aldicarb compounds should not be greater than 7 µg/L because of similar mode of action.

⁶ Value calculated using USEPA's formula for Lifetime Health Advisory.

made among AOCs and between sites regardless of varying reporting levels in order to characterize general occurrence rates and similarities, or the lack thereof, between these sites.

Human-health benchmarks are available for slightly more than half (52 of 92) of the detected compounds (table 1). About 40 percent of these benchmarks are set by the USEPA in the form of MCLs and are established for regulated chemicals (U.S. Environmental Protection Agency, 2006). The remaining compounds with benchmarks had HBSLs developed by the USGS to place water-quality data in a human-health context (Toccalino and others, 2004). In order to determine whether the concentration of a detected compound had potential adverse human-health effects, a benchmark quotient (BQ) was calculated by creating a ratio between the concentration of a compound and the appropriate human-health benchmark (either the MCL for regulated compounds or HBSL for unregulated compounds). When applied as a fraction to the highest concentration of a contaminant in a group or network of samples, the ratio is called the BQ_{max}. This ratio can be used as a conservative estimate of the potential negative impact of water consumption on human health. In general, a BQ_{max} ratio greater than or equal to 0.1 identifies concentrations of compounds that may warrant inclusion in a low-concentration trends-monitoring program, whereas a BQ_{max} greater than or equal to 1.0 identifies concentrations of potential human-health concern (Toccalino and others, 2004).

The concentration of compounds in source-water samples that had human-health benchmarks were generally between one and five orders of magnitude below the 0.1 benchmark. Seven compounds (chloroform, benzene, acrylonitrile, methylene chloride, atrazine, alachlor, and dieldrin), however, met or were greater than the 0.1 benchmark in one or more source-water samples. Without similar metrics for the remaining compounds (compounds having neither an MCL nor an HBSL), the potential human-health relevance is unknown. Two of the most frequently occurring compounds, deethylatrazine and metolachlor ESA, occurred in more than 80 percent of the samples analyzed, and both lack a human-health benchmark (table 1).

Volatile Organic Compounds

Forty-one different VOCs were detected in the source-water samples with an average of about 5 compounds per sample (table 1, fig. 3a). Chloroform, the most frequently detected compound, was detected in 13 of 15 wells or 87 percent of the samples. Chloroform and several other compounds are common disinfection by-products (DBPs) and are produced when chlorine is added to either drinking or wastewater. The detection of chloroform in groundwater can be an indicator of chlorinated water entering the hydrologic system and the input of other chloroform sources (such as direct releases) to the environment (Ivahnenko and Barbash, 2004). Chloroform can enter the hydrologic system in the form of recharge from chlorinated water. Sources include chlorinated

water used to irrigate, leaking distribution lines for finished water and wastewater, and leakage from septic fields. The use of sodium hypochlorite to disinfect wells, the dehalogenation of tetrachloromethane, and a variety of natural sources can also contribute to its occurrence in groundwater (Ivahnenko and Barbash, 2004).

Two other compounds that are associated with the chlorination of drinking water were detected — bromodichloromethane at a detection frequency of 13 percent (2 of 15 samples), and bromoform at a detection frequency of 7 percent (1 of 15 samples). Chloroform occurred in 87 percent of sampled wells (13 of 15 samples) and in all samples where 4 or fewer compounds were detected (table 1, fig. 3a). The common use of free chlorine in the drinking-water decontamination process produces one or more trihalomethanes (THMs) in addition to chloroform (Ivahnenko and Zogorski, 2006). Further, when a naturally occurring bromide ion is present during chlorination, the bromide forms halogenated DBPs. Therefore, in the presence of bromide, the detection frequency of the four principal THMs (bromoform, dibromochloromethane, bromodichloromethane, and chloroform) will decrease sequentially, inversely proportional to the concentration of bromide ion (Thiros, 2000; Grady and Casey, 2001; Moran and others, 2002). Thus, the relatively high detection frequency of chloroform in the study area and the relatively low occurrence of other DBPs indicates the use of chlorination for the disinfection of drinking water. Ivahnenko and Zogorski (2006) suggested that this pattern is indicative of the use of chlorine to disinfect domestic and, to a lesser degree, public groundwater supplies.

Other frequently detected VOCs were the gasoline additives methyl *tert*-butyl ether (MTBE) (10 of 15 samples, or 67 percent), and toluene (6 of 15 samples, or 40 percent) (table 1). Toluene is known to be toxic to a wide range of biota and MTBE is classified as a potential human carcinogen (U.S. Environmental Protection Agency, 1999). Both are relatively hydrophilic and commonly co-occur in gasoline-contaminated groundwater (Weaver and others, 1999). In a study of gasoline components in urban areas, Delzer and others (1996) and Zogorski and others (2006) suggested that contaminated stormwater could be a source for MTBE (and possibly toluene) in shallow groundwater. These findings support the results of a study by Grady (2003), which included a national review of MTBE and other VOCs, and showed that MTBE and chloroform were the most frequently detected compounds in source-water supplies (groundwater and surface water) nationwide.

Twenty-five of the VOCs detected had human-health benchmarks (table 1). Three of these compounds (methylene chloride, chloroform, and benzene) had BQ_{max} values greater than or equal to 0.1. One compound, acrylonitrile, had a BQ_{max} value (8.4) above the 1.0 level of potential human-health concern (fig. 3b). All four compounds are listed by the USEPA as high production volume (HPV) chemicals, which means that their production in the United States exceeds 1 Mlbs/yr (million pounds per year); however, their use is not restricted to manufacturing (U.S. Environmental Protection



Figure 3. Volatile organic compounds detected in source water from 15 community water-supply wells: (A) concentrations and occurrence, and (B) benchmark quotient values, Maryland and Virginia, 2003.

Agency, 1996). Benzene is used as an organic solvent and dilution agent in many industries including the manufacturing of insecticides and herbicides. Acrylonitrile is an acrylic fiber (monomer) used in the production of nylon and synthetic rubber. Chloroform, as previously described, is associated with the disinfection of drinking water. In addition, all four compounds appear on USEPA's Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Hazardous Substances list (U.S. Environmental Protection Agency, 2001). The relatively high BQmax values for acrylonitrile, methylene chloride, and benzene, but relatively low frequency of occurrence (one sample or 7 percent for acrylonitrile and methylene chloride, and two samples or 13 percent for benzene) indicates that there is a need for continued monitoring of these compounds. For VOCs that were detected, the median concentration of all maximum concentrations of VOCs was 0.51 $\mu\text{g/L}$ (fig. 4).

Pesticides

Thirty-seven different pesticide and pesticide degradate compounds were detected in the source water, which represents about 8 compounds per sample (with a maximum of 27 compounds in one sample and a minimum of 1 compound per sample) (table 1, fig. 5a). Although the number of individual pesticides and pesticide degradates detected (37) was roughly the same as for VOCs (41), pesticides were detected more frequently in comparison to VOCs (113 pesticide detections compared to 79 VOC detections). The median value of maximum concentrations of detected pesticides was 0.04 $\mu\text{g/L}$ (fig. 4). The majority of the pesticides that were found are designated as "unrestricted" with respect to use and application. The USEPA designates a pesticide as "restricted" for use based on the compound's acute (not chronic) toxicity (U.S. Environmental Protection Agency, 2007).

Nearly half (about 45 percent) of the 113 pesticide detections resulted from the quantifiable presence of atrazine and metolachlor — two common, unrestricted-use agricultural herbicides and their degradates, deethylatrazine and metolachlor ESA. Almost one quarter (27 detections) were either from atrazine (12 detections) or its degradate deethylatrazine (15 detections). Metolachlor ESA and its parent compound metolachlor accounted for 21 percent of the total number of detections (13 and 11 detections, respectively). In addition, when more than five compounds were detected at a specific site, those compounds were likely to be one or more of the six most common pesticides found, either atrazine or an atrazine degradate (deethylatrazine), metolachlor or metolachlor degradates [metolachlor ESA or metolachlor OA (metolachlor oxanilic acid)], or alachlor ESA (fig. 5a).

