

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

Anthropogenic Organic Compounds in Ground Water and Finished Water of Community Water Systems in the Greater Twin Cities Metropolitan Area, Minnesota and Wisconsin, 2004–05



Scientific Investigations Report 2007–5273

Cover. Photograph shows a pump house for a municipal well that is typical for wells sampled for this study. Photograph by Michael Menheer, U.S. Geological Survey, 2005

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By Lan H. Tornes, James R. Stark, Christopher J. Hoard, and Erik A. Smith

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

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Foreword

The U.S. Geological Survey (USGS) is committed to providing the Nation with credible 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, now measured in terms of quantity and quality, even more essential to the long-term sustainability of our communities and ecosystems.

The USGS implemented the National Water-Quality Assessment (NAWQA) Program in 1991 to support national, regional, 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 condition of our Nation's streams and ground water? How are conditions changing over time? How do natural features and human activities affect the quality of streams and ground water, and where are those effects most pronounced? By combining information on water chemistry, physical characteristics, stream habitat, and aquatic life, the NAWQA Program aims to provide science-based insights for current and emerging water issues and priorities. From 1991–2001, 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>).

Multiple national and regional assessments are ongoing in the second decade (2001–2012) of the NAWQA Program as 42 of the 51 Study Units are reassessed. These assessments extend the findings in the Study Units by determining 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 ground water. 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 topics 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. These topical studies are conducted in those Study Units most affected by these issues; they comprise a set of multi-Study-Unit designs for systematic national assessment. In addition, national syntheses of information on pesticides, volatile organic compounds (VOCs), nutrients, selected 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.

Robert M. Hirsch
Associate Director for Water

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Conversion Factors

Multiply	By	To obtain
Length		
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Area		
square mile (mi ²)	259.0	hectare (ha)
square mile (mi ²)	2.590	square kilometer (km ²)
Volume		
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m ³)
gallon (gal)	3.785	cubic decimeter (dm ³)
Flow rate		
gallon per day (gal/d)	0.003785	cubic meter per day (m ³ /d)
inch per year (in/yr)	25.4	millimeter per year (mm/yr)

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Concentrations of chemical constituents in water are given in micrograms per liter (µg/L).

Fiscal year is the accounting period of the Federal government. It begins on October 1 and ends on September 30 of the next calendar year.

Abbreviations and Acronyms

<	less than
µg/L	microgram per liter
AHTN	acetyl hexamethyl tetrahydronaphthalene
AOC	anthropogenic organic compound
BGD	billion gallons per day
BHA	3- <i>tert</i> -butyl-4-hydroxy anisole
BQ	benchmark quotient
BQ _{max}	ratio of the maximum concentration to a drinking-water benchmark (benchmark quotient)
CASR	Chemical Abstract Services Registry
CAAT	chlordiamino- <i>s</i> -triazine
CEAT	2-chloro-6-ethylamino-4-amino- <i>s</i> -triazine
CIAT	2-chloro-4-isopropylamino-6-amino- <i>s</i> -triazine
CCRs	Consumer Confidence Reports
CWSs	community water systems
DBP	disinfection by-product
DOC	dissolved organic carbon
E	estimated value
ESA	ethanesulfonic acid
HHCB	hexahydrohexamethylcyclopentabenzopyran
HBSL	Health-Based Screening Level
MRL	minimum reporting level
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MTBE	methyl <i>tert</i> -butyl ether
NAWQA	National Water-Quality Assessment
NJDEP	New Jersey Department of Environmental Protection
NWQL	National Water Quality Laboratory
OA	oxanilic acid
OHSU	Oregon Health & Science University
QA/QC	quality assurance and quality control
OIET	2-hydroxy-4-isopropylamino-6-ethylamino- <i>s</i> -triazine
SA	second amide
SWQAs	Source Water-Quality Assessments
TCEP	tris(2-chloroethyl)phosphate
TCMA	Twin Cities metropolitan area
TCPP	tris(dichloroisopropyl)phosphate
UMIS	Upper Mississippi River Basin Study Unit
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VOC	volatile organic compound

Definitions

Benchmark quotient (BQ)	Ratio of the concentration of a contaminant to its Maximum Contaminant Level (MCL) for a regulated compound or to its Health-Based Screening Level (HBSL) value for an unregulated compound. BQs greater than 1.0 identify concentrations of potential concern. BQs greater than 0.1 identify compounds that may warrant inclusion in a low-concentration, trends-monitoring program.
BQ _{max}	Maximum benchmark quotient, which is the ratio of the maximum concentration of a contaminant to its MCL or HBSL.
Blended water	As used in this report, finished water that has been blended with one or more different ground waters. Finished water blended with surface water was not sampled as part of this study.
Concentration of human-health concern	As used in this report: (1) for a regulated compound with a U.S. Environmental Protection Agency (USEPA) drinking-water standard, a concentration greater than the Maximum Contaminant Level; and (2) for an unregulated compound, a concentration greater than the Health-Based Screening Level.
Community water system (CWS)	A public water system with 15 or more connections and serving 25 or more year-round residents and thus subject to USEPA regulations enforcing the Safe Drinking Water Act. A CWS serves a residential population, such as a municipality, mobile-home park, or nursing home.
Drinking-water guideline	As used in this report, a concentration that has no regulatory status but is issued in an advisory capacity by USEPA or State agencies.
Drinking-water standard	As used in this report, a concentration that is legally enforceable (such as MCLs) by 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)	An estimate of a concentration (for a noncarcinogen) or concentration range (for a carcinogen) in water that (1) may be of human-health concern; (2) can be used as a value against which measured concentrations of contaminants in water samples can be compared; and (3) is consistent with USEPA Office of Water methodologies.
Human-health benchmarks	As used in this report, these include USEPA MCL values and HBSL values developed collaboratively by the U.S. Geological Survey, USEPA, New Jersey Department of Environmental Protection, and Oregon Health & Science University.
Maximum Contaminant Level (MCL)	As used in this report, a USEPA drinking-water standard that is legally enforceable and that sets the maximum permissible concentration 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.
Regulated compound	As used in this report, a compound for which a Federal and (or) State drinking-water standard has been established.
Source water	The raw (ambient) water collected at the supply well or surface-water intake prior to water treatment used to produce 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 Ground Water and Finished Water of Community Water Systems in the Greater Twin Cities Metropolitan Area, Minnesota and Wisconsin, 2004–05

By Lan H. Tornes, James R. Stark, Christopher J. Hoard, and Erik A. Smith

Abstract

As part of the U.S. Geological Survey's National Water-Quality Assessment (NAWQA) Program, two Source Water-Quality Assessments (SWQAs) were conducted during 2004–05 in unconfined parts of the glacial aquifer system and in unconfined parts of the Prairie du Chien-Jordan aquifer in the Greater Twin Cities metropolitan area of Minnesota and Wisconsin. SWQAs are two-phased sampling activities in the NAWQA Program. The first phase evaluated the occurrence of 265 (258 are included in this report) anthropogenic organic compounds (AOCs) through monitoring source water in 30 of the largest-producing community water system wells completed in the aquifers underlying the Greater Twin Cities metropolitan area. The AOCs included volatile organic compounds (VOCs), pesticides, and other AOCs. During the second phase of the study, 15 of the original community water system wells, those with the greatest number of AOC detections, were resampled along with associated finished water.

Results from the first phase of sampling indicated that 40 AOCs were detected, and 83 percent of the samples had at least one detected AOC. Concentrations of AOCs detected in the source water generally were low (defined in this report as concentrations less than 1.0 microgram per liter). Human-health benchmarks for these compounds (Maximum Contaminant Levels for regulated compounds or Health-Based Screening Levels for unregulated compounds, when they existed) typically were not exceeded. Fifteen VOCs were detected in the source-water samples. However, concentrations were low. Seventeen pesticide compounds were detected generally at concentrations less than concentrations for VOCs. Most of the pesticide compounds detected were triazine- or alachlor-parent compounds or their breakdown products. Eight other AOCs were detected in the source-water samples but generally at low concentrations.