After it is applied to crops (usually corn to control weeds), atrazine can pass through the soil zone and into the shallow groundwater. As it moves, it undergoes microbial degradation, forming deethylatrazine, among other compounds. In a study of commonly used pesticides, Gilliom

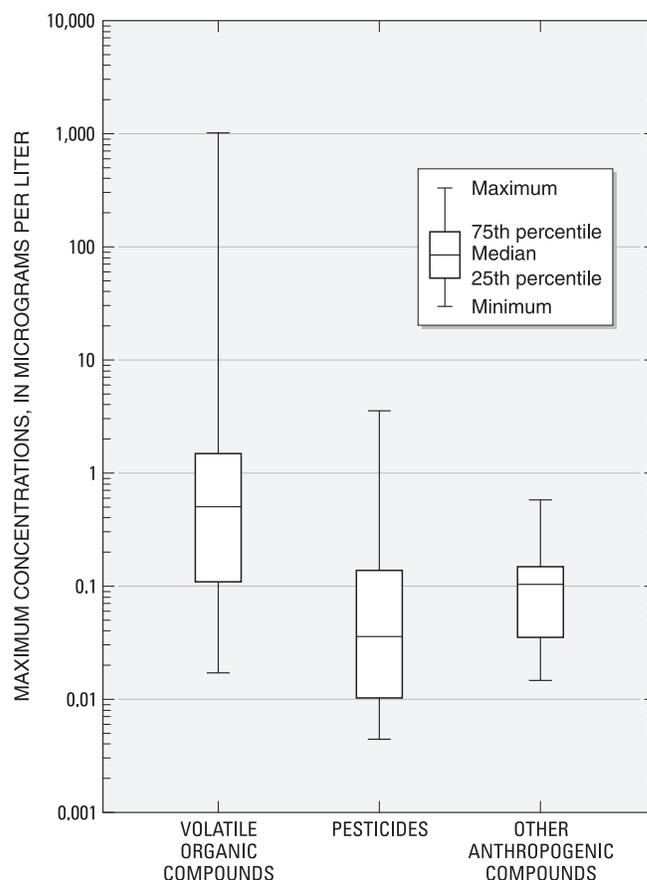


Figure 4. Distribution of maximum concentrations of detected anthropogenic organic compounds in source water from 15 community water-supply wells, Maryland and Virginia, 2003.

and others (2006) determined that atrazine was the single most used pesticide nationwide — 75 Mlbs/yr. This same study noted that atrazine and deethylatrazine were the most commonly detected compounds in groundwater nationwide — up to about 44 percent for deethylatrazine and 42 percent for atrazine, with detection frequency dependent on the surrounding land use. Atrazine is water-soluble and relatively persistent in soil with a half life (the time needed for one half of the applied compound to degrade or metabolize into one or multiple other compounds) of 146 days. This high-intensity use and relatively long half life may contribute to the high detection frequency among the 15 CWSs sampled in this study. Adams and Thurman (1991), in attempting to quantify the source term of atrazine and its degradates in groundwater, determined that deethylatrazine was the major degradate of atrazine and that it could enter the aquifer at higher concentrations than the parent compound. Other independent research has indicated that the half life for atrazine in soils can be more than 100 days, and that detectable concentrations of atrazine and deethylatrazine can persist for up to 6 years and more than 25 years, respectively (Barbash and others, 1999; Denver and Sandstrom, 1991; Gaus, 2000).

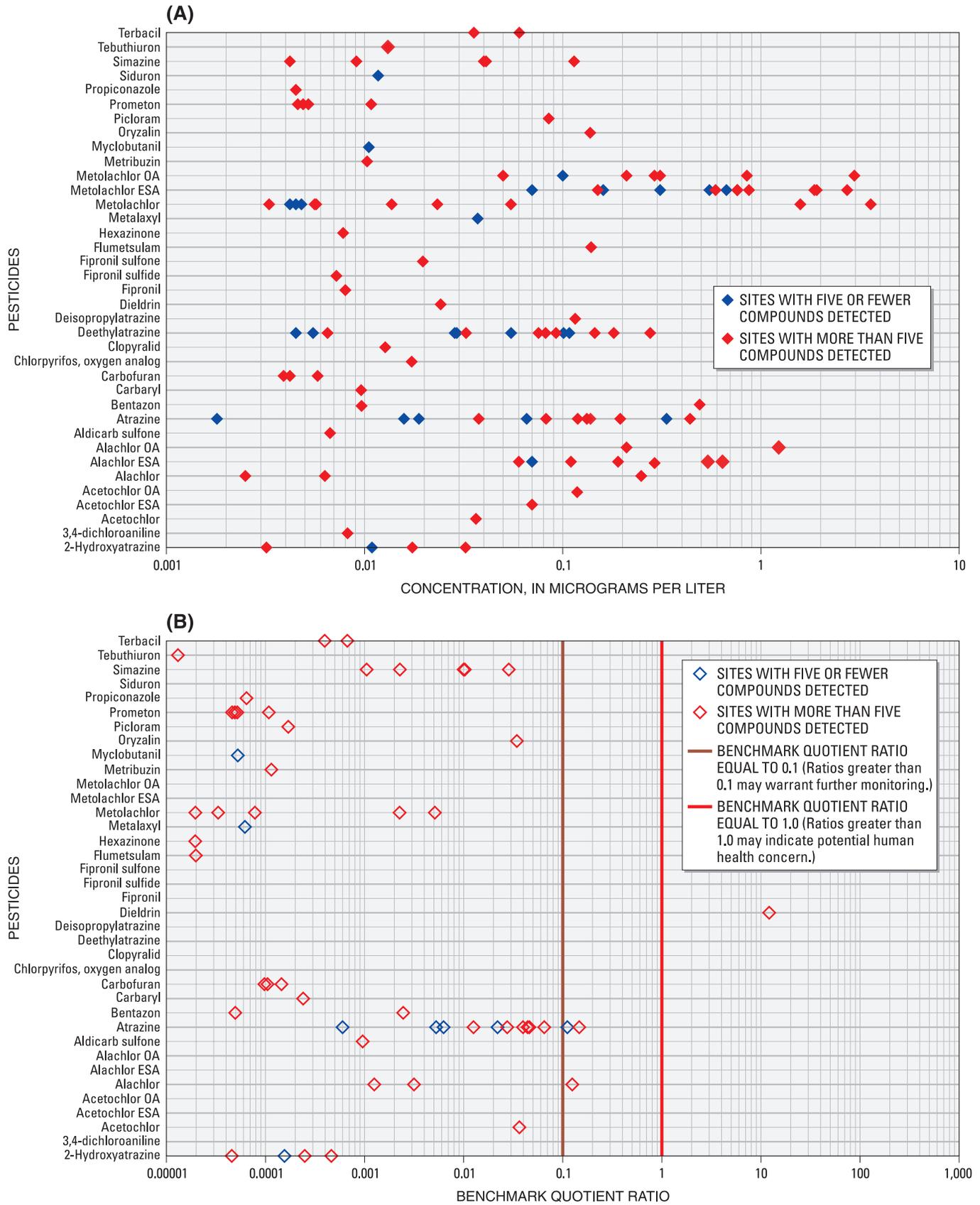


Figure 5. Pesticides detected in source water from 15 community water-supply wells: (A) concentrations and occurrence, and (B) benchmark quotient values, Maryland and Virginia, 2003. [ESA, ethanesulfonic acid; OA, oxanilic acid]

Metolachlor is a common pre-emergent herbicide used extensively to control weeds in corn and soybeans. Its estimated usage in the United States in 1997 was 67 million lbs/yr (Gianessi and Marcelli, 2000) — the second most used herbicide after atrazine. Like atrazine, metolachlor is water soluble and persistent in the environment with a half life of 114 days (Kollman and Segawa, 2000). Metolachlor was detected in groundwater nationwide at a frequency of up to 17 percent, depending on surrounding land use (Gilliom and others, 2006). Detection frequency in the current study indicates a substantially higher frequency of occurrence — about 73 percent. Once applied, metolachlor metabolizes; the two most common degradates of metolachlor are metolachlor OA and ESA. Eckhardt and others (1999) and Phillips and others (1999) found that these degradates are more soluble than their parent compounds. Both studies also indicated that the degradates are more persistent, found at higher concentrations, and detected more frequently in groundwater and surface water than the parent compounds. Similarly, Phillips and others (1999) found that the ratio of metolachlor ESA to metolachlor was higher in groundwater when compared to surface water. In a study of groundwater on the Delmarva Peninsula, Debrewer and others (2007) detected the ESA degradate of metolachlor in as many as 88 percent of shallow (less than 100 feet) wells sampled, and metolachlor OA was detected in 49 percent of the wells sampled. The current study found higher detection frequencies for both pesticides and their degradates than those found by Debrewer and others (2007). Deethylatrazine had a 100-percent detection frequency and atrazine had an 80-percent (12 out of 15) detection frequency. The detection frequency for metolachlor was 73 percent (11 out of 15) whereas metolachlor ESA and metolachlor OA were detected at 87 percent (13 out of 15) and 47 percent (7 out of 15), respectively, in source water. Other pesticides and degradates occurring in more than one third of the source-water samples collected were metolachlor OA (47 percent, or 7 of 15 samples), alachlor ESA (alachlor ethanesulfonic acid) — a degradate of the unrestricted herbicide alachlor (47 percent), and simazine (33 percent, or 5 of 15 samples). Maximum concentrations of pesticides detected in source water ranged from 0.005 (estimated) $\mu\text{g/L}$ for propiconazole, an unrestricted fungicide, to 3.58 $\mu\text{g/L}$ for metolachlor, a common unrestricted herbicide (table 1, fig. 5b).

Human-health benchmarks were available for 22 of the 37 pesticide compounds detected (fig. 5b). The BQmax values for these 22 compounds were generally one to several orders of magnitude below the benchmark quotient value of 0.1. Three compounds had BQmax values greater than or equal to the 0.1 threshold, however. Atrazine and alachlor, both unrestricted, widely used herbicides, had a BQmax value of about 0.1, indicating that further monitoring in a low-concentration trends-monitoring program may be warranted. Dieldrin had a BQmax greater than 1.0. The BQmax for dieldrin, an unregulated insecticide and known carcinogen, was 12.1 based on an HBSL of 0.002. Dieldrin is an organochlorine pesticide, is hydrophobic, tends to bioaccumulate, and was used

extensively throughout the United States in the agricultural and building industries from the 1940s until it was completely banned in 1987 (Agency for Toxic Substances and Disease Registry, 1993).

Other Anthropogenic Organic Compounds

The most frequently detected OAOs in source water were 4-octylphenol diethoxylate and 4-octylphenol monoethoxylate, both with a detection frequency of 13 percent (2 out of 15). The maximum concentrations were 0.120 (estimated) $\mu\text{g/L}$ for 4-octylphenol diethoxylate, and 0.590 (estimated) $\mu\text{g/L}$ for 4-octylphenol monoethoxylate (table 1, fig. 6a). The median concentration of all maximum concentrations of OAOs was approximately 0.10 $\mu\text{g/L}$ (fig. 4). Only one occurrence of each of the remaining 12 compounds was detected in the 15 samples. Of these 12 compounds, 2-methylnaphthalene had the highest concentration, 0.23 (estimated) $\mu\text{g/L}$, and 1-methylnaphthalene had a concentration of 0.12 (estimated) $\mu\text{g/L}$. Both 2-methylnaphthalene and 1-methylnaphthalene are HPV chemicals used in industrial manufacturing. Five of the 14 OAOs had human-health benchmarks — none generated a BQmax value that exceeded 0.1 (fig. 6b).

Comparison of Source Water and Finished Groundwater

The source and finished water from 10 of the original 15 CWS wells was resampled in August and October 2004. For the 10 finished-water samples, 3 were blended with groundwater from other CWS wells and 7 were not blended. Since these CWSs were sampled only for those AOCs that occurred most frequently during the first phase of sampling, not all pairs of CWS wells and associated finished water were sampled for the same AOCs. That is, 10 pairs of source water and the associated finished water were analyzed for VOCs, 6 for pesticides, and 1 for OAOs. Concentrations of each AOC detected in either source water and (or) the associated blended or non-blended finished water are presented in Appendix A.

Volatile Organic Compounds

Samples from 10 CWS sites and the associated finished water were analyzed for a suite of 85 VOCs. Three of the finished-water samples were blended with other sources of groundwater prior to treatment. Samples from the remaining seven CWSs were non-blended and came from a single well. A total of 21 different VOCs were detected in either the source water and (or) the finished water — 16 in source water, and 19 in finished water (table 2, fig. 7a). All BQmax values in source and finished water were well below the benchmark quotient

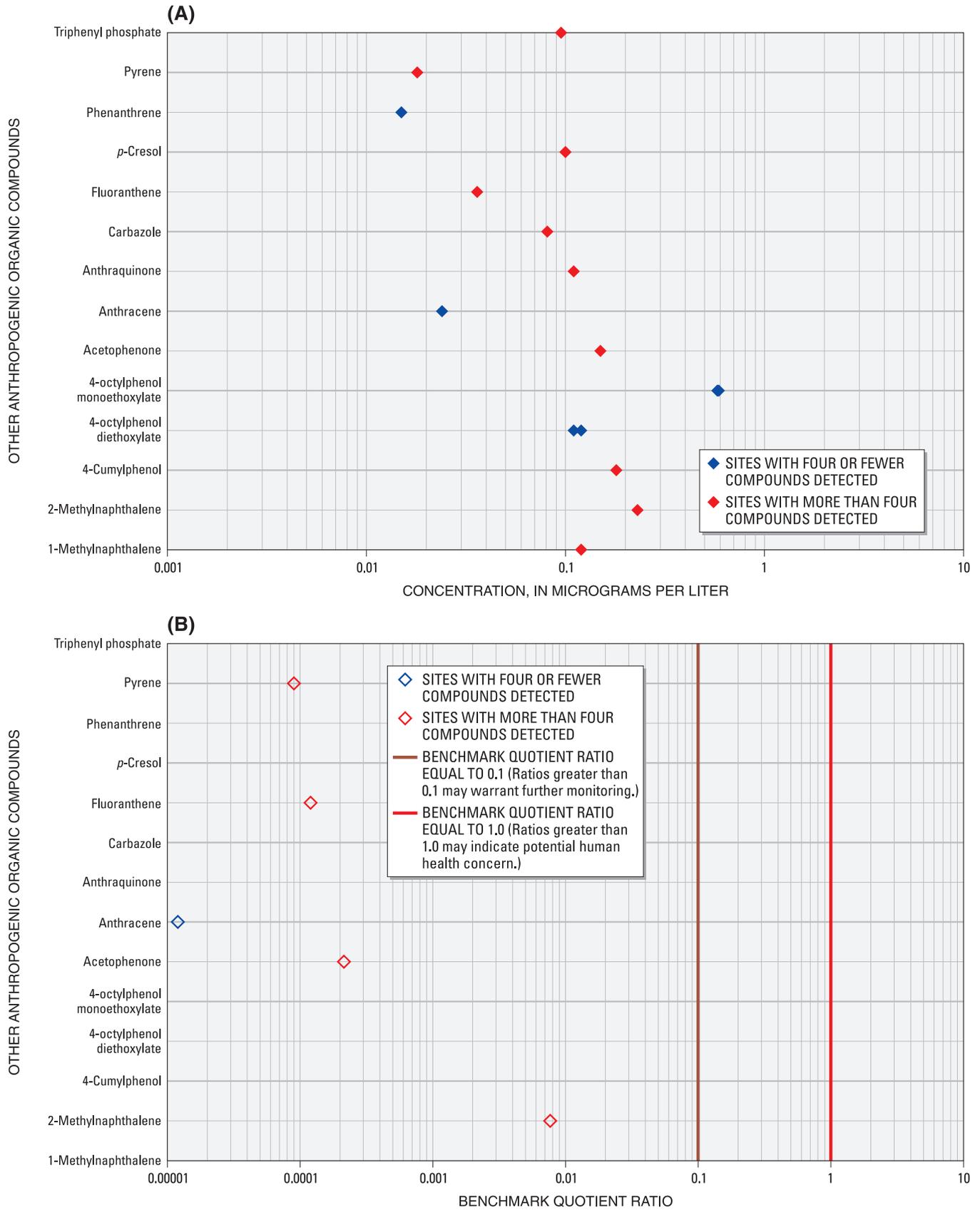


Figure 6. Other anthropogenic organic compounds detected in source water from 15 community water-supply wells: (A) concentrations and occurrence, and (B) benchmark quotient values, Maryland and Virginia, 2003.

Table 2. Maximum concentration, detection frequency, and maximum benchmark quotient for regulated and unregulated compounds detected in source water from 10 community water-supply wells and the associated finished water in the Piedmont Physiographic Province, Potomac River Basin, Maryland and Virginia, 2004.

[HBSL, Health-Based Screening Level; MCL, Maximum Contaminant Level; BQmax, Benchmark Quotient = ratio of maximum compound concentration to MCL or HBSL value; E, estimated value; µg/L, micrograms per liter; MRL, Minimum Reporting Level; --, not available; VOC, volatile organic compound; OAOC, other anthropogenic organic compounds; **Bold type** under compound heading indicates “unregulated,” a compound that has no Federal and (or) State drinking-water standard; ESA, ethanesulfonic acid; OA, oxanilic acid.]