Results from the second phase of sampling indicated a total of 13 and 12 VOCs were detected in source-water and in finished-water samples, respectively. Most of the VOCs, except for those associated with disinfection by-products, were detected more frequently in source-water samples than in finished-water samples. Concentrations of most VOCs detected in either source water or finished water were less than human-health benchmarks. Twenty-one pesticide compounds were detected in either source water or finished water. Concentrations of detected pesticides in source-water and finished-water samples were low. The most frequently detected compounds in both the source and finished water were triazine-parent pesticides or their breakdown products and breakdown products of alachlor and metolachlor. In general, pesticides, if detected in source water, also were detected in the corresponding finished water. Concentrations of pesticides detected were less than human-health benchmarks in both source and finished water. A total of nine other AOCs were detected in the source-water or finished-water samples, and about the same number of compounds was detected in each of the sample groups in either source water or finished water. Detected concentrations of other AOCs were low.

Water-quality results from source-water samples were compared to characterize differences between aquifers. VOC and other AOC detections were more frequent in water from the Prairie du Chien-Jordan aquifer compared to the glacial aquifer. Pesticides, however, were detected more frequently in the glacial aquifer. On the basis of study results, the hydrogeologic setting, land use, and aquifer productivity are important in explaining the occurrence of AOCs in community water system wells. Results of this study indicate that monitoring for pesticides in source water generally indicates the potential occurrence of pesticides in finished water but that this is not necessarily true of VOCs. Additional monitoring is needed to better understand the occurrence of other AOCs in source and finished waters.

Introduction

In 1991, the U.S. Geological Survey (USGS) began the National Water-Quality Assessment (NAWQA) Program to (1) provide a nationally consistent description of current water-quality conditions for the largest and most important river basins and aquifers across the Nation; (2) define long-term trends in water quality; and (3) identify, describe, and explain major factors that affect observed water-quality conditions and trends (fig. 1). This information was intended to allow water managers, policymakers, and the public to address and prioritize issues related to managing and protecting the Nation's water resources.

During the initial period of data collection (1995–98) in the Upper Mississippi River Basin NAWQA Study Unit (UMIS), water quality was measured in hundreds of ground-water and surface-water samples (Stark and others, 2001). These samples represented water quality in different environmental media and at various spatial and temporal scales. Samples included ground water, stream water, streambed sediment, fish tissue, and aquatic biology. To develop an integrated assessment, data were analyzed in various combinations

and interpreted in relation to natural and human factors that can affect water quality. The most significant contaminants detected in ground water and surface water included nutrients, pesticides, and volatile organic compounds (VOCs) (Stark and others, 2001). This intensive phase of data collection was an initial step in a long-term integrated water-quality assessment.

In 2001, NAWQA began a second period of intensive assessments by returning to 42 of the Study Units studied during the first decade. These assessments built on the initial assessments by establishing links between sources, transport, and effects of contaminants on humans and aquatic ecosystems. One of the second-phase activities involved characterizing the quality of major aquifers and rivers used as sources of water to large community water systems (CWSs). Previous NAWQA studies had focused on ambient (present conditions of untreated water) water quality rather than on the quality of water used as sources of drinking water (source water) or on water treated for delivery to the public (finished water). The new Source Water-Quality Assessments (SWQAs) begun during the second phase complement drinking-water monitoring required by Federal, State, and local programs that focused primarily on post-treatment compliance monitoring.

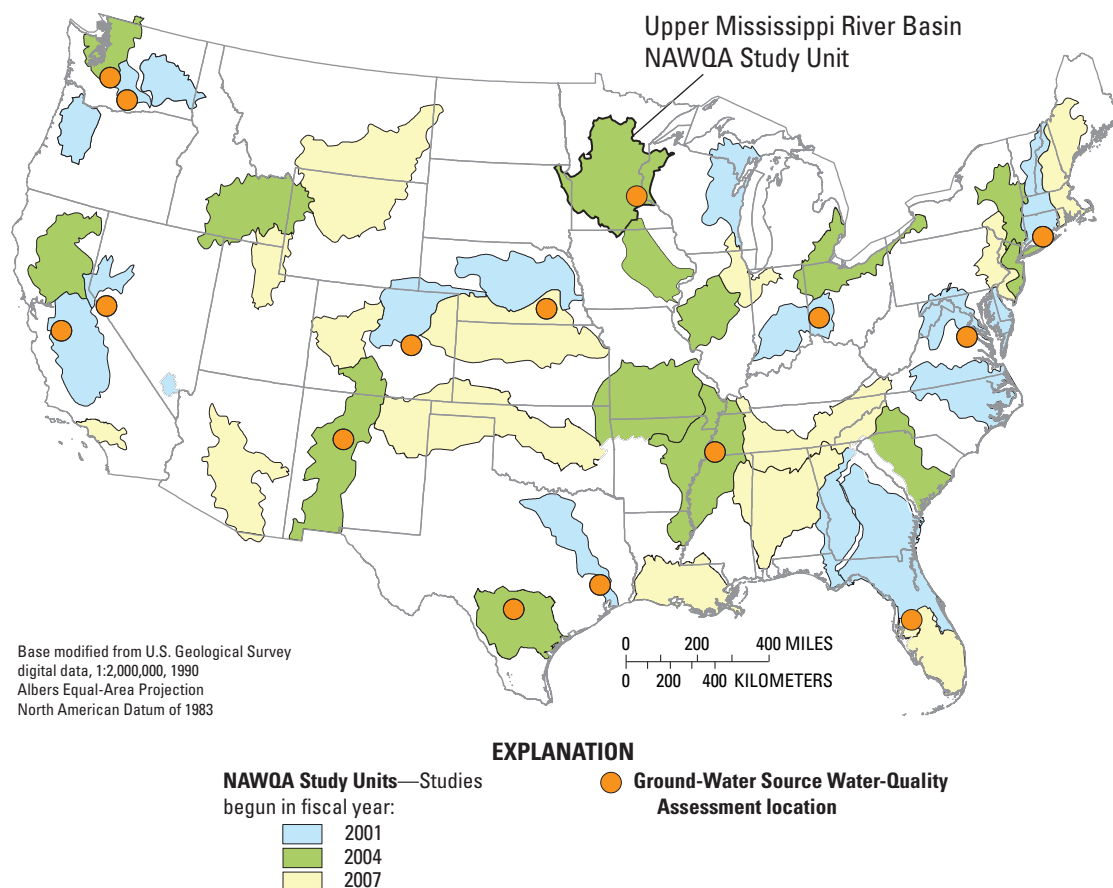


Figure 1. Location of National Water-Quality Assessment (NAWQA) Study Units and Ground-Water Source Water-Quality Assessments in contiguous United States.

Purpose and Scope

This report describes the occurrence of anthropogenic organic compounds (AOCs) in ground-water source water as well as the occurrence of selected AOCs in a subset of associated finished water during 2004–05. The report summarizes results from ground-water SWQAs of two important water-supply aquifers in the unconfined part of the glacial aquifer system and the unconfined part of the Prairie du Chien-Jordan aquifer system that underlie the Greater Twin Cities metropolitan area (TCMA) in Minnesota and Wisconsin. The aquifers are considered susceptible to anthropogenic contamination because of their direct hydraulic connection with the land surface. The glacial aquifer system, as used in this report, refers to unconfined, coarse-grained glacial deposits that yield water to wells. These deposits are part of the glacial aquifer system as defined by the NAWQA Program for the Nation. The term “system” does not imply that there is a good hydrologic connection between individual wells completed in the glacial aquifer system. For this report, wells sampled from the glacial aquifer system (termed glacial aquifer in this report) were selected from parts of the aquifer system that are unconfined.

Water-quality samples were collected and analyzed from a random selection of 30 of the largest CWS wells completed in unconfined parts of the glacial aquifer and the Prairie du Chien-Jordan aquifer. Results are compared to human-health benchmarks, which consist of U.S. Environmental Protection Agency (USEPA) Maximum Contaminant Levels (MCLs) and Health-Based Screening Levels (HBSLs) (U.S. Environmental Protection Agency, 2002).