Compound (Regulated or unregulated)	Chemical Abstracts Service Registry Number	Number of samples collected	Number of source-water samples with detections	Number of finished-water samples with detections	MRL (µg/L)	Maximum concentration for source water (µg/L)	Maximum concentration for finished water (µg/L)	MCL or HBSL ¹ concentration (µg/L)	BQMax ² for source water	BQMax ² for finished water
Volatile Organic Compounds										
Chloroform	67-66-3	10	9	10	0.024	1.569	1.574	380	0.02	0.02
1,4-Dichlorobenzene	106-46-7	10	8	8	0.034	E 0.048	E 0.056	75	0.0006	0.0007
Methyl <i>tert</i>-butyl ether	1634-04-4	10	7	8	0.1	2.671	2.565	--	--	--
1,1,1-Trichloroethane	71-55-6	10	3	3	0.032	0.105	0.106	200	0.0005	0.0005
Bromodichloromethane	75-27-4	10	3	7	0.028	0.204	0.725	380	0.003	0.009
Tetrachloroethene	127-18-4	10	3	2	0.03	E 0.037	E 0.020	5	0.007	0.004
1,1-Dichloroethene	75-35-4	10	2	2	0.024	0.112	E 0.096	7	0.02	0.01
Deisopropyl ether	108-20-3	10	2	2	0.1	0.165	0.148	--	--	--
<i>tert</i>-Amyl Methyl Ether	994-05-8	10	2	2	0.04	0.231	0.212	--	--	--
Trichloroethene	79-01-6	10	2	1	0.038	E 0.094	E 0.035	5	0.02	0.007
1,1-Dichloroethane	75-34-3	10	1	1	0.035	0.240	0.238	--	--	--
Bromoform	75-25-2	10	1	5	0.1	0.396	0.520	380	0.005	0.006
Dibromochloromethane	124-48-1	10	1	6	0.1	0.433	1.109	380	0.005	0.01
<i>cis</i> -1,2-Dichloroethene	156-59-2	10	1	1	0.024	0.506	2.188	70	0.007	0.03
Isopropylbenzene	98-82-8	1	1	0	0.5	E 0.007	--	3700	0.00001	--
Tetrahydrofuran	109-99-9	10	1	0	1.2	E 1.10	--	--	--	--
Carbon tetrachloride	56-23-5	10	0	1	0.06	--	E 0.025	5	--	0.005
Methylene chloride	75-09-2	10	0	1	0.06	--	E 0.019	5	--	0.004
Ethylbenzene	100-41-4	10	0	1	0.03	--	E 0.023	700	--	0.00003
<i>m</i> - and <i>p</i> -Xylene	m=108-38-3 p=106-42-3	10	0	1	0.06	--	E 0.085	410,000	--	0.000009
<i>o</i> -Xylene	95-47-6	10	0	1	0.038	--	E 0.027	410,000	--	0.000003
Total number of VOC detections			47	63						

Table 2. Maximum concentration, detection frequency, and maximum benchmark quotient for regulated and unregulated compounds detected in source water from 10 community water-supply wells and the associated finished water in the Piedmont Physiographic Province, Potomac River Basin, Maryland and Virginia, 2004.—Continued

[**HBSL**, Health-Based Screening Level; MCL, Maximum Contaminant Level; BQmax, Benchmark Quotient = ratio of maximum compound concentration to MCL or HBSL value; E, estimated value; µg/L, micrograms per liter; MRL, Minimum Reporting Level; --, not available; VOC, volatile organic compound; OAOC, other anthropogenic organic compounds; **Bold type** under compound heading indicates “unregulated,” a compound that has no Federal and (or) State drinking-water standard; ESA, ethanesulfonic acid; OA, oxanilic acid.]

Compound (Regulated or unregulated)	Chemical Abstracts Service Registry Number	Number of samples collected	Number of source-water samples with detections	Number of finished-water samples with detections	MRL (µg/L)	Maximum concentration for source water (µg/L)	Maximum concentration for finished water (µg/L)	MCL or HBSL ¹ concentration (µg/L)	BQMax ² for source water	BQMax ² for finished water
Pesticides										
Atrazine	1912-24-9	6	6	5	0.007	0.230	0.203	3	0.08	0.07
Deethylatrazine	6190-65-4	6	6	5	0.014	E 0.146	0.111	--	--	--
Deisopropylatrazine	1007-28-9	6	6	4	0.080	E 0.138	E 0.058	--	--	--
Metolachlor ESA	--	5	5	4	0	3.950	2.890	--	--	--
2-Hydroxyatrazine	2163-68-0	6	4	4	0.032	E 0.017	E 0.021	⁵ 70	0.0002	0.0003
Alachlor ESA	--	5	4	3	0.05	0.680	0.470	--	--	--
Metolachlor OA	--	5	4	3	0.05	3.770	2.990	--	--	--
Alachlor OA	--	5	3	3	0.05	0.840	0.750	--	--	--
Benomyl	17804-35-2	6	2	2	0.022	E 0.026	E 0.026	⁶ 40	0.0007	0.0006
Deethyldeisopropylatrazine	3397-62-4	6	2	0	0.04	E 0.029	--	--	--	--
Acetochlor ESA	--	5	1	1	0.05	0.090	0.080	--	--	--
Acetochlor OA	--	5	1	1	0.05	0.140	0.120	--	--	--
Alachlor ESA—second amide	--	5	1	2	0.05	0.070	0.040	--	--	--
Bentazon	25057-89-0	6	1	1	0.024	E 0.748	E 0.370	⁵ 200	0.004	0.002
Flumetsulam	98967-40-9	6	1	2	0.040	E 0.122	E 0.098	⁵ 7,000	0.00002	0.00001
Metolachlor	51218-45-2	1	1	1	0.006	E 0.004	E 0.005	700	0.000006	0.000007
Nicosulfuron	111991-09-4	6	1	0	0.04	E 0.006	--	⁵ 9,000	0.000001	--
Simazine	122-34-9	1	1	1	0.005	0.047	0.044	4	0.01	0.01
Tebuthiuron	34014-18-1	6	1	1	0.026	E 0.020	E 0.018	⁵ 1,000	0.00002	0.00002
Terbacil	5902-51-2	6	1	0	0.026	E 0.023	--	⁵ 90	0.0003	--
Triclopyr	55335-06-3	6	1	1	0.026	0.032	0.026	⁵ 400	0.00008	0.00007
Acetochlor/Metolachlor ESA—second amide	--	5	0	1	0.05	--	0.120	--	--	--
Imazethapyr	81335-77-5	6	0	1	0.038	--	E 0.042	⁵ 2,000	--	0.00002
Metsulfuron methyl	74223-64-6	6	0	3	0.067	--	E 0.105	⁵ 2,000	--	0.00005

Table 2. Maximum concentration, detection frequency, and maximum benchmark quotient for regulated and unregulated compounds detected in source water from 10 community water-supply wells and the associated finished water in the Piedmont Physiographic Province, Potomac River Basin, Maryland and Virginia, 2004.—Continued

[HBSL, Health-Based Screening Level; MCL, Maximum Contaminant Level; BQmax, Benchmark Quotient = ratio of maximum compound concentration to MCL or HBSL value; E, estimated value; µg/L, micrograms per liter; MRL, Minimum Reporting Level; -, not available; VOC, volatile organic compound; OAOC, other anthropogenic organic compounds; **Bold type** under compound heading indicates “unregulated,” a compound that has no Federal and (or) State drinking-water standard; ESA, ethanesulfonic acid; OA, oxanilic acid.]

Compound (Regulated or unregulated)	Chemical Abstracts Service Registry Number	Number of samples collected	Number of source-water samples with detections	Number of finished-water samples with detections	MRL (µg/L)	Maximum concentration for source water (µg/L)	Maximum concentration for finished water (µg/L)	MCL or HBSL ¹ concentration (µg/L)	BQMax ² for source water	BQMax ² for finished water
Picloram	0918-02-1	6	0	1	0.032	--	0.151	500	--	0.0003
Total number of pesticide detections			53	50						
Other Anthropogenic Organic Compounds										
4-octylphenol, diethoxylate	26636-32-8	1	1	0	1	E 0.070	--	--	--	--
4-octylphenol, monoethoxylate	26636-32-8	1	1	0	1	E 0.32	--	--	--	--
Total number of OAOC detections			2	0						

¹ HBSL range corresponds to a 10⁻⁶ to 10⁻⁴ cancer risk range for unregulated carcinogens.

² BQmax for unregulated compounds was calculated using HBSL concentration at the low end of the HBSL range, and was rounded to one significant figure.

³ 1998 Final Rule for Disinfectants and Disinfection By-Products: The total for trihalomethanes is 80 micrograms per liter.

⁴ MCL is for the sum of concentrations for mixed isomers of xylene.

⁵ Value calculated using United States Environmental Protection Agency’s (USEPA) formula for Lifetime Health Advisory.

⁶ HBSL calculated using USEPA’s Lifetime Health Advisory approach for Group C carcinogens.

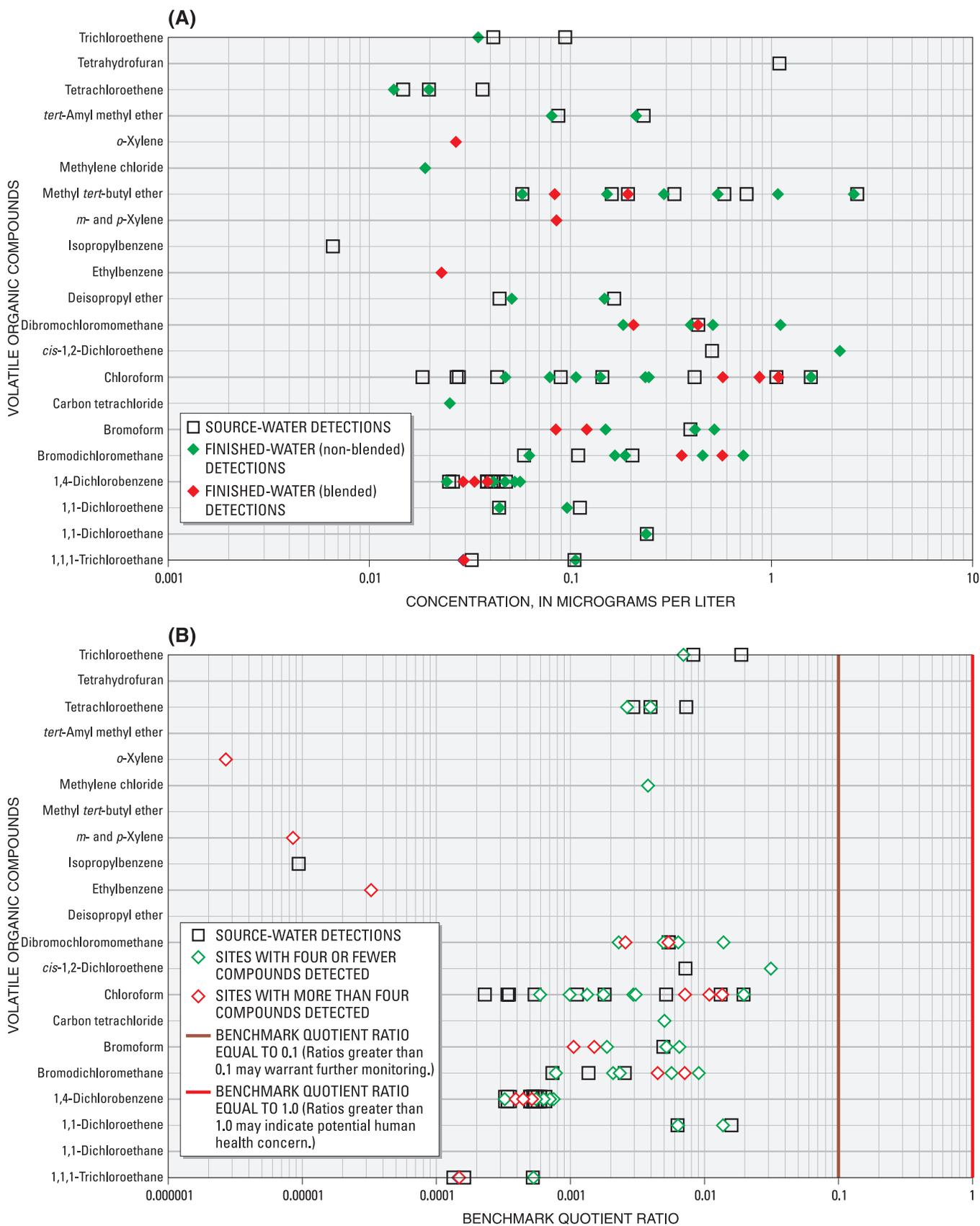


Figure 7. Volatile organic compounds detected in source water from 10 community water-supply wells and associated finished water (non-blended and blended): (A) concentrations and occurrence, and (B) benchmark quotient values, Maryland and Virginia, 2004.

value of 0.1. The compound with the highest BQmax values in source and finished water was chloroform, with a BQmax value of 0.02. In many instances, a compound's BQmax value was several (and, in the case of *o*-Xylene, four) orders of magnitude below the threshold (table 2, fig. 7b).

As a group, the THMs contributed about 30 percent and 44 percent of all detections in source and finished water, respectively. This group of compounds (chloroform, bromodichloromethane, bromochloromethane, and dibromochloromethane — all of which were found in both source and finished water) can be formed when chlorine, used to disinfect drinking water, reacts with organic and inorganic matter in the source water. As previously discussed, these compounds are collectively known as DBPs and are regulated by the USEPA at a maximum allowable, annual average of 80 µg/L for the sum of the four compounds (U.S. Environmental Protection Agency, 2006). The differences in median concentrations of chloroform and bromodichloromethane between finished and source water, when these compounds were detected above their minimum reporting levels, were 0.15 µg/L and 0.25 µg/L, respectively (fig. 8). Collectively, there were 28 detections of DBPs in finished water compared to half that number in source water (table 2, Appendix A). Chloroform had some of the highest concentrations of DBPs found, and was detected in 9 of the source-water samples and all 10 of the finished-water samples (Appendix A). If the maximum concentrations of all four THMs are added together, however, the total concentration of 3.9 µg/L is still well below the 80 µg/L MCL set by the USEPA.

The next most commonly occurring compounds were 1,4-dichlorobenzene and MTBE. 1,4-dichlorobenzene is one of three common dichlorobenzene isomers and does not occur naturally. As a class of chemicals, dichlorobenzenes are hydrophobic, and tend to volatilize easily. 1,4-dichlorobenzene is a HPV industrial chemical and a white solid that will sublime at room temperature and is commonly used in toilet deodorizer products, thus finding its way into the wastewater stream. It was detected in eight of the source- and finished-water samples. The gasoline oxygenate MTBE was found in seven source-water and eight finished-water samples (table 2, Appendix A).

Overall, there were 16 fewer VOC detections in source water than in finished water (47 and 63, respectively). However, DBPs account for most of the additional detections in finished water, and the difference is reduced to two when the DBPs are excluded. Concentrations of detected non-DBP VOCs were very similar in source water and in finished water (table 2, fig. 9).

Pesticides

Source- and finished-water samples for pesticides were collected from one to six CWS wells and analyzed for a suite of 141 common pesticides. Not all compounds were analyzed in all samples. Twenty-five pesticides were detected among the

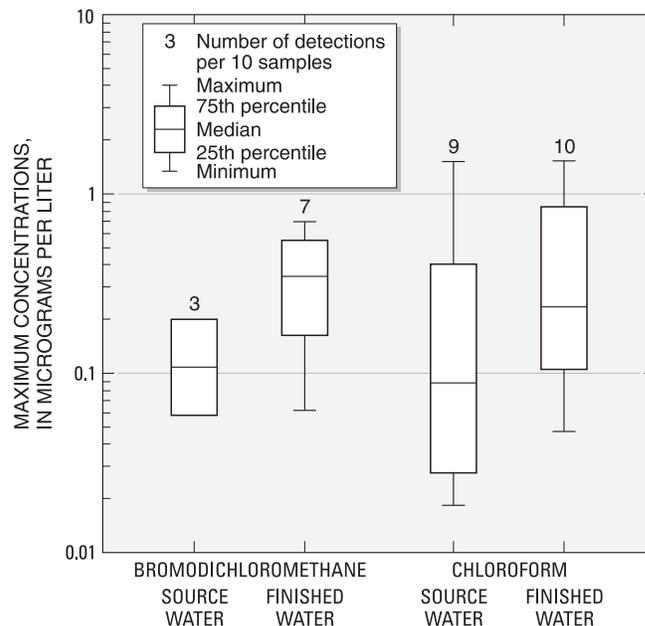


Figure 8. Concentrations of bromodichloromethane and chloroform detected in source water from 10 community water-supply wells and associated finished water (non-blended and blended), Maryland and Virginia, 2004.