AOCs analyzed included VOCs, pesticides, and other AOCs (Appendixes 1, 2, and 3). VOCs are a subset of organic chemicals that have been produced and used in commercial, industrial, and household applications. Pesticides are used extensively throughout the Nation to increase crop yields, to enhance the aesthetics of lawns, gardens, golf courses, and recreational areas, and to protect crops and the public from insects. The widespread use of pesticides over the past several decades has led to their frequent detection in ground water (Barbash and Resek, 1996). Other AOCs represent a select group of compounds that are present in a wide variety of products commonly used in homes, industry, and agriculture, including personal-care and domestic-use products, plant- or animal-derived biochemicals, and fumigants, for which analytical methods are available. Little is known about the environmental occurrence, transport, and ultimate fate of other AOCs after their use. However, it is known that these compounds often are released directly to the environment after passing through wastewater treatment plants or domestic septic systems, which often are not designed to remove these compounds from the effluent (Herberer, 2002; Ternes and others, 2002). Until recently, few analytical methods were capable of detecting these compounds at the low concentra-

tions expected in the environment. Linking ground-water source water and finished water from CWSs to ambient water-quality data and to drinking-water monitoring required by Federal, State, and local programs is important, considering the documented occurrence of organic contaminants in finished water at concentrations similar to those found in source water (Stackelberg and others, 2004; Westerhoff and others, 2005; Loraine and Pettigrove, 2006).

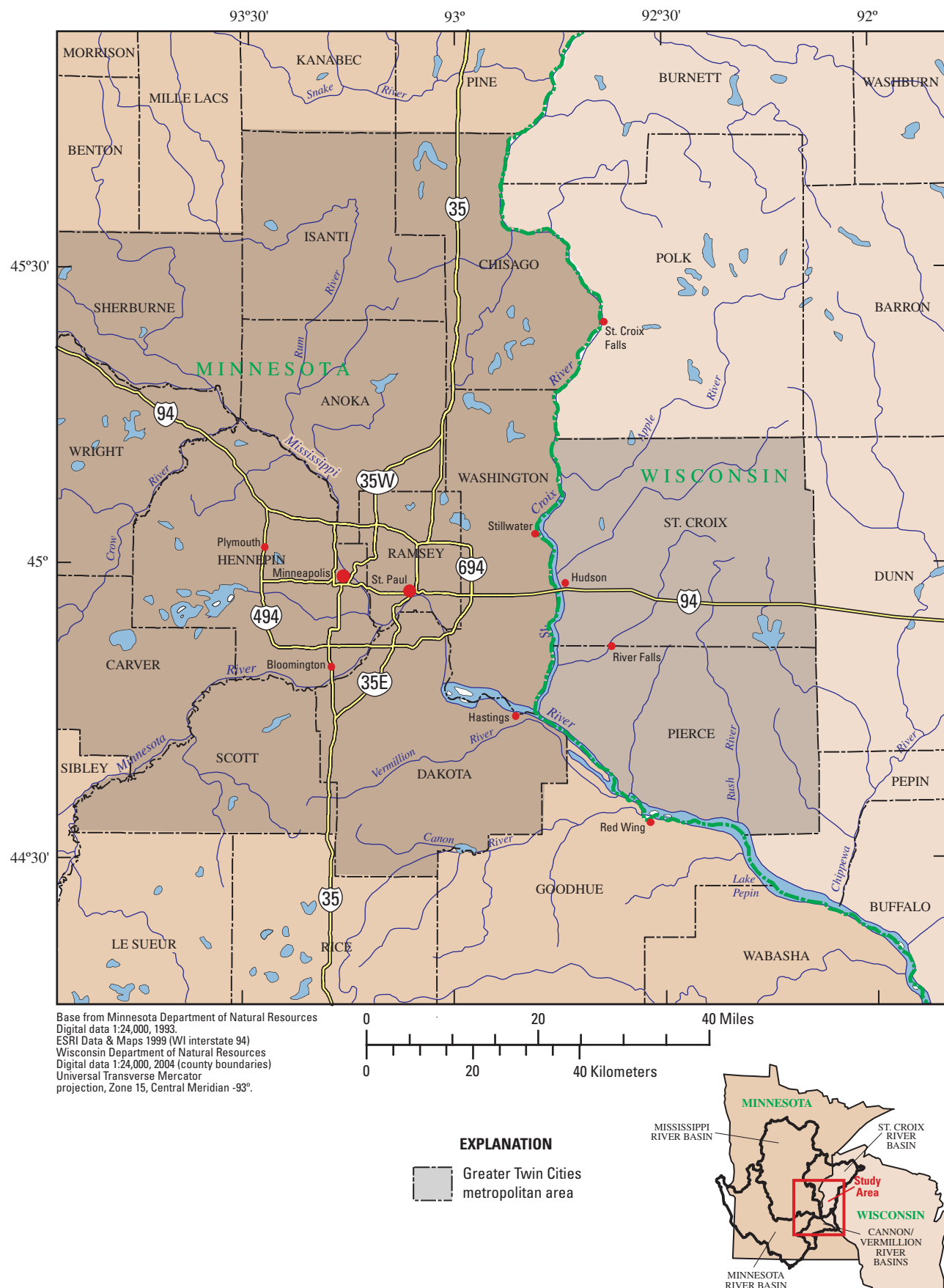
Acknowledgments

The authors are grateful to staff from the participating municipalities for providing information pertaining to the wells used for this study and for permitting the collection of samples. The authors also express appreciation for technical assistance from Bruce Olsen and other staff from the Minnesota Department of Health and thank the following USGS employees for their help with data collection and compilation: Allan Arntson (retired), Robert Borgstede (retired), Timothy Cowdery, Gregory Delzer, Landon Gryczkowski, Michael Menheer, Thomas Reppe, Chris Sanocki, and Greg Stratton (retired).

Description of Study Area

The study area (fig. 2) covers approximately 11,000 mi² and includes parts of the TCMA. The study area is part of the 47,000-mi² UMIS Study Unit that includes the Mississippi River Basin upstream from Lake Pepin and the tributary basins of the Minnesota and St. Croix Rivers. Ground-water quality in the study area is affected by natural and human factors (precipitation, evaporation, geology, drainage, population density, and land use). The environmental and hydrologic setting of the study area is complex, and natural and human factors, in addition to ground-water withdrawals from wells, affect the areal distribution and flow of ground water and the distribution and concentration of water-quality constituents in the aquifers.

The environmental setting of the study area is described in detail by Stark and others (1996). The TCMA consists of 13 counties located in both Minnesota and Wisconsin. The counties are Anoka, Carver, Chisago, Dakota, Hennepin, Isanti, Ramsey, Scott, Sherburne, Washington, and Wright in Minnesota and Pierce and St. Croix in Wisconsin. Increased urbanization of the study area has resulted in substantial land-use change. The TCMA, which includes most of the population of the study area, is the 15th largest metropolitan area in the Nation according to population figures from the last two censuses. The area grew by 16.9 percent from 2,538,834 in 1990 to 2,968,806 in 2000 (Minnesota State Demographic Center, 2002). The most significant ground-water-quality concerns in the study area are related to nutrients, pesticides, and VOCs (Stark and others, 2001).



Hydrogeologic units (fig. 3), integral parts of the hydrologic setting, underlie the study area and consist of glacial till and glacial sand and gravel of Quaternary age and underlying sandstone, shale, and carbonate rocks of Paleozoic and Precambrian age. The uppermost unconsolidated deposits consist of sand and gravel of Quaternary age. (Norvitch and others, 1973; Bloomgren and others, 1989; Meyer and Hobbs, 1989; Meyer, 1993; Andrews and others, 1998). Sand and gravel deposits of the surficial glacial aquifer commonly are overlain or underlain by sandy to clayey glacial till (fig. 4). Ground water in the glacial aquifer generally flows toward the Mississippi River or to its tributaries (Kanivetsky, 1989; Palen and others, 1989). Within the aquifer, the water table generally is within 20 ft of land surface (Helgesen and Lindholm, 1977). Estimated recharge to the aquifer can be as great as 11 in/yr based on analyses of hydrographs of water levels in shallow wells. The surficial part of the aquifer is highly susceptible to contamination from activities at the land surface (Piegat, 1989; Meyer, 1993).

Quaternary deposits are underlain by as much as 1,000 ft of sedimentary rock of Cretaceous through Cambrian age (fig. 3). These sedimentary rocks are, in turn, underlain by “basement” rocks (metamorphic and igneous) of Precambrian age. The primary bedrock aquifer underlying the study area is the Prairie du Chien-Jordan aquifer (fig. 5). The aquifer consists of fractured sandy dolomite (Prairie du Chien Group of Ordovician age) and underlying quartz sandstone (Jordan Sandstone of Cambrian age) (Setterholm and others, 1991). The Prairie du Chien Group of rocks is karstic, and ground water flows mainly through joints, fractures, and solution cavities. Flow in the Jordan Sandstone is primarily through intergranular pore spaces and joint partings (Delin and Woodward, 1984). The Prairie du Chien Group and the Jordan Sandstone are in good hydraulic connection and have traditionally been considered a single aquifer although recent research indicates that the aquifers are less hydraulically well connected in some areas (Delin and Woodward, 1984; Young, 1992a, 1992b; Tipping and others, 2006). In some areas, the aquifer is in good hydraulic connection with the overlying glacial deposits, especially through flow in glacial valleys cut into the bedrock, and later filled with glacial sand and gravel. Ground water in the aquifer generally flows toward major rivers.

Public water suppliers in the study area rely on ground water and on the Mississippi River. Ground water is particularly important in the suburbs of Minneapolis and St. Paul. More than 276 public-supply wells are permitted for use within the study area (A.D. Arntson, U.S. Geological Survey, oral commun., 2006). These wells are publicly owned, and source water generally is treated prior to distribution. In 2003, approximately 1.45 billion gallons per day (BGD) of ground water were withdrawn from the study area. Figure 6 shows a typical pump house and well where water is disinfected at the well before being distributed.

Methods

Wells sampled were selected at random from the largest producing CWS wells (upper 25th percentile of pumping volume) completed in the unconfined parts of each of the two aquifers (figs. 4 and 5). Because of this random selection, the wells generally represent the variability in hydrogeology and land use and land cover across the study area. As used in this report, source water is the untreated (ambient) water from a supply well prior to water treatment, blended water is a mixture of water from several wells, and finished water is the source water or blended water that is treated and delivered to consumers. Individual well names and locations are not included in this report to protect the security of these wells. The wells are approximately located on figures in this report.

Fifteen wells were selected from unconfined parts of the glacial aquifer, and 15 wells were selected from unconfined parts of the Prairie du Chien-Jordan aquifer (figs. 4 and 5). Wells were selected at random from the upper 25th percentile of pumping volume while maintaining a minimum distance of 0.62 mi (1 kilometer) between sampled wells. The initial sampling occurred during November and December 2004. The second phase of sampling in 2005 focused on wells where AOCs were detected most frequently during the first phase. The second phase evaluated the occurrence of these compounds in source water and associated finished water. During the second phase, samples of source water were obtained from 15 wells. Samples of finished waters were obtained at 14 sites (figs. 4 and 5) because two of the wells were in the same municipality and had potential to be blended, depending on pumping schedules, prior to the point where the finished water could be sampled. Chemical compounds analyzed varied among sites based on results from the first phase of sampling.

Ground-water samples were collected using established USGS and USGS-NAWQA protocols described in the USGS “National Field Manual for the Collection of Water-Quality Data” available at <http://water.usgs.gov/owq/FieldManual/> (last accessed on February 14, 2007). Additional sample-collection and processing information can be found in Koterba and others (1995) and Menheer and Brigham (1997). Finished-water samples were collected after treatment and prior to the entry to transport pipelines. Finished-water samples typically contain free chlorine, which has been documented to degrade certain organic compounds that may be present in the water samples. Therefore, a dechlorination reagent (ascorbic acid) and, for certain contaminant groups, pH buffers, were added to finished-water samples during sample collection to stabilize them prior to analyses. The addition of dechlorination reagents to water samples has been tested in a laboratory setting, and results indicated that they do not interfere with the analytical performance (Sandstrom and Delzer, 2007).

ERATHEM	SYSTEM OR SERIES	FORMATION OR GROUP		THICKNESS (IN FEET)	GENERAL LITHOLOGY	HYDROGEOLOGIC UNIT	
		MINNESOTA	WISCONSIN			MINNESOTA	WISCONSIN
CENOZOIC	QUATERNARY	Glacial deposits	Glacial deposits	0-450		Surficial sand and gravel aquifer, till and clay confining unit, and buried sand and gravel aquifer	Surficial sand and gravel aquifer, till and clay confining unit, and buried sand and gravel aquifer
MESOZOIC	CRETACEOUS	Carlisle Shale Greenhorn Fm. Graneros Shale Dakota Fm.	--	0-500		Cretaceous aquifer	--
PALEOZOIC	ORDOVICIAN	Cedar Valley Formation	--	0-50?		Upper carbonate aquifer	Devonian aquifer
		Maquoketa Shale	--	0-50?			Maquoketa shale confining unit
		Galena Dolomite	Galena Dolomite	0-110?		Decorah-Platteville-Glenwood confining unit	Galena-Platteville aquifer
		Decorah Shale	--	0-90			
		Platteville Formation	Platteville Formation	0-30			
		Glenwood Formation	Glenwood Formation	0-16			Glenwood confining unit
		St. Peter Sandstone	St. Peter Sandstone	0-130		St. Peter aquifer	St. Peter aquifer
				0-65		Basal St. Peter confining unit	
		Prairie du Chien Group	Prairie du Chien Group	0-335		Prairie du Chien-Jordan aquifer	Prairie du Chien-Trempealeau aquifer
	CAMBRIAN	Jordan Sandstone	Trempealeau Formation	0-130		St. Lawrence confining unit	St. Lawrence confining unit
		St. Lawrence Formation	St. Lawrence Formation	0-70			
		Franconia Formation	Franconia Sandstone	0-200		Franconia-Ironton-Galesville aquifer	Tunnel City-Wonewoc-Eau Claire aquifer
		Ironton Sandstone	Wonewoc Formation	0-100			
		Galesville Sandstone				Eau Claire confining unit	
		Eau Claire Formation	Eau Claire Sandstone	0-200			
		Mount Simon Sandstone	Mt. Simon Sandstone	0-200		Mt. Simon-Hinckley-Fond du Lac aquifer	Mt. Simon-Hinckley-Fond du Lac aquifer
	PRECAMBRIAN	Hinckley Sandstone	Bayfield Group	0-650			
		Fond du Lac Formation				Undifferentiated Precambrian sandstone aquifer	Undifferentiated Precambrian sandstone aquifer
		Solor Church Formation	Oronto Group	0-1,100			
		Igneous/metamorphic rocks	Igneous/metamorphic rocks	UP TO 20,000		Precambrian igneous/metamorphic aquifers	Precambrian igneous/metamorphic aquifers

EXPLANATION OF GENERAL LITHOLOGY

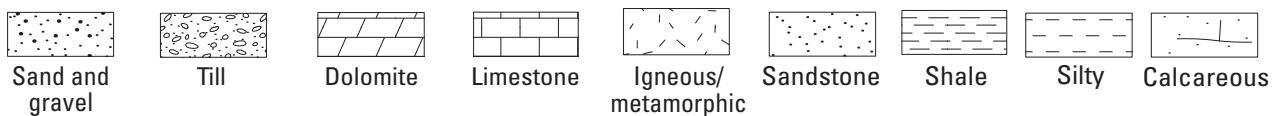


Figure 3. Generalized hydrogeologic column showing aquifers and confining units in the Upper Mississippi River Basin Study Unit (modified from Green, 1977; Delin and Woodward, 1984; Olcott, 1992).