CWS samples in either the source or finished water, or both. Two of the six sites had blended finished water, indicating that those sites received water from groundwater sources other than the one analyzed (table 2, fig. 10a).

The most commonly detected pesticides in both source and finished water were atrazine and its degradate, deethylatrazine. These two compounds were detected in six of six source-water samples and five of six finished-water samples. When detections from two other atrazine degradates, deisopropylatrazine and 2-hydroxyatrazine are included, atrazine and its degradates account for about 42 percent of the detections in source-water samples and 36 percent of all detections in finished-water samples. If detected in source water, these four compounds often were detected in the associated finished-water product, whether it was blended or non-blended (fig. 10a).

The next most commonly detected pesticides were the OA and ESA degradates of alachlor and metolachlor. Five samples were collected and analyzed for each of the four compounds. One sample was analyzed for the parent compound metolachlor. Finished-water detection frequencies were 80 percent for metolachlor ESA and 60 percent for alachlor ESA and both metolachlor OA and alachlor OA. When taken collectively, metolachlor and its degradates and the degradates of alachlor accounted for about 32 percent of the detections in source water and 28 percent of the detections in finished water. The two metolachlor degradates were detected at the highest concentrations of all pesticides detected in source water (metolachlor ESA, 3.950 µg/L, and metolachlor OA, 3.770 µg/L)

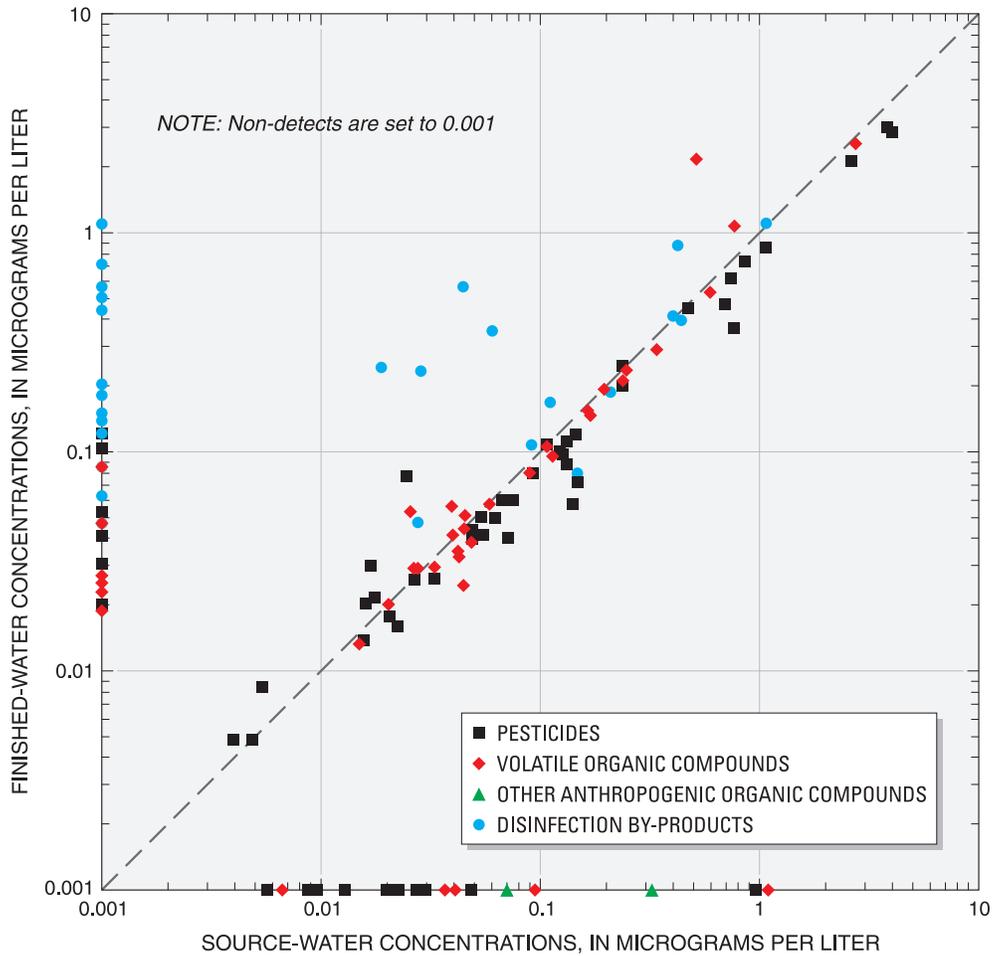


Figure 9. Comparison of concentrations of pesticides, volatile organic compounds, and other anthropogenic compounds in source water from 10 community water-supply wells and associated finished water (non-blended and blended), Maryland and Virginia, 2004

— concentrations almost four orders of magnitude greater than that of the parent compound (metolachlor) in source water, 0.004 (estimated) $\mu\text{g/L}$ (table 2, fig. 10a).

Detection frequencies for the remaining 16 compounds were two or fewer detections in the well(s) sampled for both source and finished water. Concentrations in source water ranged from 0.006 (estimated) $\mu\text{g/L}$ for nicosulfuron to 0.748 (estimated) $\mu\text{g/L}$ for bentazon — both herbicides. Finished-water concentrations ranged from 0.018 (estimated) $\mu\text{g/L}$ for tebuthiuron (a herbicide) to 0.370 (estimated) $\mu\text{g/L}$ for bentazon (table 2, fig. 10a). The herbicide metsulfuron methyl occurred only in finished water at three CWSs. One of these sites blended the sampled source water with other sources. Other compounds that were detected only in finished water were picloram (one detection), imazethapyr (one detection), and acetochlor/metolachlor ESA—second amide (one detection). The picloram and imazethapyr came from a single CWS that was not blending multiple sources for the finished product. Acetochlor/metolachlor ESA — second amide

(a degradate common to both acetochlor and metolachlor) occurred in separate, non-blended CWSs (Appendix A).

Although no BQmax value equaled or exceeded 0.1, atrazine neared the threshold with a BQmax of 0.08 in source water and about 0.07 in finished water. All other BQmax values were between 0.000001 for nicosulfuron (in source water) and 0.01 for simazine (in source water and finished water) (fig. 10b).

The detection frequency and concentrations of pesticides in source water can indicate the potential for certain pesticides to be present in some finished waters, but not all (fig. 9). In addition, the introduction of multiple unquantifiable source terms (blended finished water) can decrease the concentration of a given compound in the finished product (dilution). However, blending with contaminated source waters may have actually increased the concentration of five pesticides (metolachlor ESA, atrazine, 2-hydroxyatrazine, metsulfuron methyl, and flumetsulam) at two different sites (Appendix A).



Figure 10. Pesticides detected in source water from 10 community water-supply wells and associated finished water (non-blended and blended): (A) concentrations and occurrence, and (B) benchmark quotient values, Maryland and Virginia, 2004. [ESA, ethanesulfonic acid; OA, oxanilic acid]

Other Anthropogenic Organic Compounds

Samples from a single CWS well and the associated blended finished water were analyzed for OAOCs. Only two OAOCs, 4-octylphenol monoethoxylate and 4-octylphenol diethoxylate, were detected in the source water, and none were detected in finished water (table 2, fig. 9). Both are degradates of common detergents. The highest detected concentration of 4-octylphenol monoethoxylate was 0.32 (estimated) $\mu\text{g/L}$. The absence of the compound in the finished product may be attributed to dilution as the analyzed source water was blended with water from one or more other wells. Conversely, chlorination (as part of the disinfection process) may alter some compounds so that they may be present, but are in a chlorinated form that is not quantifiable (Appendix A). Due to the lack of health guidelines (MCLs or HBSLs) for these OAOCs, no BQmax values were obtained (table 2).

Summary

A source-water-quality assessment was performed in the Piedmont Physiographic Province of the Potomac River Basin in 2003 and 2004. The assessment included two sampling phases. The first phase focused on determining the occurrence of 284 anthropogenic organic compounds in the source water of some of the highest-producing community water systems in the study area. The anthropogenic organic compounds monitored included volatile organic compounds, pesticides and pesticide degradates, and other anthropogenic organic compounds. The second phase of the program focused on those anthropogenic organic compounds that were detected most frequently during the first phase of sampling, and characterized their occurrence in source water as well as associated finished water prior to distribution.