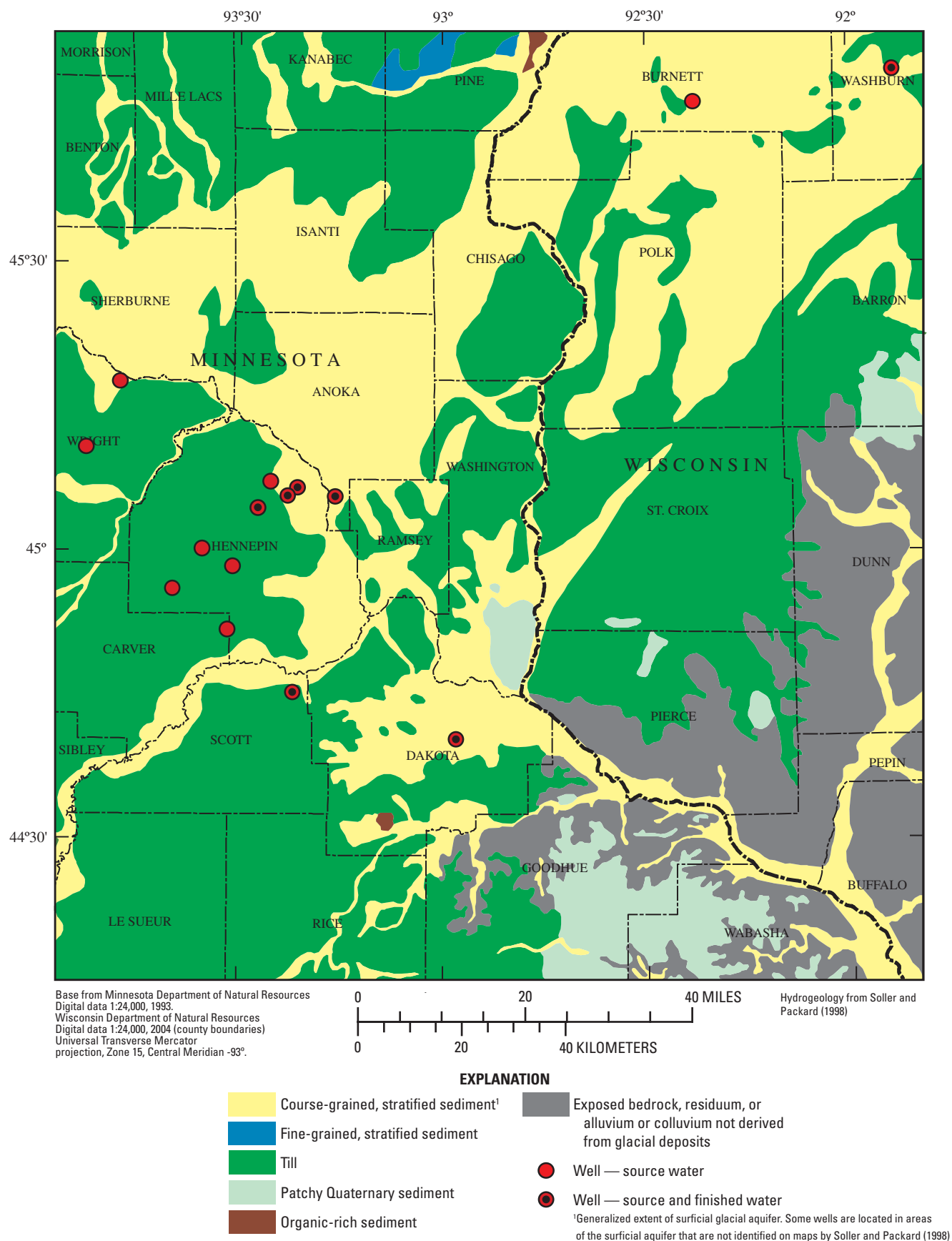


Figure 4. Surficial glacial aquifer and wells sampled in study area, 2004–05.

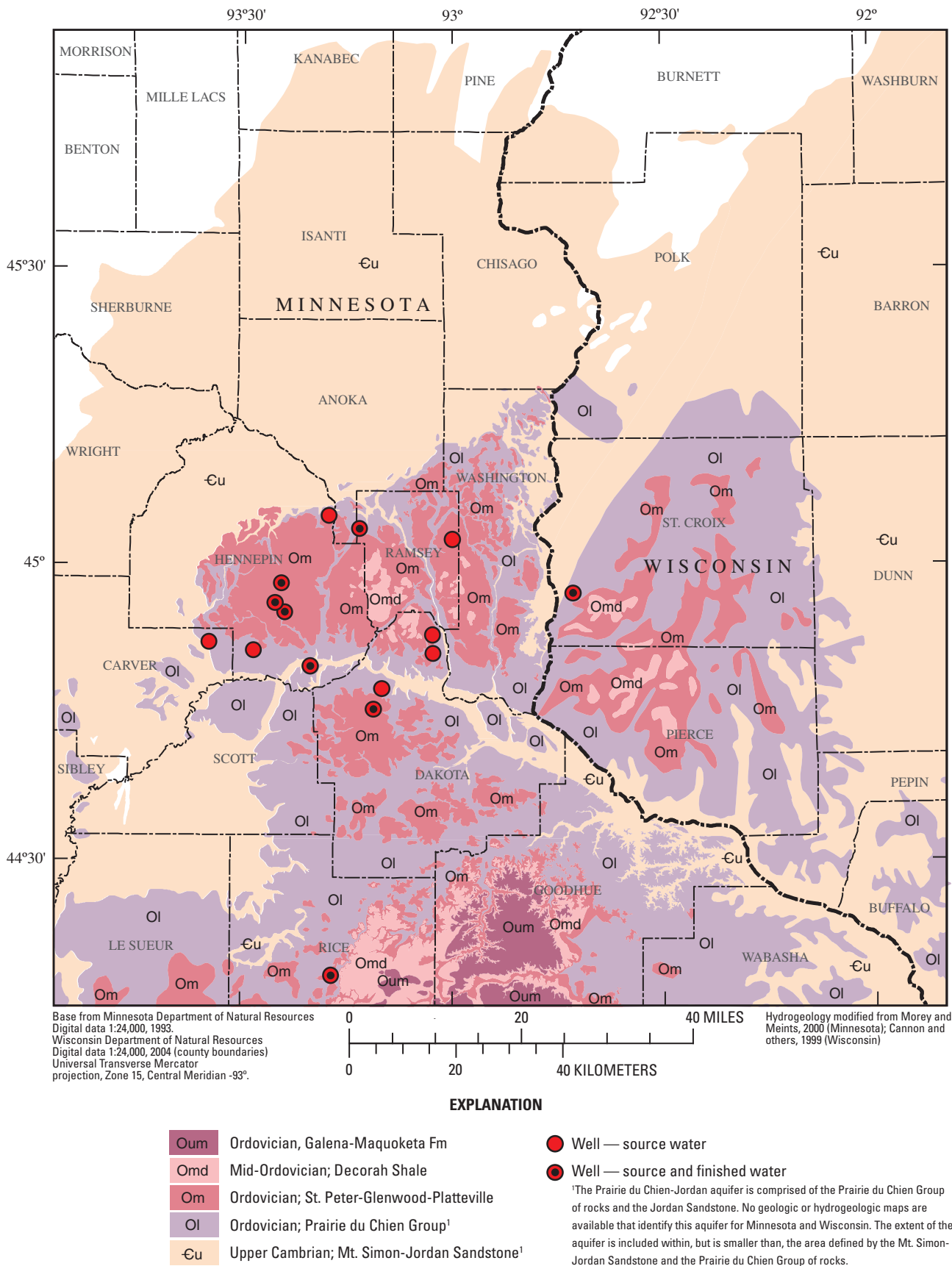


Figure 5. Extent of unconfined Prairie du Chien-Jordan aquifer and wells samples in study area, 2004–05.

Most samples were analyzed at the USGS National Water Quality Laboratory (NWQL) in Lakewood, Colorado. For documentation pertaining to the analytical methods see 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). Pesticide metabolites were analyzed at the USGS Organic Geochemistry Research Laboratory in Lawrence, Kansas. The methods used are documented in Lee and Strahan (2003). Analytical results of samples are reported by Carter and others (2007).

The constituents are described in this report by the group the constituent belonged to (VOCs, pesticides, or other AOCs). Within each group, the individual constituents are sorted by the total number of detections. The constituents detected in source water are ranked in descending order with the highest number of detections at the top and the lowest number of detections at the bottom (table 1). In table 2, the constituents are placed in their respective groups, and constituents with

the highest number of detections, in both finished and source waters, are placed first, followed by constituents detected only in finished waters, then by constituents detected only in source waters.

Analytical results in this report are sometimes censored; that is, they are qualified with a less than (<) symbol. A “<” symbol means that the compound was not detected but may be present at a concentration below the level at which a concentration can be accurately reported. These censoring limits are developed over time and are subject to change as analytical refinements are made. Another qualifier is an “E” to designate an estimated value. This frequently is applied when interferences or degradation during analysis results in uncertain recoveries so that the reported value has a large degree of uncertainty. An “E” qualifier also may be applied when the presence of a compound is identified at a concentration below the reporting level, but it is not in the range where the value provided by the analysis instrument is considered reliable and able to be confirmed by multiple lines of evidence.



Figure 6. Example of a pump house and well where water is disinfected at the well before being distributed (photographs by Michael Menheer, U.S. Geological Survey, 2005).

10 Organic Compounds in Community Ground-Water Systems, Twin Cities Area, Minnesota and Wisconsin

Table 1. Maximum concentrations, detection frequencies, and maximum benchmark quotients for compounds detected in source water from community water systems in studied aquifers in the Greater Twin Cities metropolitan area, Minnesota and Wisconsin, 2004.

[MRL, minimum reporting level; USEPA, U.S. Environmental Protection Agency; MCL, Maximum Contaminant Level; HBSL, Health-Based Screening Level; BQmax, benchmark quotient = ratio of maximum compound concentration to MCL or HBSL value; ESA, ethanesulfonic acid; SA, second amide; OA, oxanilic acid; E, estimated value; µg/L, micrograms per liter; --, not available; **bold type** indicates unregulated compound for which no Federal and (or) State drinking-water standards have been established]

Regulated or unregulated compound	Chemical Abstracts Service Registry number	Number of detections for source water	Detection frequency (percent)	MRL (µg/L)	Maximum concentration for source water (µg/L)	USEPA MCL (or HBSL) concentration (µg/L)	BQmax for source water
Volatile organic compounds (VOCs)							
<i>cis</i> -1,2-Dichloroethene	156-59-2	7	23	0.038	1.496	70	0.02
Trichloroethene	79-01-6	5	17	.038	69.52	5	10
Chloroform	67-66-3	3	10	.024	E.097	180	.001
<i>trans</i> -1,2-Dichloroethene	156-60-5	3	10	.032	E.110	100	.001
Vinyl chloride	75-01-4	2	7	.08	.677	2	.3
Perchloroethene	127-18-4	2	7	.03	.285	5	.06
Benzene	71-43-2	2	7	.021	.101	5	.02
1,1-Dichloroethene	75-35-4	2	7	.024	6.533	7	.9
1,1-Dichloroethane	75-34-3	2	7	.035	4.878	--	--
1,1,1-Trichloroethane	71-55-6	2	7	.032	5.306	200	.03
Methyl <i>tert</i>-butyl ether (MTBE)	1634-04-4	1	3	.1	.1035	--	--
1,2-Dichloroethane	107-06-2	1	3	.13	.1651	5	.03
Dichlorodifluoromethane (Freon 112)	75-71-8	1	3	.18	E.068	1,000 (HBSL)	.00007
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	76-13-1	1	3	.038	.195	200,000 (HBSL)	.000001
1,1,2-Trichloroethane	79-00-5	1	3	.04	E.079	5	.02
Total number of VOC detections		35					
Pesticides							
Alachlor ESA	140939-15-7	9	30	0.02	0.32	--	--
Fenuron	101-42-8	6	20	.018	.019	--	--
Deethylatrazine (CIAT)²	6190-65-4	6	20	.006	E.018	--	--
Atrazine	1912-24-9	5	17	.007	.034	3	0.01
Prometon	1610-18-0	4	13	.01	.019	100 (HBSL)	.0002
Metolachlor ESA	--	4	13	.02	.25	--	--
Alachlor ESA SA	--	4	13	.02	.05	--	--
Metolachlor OA	152019-73-3	3	10	.02	.40	--	--
Didealkyatrazine (CAAT)³	3397-62-4	2	7	.022	E.068	--	--

Table 1. Maximum concentrations, detection frequencies, and maximum benchmark quotients for compounds detected in source water from community water systems in studied aquifers in the Greater Twin Cities metropolitan area, Minnesota and Wisconsin, 2004. —Continued

[MRL, minimum reporting level; USEPA, U.S. Environmental Protection Agency; MCL, Maximum Contaminant Level; HBSL, Health-Based Screening Level; BQmax, benchmark quotient = ratio of maximum compound concentration to MCL or HBSL value; ESA, ethanesulfonic acid; SA, second amide; OA, oxanilic acid; E, estimated value; µg/L, micrograms per liter; --, not available; **bold type** indicates unregulated compound for which no Federal and (or) State drinking-water standards have been established]

Regulated or unregulated compound	Chemical Abstracts Service Registry number	Number of detections for source water	Detection frequency (percent)	MRL (µg/L)	Maximum concentration for source water (µg/L)	USEPA MCL (or HBSL) concentration (µg/L)	BQmax for source water
Pesticides—Continued							
Bromacil	314–40–9	2	7	0.018	0.337	70 (HBSL)	0.005
Alachlor OA	140939–14–6	2	7	.02	.04	--	--
Sulfometuron-methyl	74222–97–2	1	3	.038	E.004	--	--
2-Hydroxyatrazine (OIET)⁴	2163–68–0	1	3	.032	E.013	70 (HBSL)	.0002
Metolachlor	51218–45–2	1	3	.006	E.003	70 (HBSL)	.00004
Imazethapyr	81335–77–5	1	3	.038	E.007	100 (HBSL)	.00007
Diuron	330–54–1	1	3	.014	.018	2 (HBSL)	.009
Deisopropylatrazine (CEAT)⁵	1007–28–9	1	3	.08	E.058	--	--
Total number of pesticide detections		53					
Other anthropogenic organic compounds (OAOCs)							
Menthol	89–78–1	6	20	0.5	E0.21	--	--
Hexahydrohexamethyl-cyclopentabenzopyran (HHCB)	1222–05–5	5	17	.5	E.005	--	--
Tributyl phosphate	126–73–8	4	13	.5	E.065	--	--
Methyl salicylate	119–36–8	3	10	.5	E.11	--	--
Triphenyl phosphate	115–86–6	1	3		E.002	--	--
Acetyl hexamethyl tetrahydronaphthalene (AHTN)	21145–77–7	1	3	.5	E.036	--	--
Octylphenol, (mono-ethoxy)	26636–32–8	1	3	1	E.11	--	--
2,6-Dimethylnaphthalene	581–42–0	1	3	.5	E.003	--	--
Total number of OAOC detections		22					
Total number of detections for all compounds		110					

¹1998 Final Rule for Disinfectants and Disinfection By-products: The total for trihalomethanes is 80 micrograms per liter.

²CIAT = 2-Chloro-4-isopropylamino-6-amino-*s*-triazine.

³CAAT = Chlorodiamino-*s*-triazine.