During phase one, 92 of the 284 anthropogenic organic compounds were detected (41 volatile organic compounds, 37 pesticides and pesticide degradates, and 14 other anthropogenic organic compounds) in source-water samples collected in August and September 2003. The five most frequently occurring anthropogenic organic compounds were detected in more than 70 percent of the 15 source-water samples. Deethylatrazine (an atrazine degradate) was present in all 15 samples. Metolachlor ethanesulfonic acid, a degradate of the herbicide metolachlor, and chloroform, a volatile organic compound and known disinfection by-product, were present in 87 percent of the samples. Atrazine and metolachlor were present in 80 percent and 73 percent of the samples, respectively. All samples contained a mixture of compounds with an average of about 14 compounds per sample.

Concentrations for compounds detected in source water were generally low, ranging from 0.005 (estimated) micrograms per liter for the fungicide propiconazole to 13.51 micrograms per liter for chloroform. Two industrial solvents, methyl ethyl ketone and tetrahydrofuran, were detected at

concentrations that exceeded the next highest concentration by an order of magnitude. Chloroform and methyl *tert*-butyl ether were the most frequently detected volatile organic compounds (87 and 67 percent, respectively). They were most often found at sites that contained at least four other volatile organic compounds, which is consistent with other studies that indicate that these are the two most frequently detected volatile organic compounds nationwide.

Two measurements for human-health assessment — the Maximum Contaminant Levels set by the U.S. Environmental Protection Agency and Health-Based Screening Levels developed by the U.S. Geological Survey — were used to place water-quality data in a human-health context. Slightly more than half (56 percent) of the detected compounds had either a Maximum Contaminant Level or a Health-Based Screening Level that was used to create a ratio of the maximum detected concentration of a compound to one of these two human-health standards; this unitless ratio is called the benchmark quotient or BQmax. One tenth of this ratio (BQmax greater than or equal to 0.1), was used as a threshold value, allowing investigators to determine which compounds may warrant further investigation. Samples collected in phase one yielded concentrations for some compounds that had BQmax values between one and five orders of magnitude below a BQmax of 0.1. Seven compounds (chloroform, benzene, acrylonitrile, methylene chloride, atrazine, alachlor, and dieldrin) met or exceeded a BQmax of 0.1, however. Benchmark quotient values were not calculated for compounds that had neither Maximum Contaminant Levels nor Health-Based Screening Levels.

Pesticides were detected more frequently but at lower median concentrations than volatile organic compounds. Nearly half of the detections (51 of 113) resulted from the presence of the herbicides atrazine and metolachlor and two degradates of these compounds (deethylatrazine and metolachlor ethanesulfonic acid). Maximum concentrations of pesticides detected in source water ranged from 0.005 (estimated) micrograms per liter for propiconazole to 3.58 micrograms per liter for metolachlor. Benchmark quotient values were available for 22 pesticides and were generally one to several orders of magnitude below the 0.1 threshold that would warrant further monitoring. Three compounds — atrazine, alachlor, and dieldrin — were at or significantly above the threshold in one or more samples. Dieldrin had a BQmax of 12.1 — the maximum concentration of dieldrin was 12 times higher than the health standard for that compound in one sample.

In August and October 2004, 10 of the 15 community water supply wells, along with their associated finished water, were selectively resampled for the anthropogenic organic compounds that occurred most frequently during phase one. Three of the 10 sites blended source water with other sources of groundwater or surface water. Seven sites were non-blended. Ten sample pairs (source and finished water) were analyzed for volatile organic compounds, six pairs for pesticides, and one pair for other anthropogenic

organic compounds. In total, 21 volatile organic compounds, 25 pesticides and pesticide degradates, and two other anthropogenic organic compounds were detected. Overall, there were 113 anthropogenic organic compounds detected in finished water and 102 detected in source water.

The most common group of volatile organic compounds that were detected was the trihalomethanes, a group of disinfection by-products. Trihalomethanes accounted for about 30 percent of the detections in source water and 44 percent of the detections in finished water. Other commonly detected volatile organic compounds included 1,4-dichlorobenzene, detected in 8 of 10 source-water and finished-water samples, and the gasoline oxygenate methyl *tert*-butyl ether, found in 7 source-water samples and 8 finished-water samples. This indicates that blended finished water may introduce additional contaminant sources or the creation of compounds through the disinfection process. No volatile organic compound exceeded the 0.1 BQmax threshold.

Twenty-five pesticides were detected in either source water, finished water, or both among the community water systems sampled in phase two. In total, there were slightly more pesticide detections in source water (53) than in finished water (50). The most commonly detected pesticide compounds in both source water and finished water were atrazine and its degradate, deethylatrazine. With the inclusion of deisopropylatrazine and 2-hydroxyatrazine, atrazine and its degradates accounted for about 42 percent of the detections in source-water samples and 36 percent of all detections in finished-water samples. The next most commonly detected pesticide compounds were the parent compounds and degradates of alachlor and metolachlor. These compounds accounted for about 32 percent of detections in source water and 28 percent of the detections in finished water. Three degradates (metolachlor ethanesulfonic acid, alachlor ethanesulfonic acid, and metolachlor oxanilic acid) were found more often in source-water than finished-water samples. Two of the metolachlor degradates were detected at the highest concentrations of all pesticides detected in source water — metolachlor ethanesulfonic acid at 3.950 micrograms per liter, and metolachlor oxanilic acid at 3.770 micrograms per liter. Metolachlor ethanesulfonic acid and oxanilic acid were detected at frequencies of 100 and 80 percent, respectively, in source water, and 80 and 60 percent in finished water.

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Appendix A

Appendix A. Comparison between source water and associated finished water (non-blended and blended) for detected anthropogenic organic compounds in community water-supply systems in the Piedmont Physiographic Province, Potomac River Basin, Maryland and Virginia, 2004.

[E, estimated value; --, no detection; µg/L, micrograms per liter; **red type** indicates blended water; **Bold type** under compound heading indicates “unregulated,” a compound that has no Federal and (or) State drinking-water standard; ESA, ethanesulfonic acid; OA, oxanilic acid.]

Well identifier	Compound (Regulated or unregulated)	Source-water concentration (µg/L)	Finished-water concentration (non-blended and blended) (µg/L)
Volatile Organic Compounds			
49X 10	1,1,1-Trichloroethane	E 0.027	E 0.029
CL Bd 179	1,1,1-Trichloroethane	0.105	0.106
FR Dc 62	1,1,1-Trichloroethane	E 0.032	E 0.030
49X 10	1,1-Dichloroethane	0.240	0.238
49X 10	1,1-Dichloroethene	0.112	E 0.096
CL Bd 179	1,1-Dichloroethene	E 0.044	E 0.044
49X 10	1,4-Dichlorobenzene	E .040	--
49X 11	1,4-Dichlorobenzene	E 0.038	E 0.056
CL Bd 179	1,4-Dichlorobenzene	E 0.025	E 0.053
CL Bd 180	1,4-Dichlorobenzene	E 0.044	E 0.024
FR Dc 62	1,4-Dichlorobenzene	E 0.048	E 0.039
FR Ec 43	1,4-Dichlorobenzene	--	E 0.047
FR Ef 54	1,4-Dichlorobenzene	E 0.026	E 0.029
FR Eg 36	1,4-Dichlorobenzene	E 0.039	E 0.041
FR Eg 37	1,4-Dichlorobenzene	E 0.042	E 0.033
49X 10	Bromodichloromethane	--	0.725
49X 11	Bromodichloromethane	--	E 0.062
CL Bd 179	Bromodichloromethane	0.109	0.167
FR Dc 69	Bromodichloromethane	--	0.454
FR Ef 54	Bromodichloromethane	--	0.569
FR Eg 36	Bromodichloromethane	0.204	0.187
FR Eg 37	Bromodichloromethane	E 0.059	0.358
49X 10	Bromoform	--	0.520
FR Dc 69	Bromoform	--	E 0.150
FR Ef 54	Bromoform	--	0.121
FR Eg 36	Bromoform	0.396	0.417
FR Eg 37	Bromoform	--	E 0.085
49X 10	Carbon tetrachloride	--	E 0.025
49X 10	Chloroform	E 0.028	0.236
49X 11	Chloroform	--	0.141
CL Bd 179	Chloroform	1.569	1.574
CL Bd 180	Chloroform	E 0.090	0.107
FR Dc 62	Chloroform	1.058	1.085
FR Dc 69	Chloroform	E 0.018	0.245
FR Ec 43	Chloroform	E 0.027	E 0.048
FR Ef 54	Chloroform	E 0.043	0.573
FR Eg 36	Chloroform	0.144	E 0.079
FR Eg 37	Chloroform	0.415	0.871
49X 11	cis-1,2-Dichloroethene	0.506	2.188

Appendix A. Comparison between source water and associated finished water (non-blended and blended) for detected anthropogenic organic compounds in community water-supply systems in the Piedmont Physiographic Province, Potomac River Basin, Maryland and Virginia, 2004.—Continued

[E, estimated value; --; no detection; µg/L, micrograms per liter; **red type** indicates blended water; **Bold type** under compound heading indicates “unregulated,” a compound that has no Federal and (or) State drinking-water standard; ESA, ethanesulfonic acid; OA, oxanilic acid.]