⁴OIET = 2-Hydroxy-4-isopropylamino-6-ethylamino-*s*-triazine.

⁵CEAT = 2-Chloro-6-ethylamino-4-amino-*s*-triazine.

Table 2. Maximum concentrations, detection frequencies, and maximum benchmark quotients for compounds detected in source-water wells and in associated finished water from community water systems in studied aquifers in the Greater Twin Cities metropolitan area, Minnesota and Wisconsin, 2005.

[MRL, minimum reporting level; USEPA, U.S. Environmental Protection Agency; MCL, Maximum Contaminant Level; HBSL, Health-Based Screening Level; BQmax, benchmark quotient = ratio of maximum compound concentration to MCL or HBSL value; ESA, ethanesulfonic acid; SA, second amide; OA, oxanilic acid; E, estimated value; µg/L, micrograms per liter; --, not available; **bold type** indicates unregulated compound for which no Federal and (or) State drinking-water standards have been established]

Regulated or unregulated compound	Chemical Abstracts Service Registry Number	Number of detections for source water out of 15 samples	Number of detections for finished water out of 14 samples	MRL (µg/L)	Maximum concentration for source water (µg/L)	Maximum concentration for finished water (µg/L)	USEPA MCL (or HBSL) (µg/L)	BQmax for source water	BQmax for finished water
Volatile organic compounds (VOCs)									
Trichloroethene	79-01-6	4	4	0.038	64	0.63	5	10	0.13
<i>cis</i> -1,2-Dichloroethene	156-59-2	4	4	.024	2.4	1.8	70	.03	.026
<i>trans</i> -1,2-Dichloroethene	156-60-5	3	3	.032	.18	.15	100	.002	.002
Chloroform	67-66-3	1	4	.024	E.069	1.8	¹ 80	.001	.002
Perchloroethene	127-18-4	2	2	.03	E.14	E.092	5	.02	.018
Benzene	71-43-2	3	1	.021	.13	.12	5	.03	.024
1,1-Dichloroethane	75-34-3	2	2	.035	5.1	.14	--	--	--
1,1-Dichloroethene	75-35-4	2	1	.024	7.0	E.018	7	1	.003
Bromoform	75-25-2	0	4	.1	--	E8.9	¹ 80	--	.11
Dibromochloromethane	124-48-1	0	3	.1	--	.84	¹ 80	--	.011
Bromodichloromethane	75-27-4	0	3	.028	--	1.2	¹ 80	--	.010
Chloromethane	74-87-3	0	1	.17	--	E.15	30 (HBSL)	--	.005
Vinyl chloride	75-01-4	1	0	.08	.39	--	2	.2	--
Methyl <i>tert</i>-butyl ether	1634-04-4	1	0	.1	.10	--	--	--	--
Dichlorodifluoromethane (Freon-112)	75-71-8	1	0	.18	E.050	--	1,000 (HBSL)	.00005	--
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon-113)	76-13-1	1	0	.038	E.18	--	200,000 (HBSL)	.000001	--
1,1,1-Trichloroethane	71-55-6	1	0	.032	5.1	--	200	.03	--
Total number of VOC detections		26	32						
Pesticides									
Alachlor ESA	140939-15-7	6	5	0.02	0.54	0.53	--	--	--
Metolachlor ESA	--	5	4	.02	.14	.23	--	--	--
Atrazine	1912-24-9	5	3	.007	.05	.047	3	0.02	0.02
Metolachlor OA	152019-73-3	3	3	.02	.41	.62	--	--	--
Alachlor OA	140939-14-6	3	3	.02	.14	.32	--	--	--
Deethylatrazine (CIAT)²	6190-65-4	4	2	.006	.041	.033	--	--	--
3-Ketocarbafuran	16709-30-1	3	2	.02	E.25	E.25	--	--	--
Metsulfuron methyl	74223-64-6	2	2	.025	E.07	E.07	2,000 (HBSL)	.00004	.00004
Alachlor ESA SA	--	3	1	.02	.13	.21	--	--	--
Deisopropylatrazine (CEAT)³	1007-28-9	2	2	.08	E.052	E.006	--	--	--
Acetochlor ESA	187011-11-3	2	1	.02	.04	.02	--	--	--

Table 2. Maximum concentrations, detection frequencies, and maximum benchmark quotients for compounds detected in source-water wells and in associated finished water from community water systems in studied aquifers in the Greater Twin Cities metropolitan area, Minnesota and Wisconsin, 2005.—Continued

[MRL, minimum reporting level; USEPA, U.S. Environmental Protection Agency; MCL, Maximum Contaminant Level; HBSL, Health-Based Screening Level; BQmax, benchmark quotient = ratio of maximum compound concentration to MCL or HBSL value; ESA, ethanesulfonic acid; SA, second amide; OA, oxanilic acid; E, estimated value; µg/L, micrograms per liter; --, not available; **bold type** indicates unregulated compound for which no Federal and (or) State drinking-water standards have been established]

Regulated or unregulated compound	Chemical Abstracts Service Registry Number	Number of detections for source water out of 15 samples	Number of detections for finished water out of 14 samples	MRL (µg/L)	Maximum concentration for source water (µg/L)	Maximum concentration for finished water (µg/L)	USEPA MCL (or HBSL) (µg/L)	BQmax for source water	BQmax for finished water
Pesticides—Continued									
Prometon	1610–18–0	1	1	0.01	E0.009	E0.008	100 (HBSL)	0.00009	0.00008
Acetochlor OA	--	0	1	.02	--	.04	--	--	--
N(Ethmethphen)ox ESA	--	0	1	.02	--	.02	--	--	--
Flufenacet	142459–58–3	2	0	.02	.02	--	--	--	--
Bromacil	314–40–9	2	0	.018	.258	--	70 (HBSL)	.004	--
Oryzalin	19044–88–3	1	0	.012	E.01	--	4 (HBSL)	.002	--
Metolachlor	51218–45–2	1	0	.006	.02	--	70 (HBSL)	.0003	--
Hexazinone	51235–04–2	1	0	.0129	.017	--	400 (HBSL)	.00004	--
Fenuron	101–42–8	1	0	.018	.019	--	--	--	--
Didealkyatrazine (CAAT) ⁴	3397–62–4	1	0	.022	E.052	--	--	--	--
Total number of pesticide detections		48	31						
Other anthropogenic organic compounds (OAOCs)									
Caffeine	58–08–2	2	2	0.012	E0.097	E0.065	--	--	--
Methyl salicylate	119–36–8	1	1	.5	E.014	E.011	--	--	--
Triphenyl phosphate	115–86–6	0	1	.5	--	E.017	--	--	--
Menthol	89–78–1	0	1	.5	--	E.033	--	--	--
Tributyl phosphate	126–73–8	3	0	.5	E.13	--	--	--	--
Tris(2-chloroethyl) phosphate (TCEP)	115–96–8	1	0	.5	E.04	--	--	--	--
Tris(2-butoxyethyl) phosphate	78–51–3	1	0	.5	E.18	--	--	--	--
Octylphenol, (mono-ethoxy)	26636–32–8	1	0	1	E.066	--	--	--	--
HHCB ⁵	1222–05–5	1	0	.5	E.012	--	--	--	--
Total number of OAOC detections		10	5						
Total detections for all compounds		84	68						

¹1998 Final Rule for Disinfectants and Disinfection By-products: The total for trihalomethanes is 80 micrograms per liter.

²CIAT = 2-Chloro-4-isopropylamino-6-amino-*s*-triazine.

³CEAT = 2-Chloro-6-ethylamino-4-amino-*s*-triazine.

⁴CAAT = Chlorodiamino-*s*-triazine.

⁵HHCB = Hexahydrohexamethylcyclopentabenzopyran.