Well identifier	Compound (Regulated or unregulated)	Source-water concentration (µg/L)	Finished-water concentration (non-blended and blended) (µg/L)
49X 10	Dibromochloromomethane	--	1.109
CL Bd 179	Dibromochloromomethane	--	0.183
FR Dc 69	Dibromochloromomethane	--	0.511
FR Ef 54	Dibromochloromomethane	--	0.431
FR Eg 36	Dibromochloromomethane	0.433	0.397
FR Eg 37	Dibromochloromomethane	--	0.206
49X 10	Deisopropyl ether	0.165	0.148
CL Bd 180	Deisopropyl ether	E 0.044	E 0.051
FR Ef 54	Ethylbenzene	--	E 0.023
FR Ef 54	Isopropylbenzene	E 0.007	--
FR Ef 54	<i>m</i> - and <i>p</i> -Xylene	--	E 0.085
49X 10	Methyl tert-butyl ether	0.583	0.540
49X 11	Methyl tert-butyl ether	0.752	1.076
CL Bd 179	Methyl tert-butyl ether	0.329	0.292
CL Bd 180	Methyl tert-butyl ether	2.671	2.565
FR Dc 62	Methyl tert-butyl ether	--	E 0.084
FR Dc 69	Methyl tert-butyl ether	E 0.058	E 0.058
FR Eg 36	Methyl tert-butyl ether	E 0.161	E 0.152
FR Eg 37	Methyl tert-butyl ether	0.193	0.193
CL Bd 179	Methylene chloride	--	E 0.019
FR Ef 54	<i>o</i> -Xylene	--	E 0.027
49X 10	tert-Amyl methyl ether	E 0.087	E 0.081
CL Bd 180	tert-Amyl methyl ether	0.231	0.212
49X 10	Tetrachloroethene	E 0.020	E 0.020
CL Bd 179	Tetrachloroethene	E 0.015	E 0.013
FR Dc 62	Tetrachloroethene	E 0.037	--
FR Dc 69	Tetrahydrofuran	E 1.096	--
49X 10	Trichloroethene	E 0.041	E 0.035
49X 11	Trichloroethene	E 0.094	--
Pesticides			
49X 10	2-Hydroxyatrazine	E 0.017	E 0.021
FR Dc 62	2-Hydroxyatrazine	E 0.005	E 0.005
FR Dc 69	2-Hydroxyatrazine	E 0.015	E 0.014
FR Ef 54	2-Hydroxyatrazine	E 0.016	E 0.020
49X 10	Acetochlor ESA	0.090	0.080
49X 10	Acetochlor/Metolachlor ESA—second amide	--	0.120
49X 10	Actochlor OA	0.140	0.120
FR Ef 54	Alachlor ESA—second Amide	0.070	0.040
FR Eg 36	Alachlor ESA—second Amide	--	0.020
49X 10	Alachlor OA	0.120	0.100

Appendix A. Comparison between source water and associated finished water (non-blended and blended) for detected anthropogenic organic compounds in community water-supply systems in the Piedmont Physiographic Province, Potomac River Basin, Maryland and Virginia, 2004.—Continued

[E, estimated value; --, no detection; µg/L, micrograms per liter; **red type** indicates blended water; **Bold type** under compound heading indicates “unregulated,” a compound that has no Federal and (or) State drinking-water standard; ESA, ethanesulfonic acid; OA, oxanilic acid.]

Well identifier	Compound (Regulated or unregulated)	Source-water concentration (µg/L)	Finished-water concentration (non-blended and blended) (µg/L)
FR Ef 54	Alachlor OA	0.020	0.020
FR Eg 36	Alachlor OA	0.840	0.750
49X 10	Alachlor ESA	0.060	0.050
49X 11	Alachlor ESA	0.030	--
FR Ef 54	Alachlor ESA	0.680	0.470
FR Eg 36	Alachlor ESA	0.330	0.290
49X 10	Atrazine	0.230	0.203
49X 11	Atrazine	0.013	--
FR Dc 62	Atrazine	0.053	0.050
FR Dc 69	Atrazine	0.074	0.060
FR Ef 54	Atrazine	0.106	0.108
FR Eg 36	Atrazine	0.066	0.060
49X 10	Benomyl	E 0.026	E 0.026
FR Eg 36	Benomyl	E 0.005	E 0.008
49X 10	Bentazon	E 0.748	E 0.370
49X 10	Deethylatrazine	0.048	0.040
49X 11	Deethylatrazine	0.049	--
FR Dc 62	Deethylatrazine	0.129	0.111
FR Dc 69	Deethylatrazine	E 0.129	E 0.087
FR Ef 54	Deethylatrazine	E 0.146	E 0.073
FR Eg 36	Deethylatrazine	E 0.024	0.078
FR Dc 62	Deethyldeisopropylatrazine	E 0.027	--
FR Dc 69	Deethyldeisopropylatrazine	E 0.029	--
49X 10	Deisopropylatrazine	E 0.053	E .042
49X 11	Deisopropylatrazine	E 0.010	--
FR Dc 62	Deisopropylatrazine	E 0.022	E 0.016
FR Dc 69	Deisopropylatrazine	E 0.009	--
FR Ef 54	Deisopropylatrazine	E 0.138	E 0.058
FR Eg 36	Deisopropylatrazine	E 0.016	E 0.030
49X 10	Flumetsulam	E 0.122	E 0.098
FR Ef 54	Flumetsulam	--	E 0.046
FR Eg 36	Imazethapyr	--	E 0.042
FR Ef 54	Metolachlor	E 0.004	E 0.005
49X 10	Metolachlor ESA	2.570	2.150
49X 11	Metolachlor ESA	0.960	--
FR Dc 62	Metolachlor ESA	0.230	0.250
FR Ef 54	Metolachlor ESA	3.950	2.890
FR Eg 36	Metolachlor ESA	1.040	0.860
49X 10	Metolachlor OA	3.770	2.990
49X 11	Metolachlor OA	0.020	--

Appendix A. Comparison between source water and associated finished water (non-blended and blended) for detected anthropogenic organic compounds in community water-supply systems in the Piedmont Physiographic Province, Potomac River Basin, Maryland and Virginia, 2004.—Continued

[E, estimated value; --, no detection; µg/L, micrograms per liter; **red type** indicates blended water; **Bold type** under compound heading indicates “unregulated,” a compound that has no Federal and (or) State drinking-water standard; ESA, ethanesulfonic acid; OA, oxanilic acid.]

Well identifier	Compound (Regulated or unregulated)	Source-water concentration (µg/L)	Finished-water concentration (non-blended and blended) (µg/L)
FR Ef 54	Metolachlor OA	0.460	0.450
FR Eg 36	Metolachlor OA	0.720	0.630
49X 10	Metsulfuron methyl	--	E 0.053
FR Ef 54	Metsulfuron methyl	--	E 0.105
FR Eg 36	Metsulfuron methyl	--	E 0.031
FR Dc 69	Nicosulfuron	E 0.006	--
FR Eg 36	Picloram	--	0.151
FR Ef 54	Simazine	0.047	0.044
49X 10	Tebuthiuron	E 0.020	E 0.018
49X 10	Terbacil	E 0.023	--
FR Eg 36	Triclopyr	0.032	0.026
Other Anthropogenic Organic Compounds			
FR Ef 54	4-octylphenol diethoxylate	E 0.070	--
FR Ef 54	4-octylphenol monoethoxylate	E 0.320	--

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