Consumer Confidence Reports and Source Water-Quality Assessments

Since 1999, the U.S. Environmental Protection Agency (USEPA) has required water suppliers to provide annual drinking-water quality reports called Consumer Confidence Reports (CCRs) to their customers (<http://www.epa.gov/safewater/ccr/>). 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 selected 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 untreated (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, therefore, may 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). HBSLs are estimates of concentrations of contaminants in water that may be of human-health concern and are consistent with USEPA Office of Water methodologies for setting nonenforceable drinking-water guideline values. HBSLs are not legally enforceable regulatory standards, and water utilities are not required to compare contaminant monitoring results to HBSLs.

Environmental-sample data were compared to quality-assurance data to document sample integrity. The effectiveness of cleaning methods of sampling equipment was quantified using blank samples. Replicate samples were collected from selected wells to verify the stability of water quality and efficacy of purging procedures, to assess the reproducibility of sampling and analytical methods, and to quantify the resulting variability. Spiked samples were submitted for selected VOC and pesticide samples to measure changes in concentrations during shipment and to check analytical recoveries from the sample matrix.

Eight quality-assurance/quality-control (QA/QC) samples were collected during this study. These samples include two field-equipment blank, two field-spiked, and three replicate samples. Standard NAWQA QA/QC procedures are described in Koterba and others (1995). Field-equipment blanks consisted of three types of water prepared and tested to be free of organic and inorganic compounds that were pumped through the sampling systems. Field-equipment blanks were used to determine whether cleaning procedures prevented contamination between sites and to ensure that field methods, sample shipment, and laboratory procedures had not contaminated samples. The field-equipment blanks for pesticides, VOCs, and other AOCs were collected after a full cleaning and methanol and de-ionized water rinses of the equipment and sampling lines. A few compounds were detected at concentrations below reporting-level concentrations in blank QA/QC samples. These blank-sample concentrations were much less than those generally reported in ground-water samples, indicating a low likelihood of cross-contamination of ground-water samples. When ground-water samples were collected from spigots located near the well prior to any water treatment, large volumes (typically greater than 30 gal) of water were passed through the sampling system prior to blank-sample collection, which substantially minimizes the possibility of contamination to samples by the sampling equipment.

Pervasive detection of compounds in field-equipment blanks processed as part of this study, as well as from other SWQAs conducted across the Nation, resulted in the removal of all data for 7 of the 265 compounds. Specifically, data for phenol, N,N-diethyl-*meta*-toluamide (DEET), benzophenone, 4-nonylphenol, isophorone, acetone, and toluene were removed from inclusion in this report. In addition, data for caffeine and *p*-cresol were censored to their highest blank concentration of 0.012 µg/L and 0.013 µg/L, respectively. Therefore, only concentrations greater than these levels are reported.

Field-spiked samples were used to assess the recovery bias and precision or variability in recoveries of pesticides and VOCs. Field-spiked samples were submitted for four schedules (groups of associated constituents) analyzed by the NWQL during this study. One spike each was submitted for schedules 1433 (wastewater compounds), 2003 (triazine and related pesticides with degradates), 2020 (VOCs), and 2060 (polar pesticides with metabolites). Review of the results showed that most of the analyses provided good results, although certain constituents showed poor recovery. The recoveries of spiked concentrations of wastewater

compounds generally were within 20 percent of the target concentration. Five of the spiked compounds analyzed had concentrations less than one-half or more than twice the target concentration, and dichlorvos was not detected. The recoveries of spiked samples for schedule 2003 generally were within 20 percent of the target concentration. However, 22 of the recovered concentrations were less than one-half of the spiked target concentration, and the insecticide phosmet and its oxon degradate were not detected. VOCs recovered from spiked samples showed some problems in their recoveries. Of the 80 VOCs spiked and analyzed, 52 were detected at less than one-half or more than twice the target concentration. Because most recoveries were below the target concentrations and surrogate recoveries ranged from 94 to 106 percent, it is suspected that spiked compounds may have been lost during the field-spiking procedure. Schedule 2060, polar pesticides and metabolites, showed spike recoveries close to the expected values, with only 6 of the 61 constituents detected at less than one-half of the target concentration.

The mean recoveries for the 2060 surrogates (diazinon-d10, a-HCH-d6, and terbuthylazine) ranged from 103 to 133 percent. Mean recoveries in VOC spiked samples ranged from 69.3 to 115 percent. Mean VOC surrogate recoveries ranged from 77.7 to 111 percent for 1,2-dichloroethane d-4, toluene d-8, and *p*-bromofluorobenzene. Spike and surrogate recoveries for both pesticides and VOCs generally were within acceptable ranges. Concentrations of pesticides or VOCs in the environmental samples were not adjusted for surrogate recoveries.

Replicate samples were collected sequentially with environmental samples and both were analyzed for the same groups of compounds. Replicate samples determine the sample variability resulting from sample collection and laboratory analysis. The differences in concentrations between the environmental sample and replicate sample for these constituents were 0.001 µg/L or less for pesticides, 0.1 µg/L or less for VOCs, and 0.9 µg/L or less for other AOCs, which were all qualified as estimated.

Anthropogenic Organic Compounds in Ground Water and Finished Water of Community Supply Wells

SWQAs were conducted for the unconfined parts of the glacial and Prairie du Chien-Jordan aquifers. The first phase during 2004 measured the concentrations of 265 AOCs (258 are included in this report) in source water from 30 wells completed in the two aquifers underlying TCMA. In the second phase, 15 of the original 30 CWS wells, those with the greatest number of AOC detections, were re-sampled along with finished water from 14 associated CWS wells. Water-quality results from source-water samples were compared among wells completed in the two aquifers to characterize differences between the aquifers.

Anthropogenic Organic Compounds in Ground Water Used as Source Water for Community Supply Wells

A total of 40 of the 258 individual AOCs (Appendixes 1, 2, and 3) were detected (15 VOCs, 17 pesticides, and 8 other AOCs) in phase-1 samples collected during November and December 2004 (table 1, figs. 7 and 8). The most frequently occurring AOCs detected, those detected in 10 percent or more of the source-water samples, were (table 1): alachlor ethane-sulfonic acid (ESA) (30 percent), *cis*-1-2-dichloroethene (23 percent), menthol (20 percent), fenuron (20 percent), deethylatrazine (CIAT) (20 percent), trichloroethene (17 percent), atrazine (17 percent), hexahydrohexamethylcyclopentabenzopyran (HHCB) (17 percent), prometon (13 percent), metolachlor ESA (13 percent), alachlor ESA second amide (SA) (13 percent), tributyl phosphate (13 percent), methyl salicylate (10 percent), metolachlor oxanilic acid (OA) (10 percent), chloroform (10 percent), and *trans*-1,2-dichloroethene (10 percent). Samples generally contained a mixture of AOC compounds (average of three compounds per sample), and at least one AOC was detected in 83 percent of the samples.

Concentrations of AOCs detected in source waters generally were low (defined in this report as concentrations less than 1.0 µg/L). Human-health benchmarks were available for 20 of the 40 detected compounds. For most of these AOC compounds, concentrations from untreated source-water samples were several orders of magnitude less than their human-health benchmark standards. Benchmarks include USEPA MCLs and USGS HBSLs. The human-health relevance of the remaining detected, but unregulated, contaminants cannot be evaluated because human-health toxicity information is not available. Because compounds with established benchmarks typically were detected at concentrations that were several orders of magnitude less than their established benchmark standards, additional monitoring for those compounds may not be warranted. However, additional monitoring for frequently occurring AOCs without established benchmark standards may be warranted to better understand their spatial and temporal distribution, as well as sources, transport, and fate and the synergetic effects of mixtures of compounds detected.

When comparing analytical results among different AOCs, it is important to consider the analytical reporting level of each AOC. For example, an AOC with a lower reporting level may be expected to be detected more frequently than an AOC with a higher reporting level. A true comparison is possible only when comparing individual compounds analyzed using the same analytical method (same reporting level). For the purposes of this report, comparisons are made among AOCs, regardless of varying reporting levels (Appendixes 1, 2, and 3) to characterize general occurrence rates and similarities, or the lack thereof, between source water and finished waters.

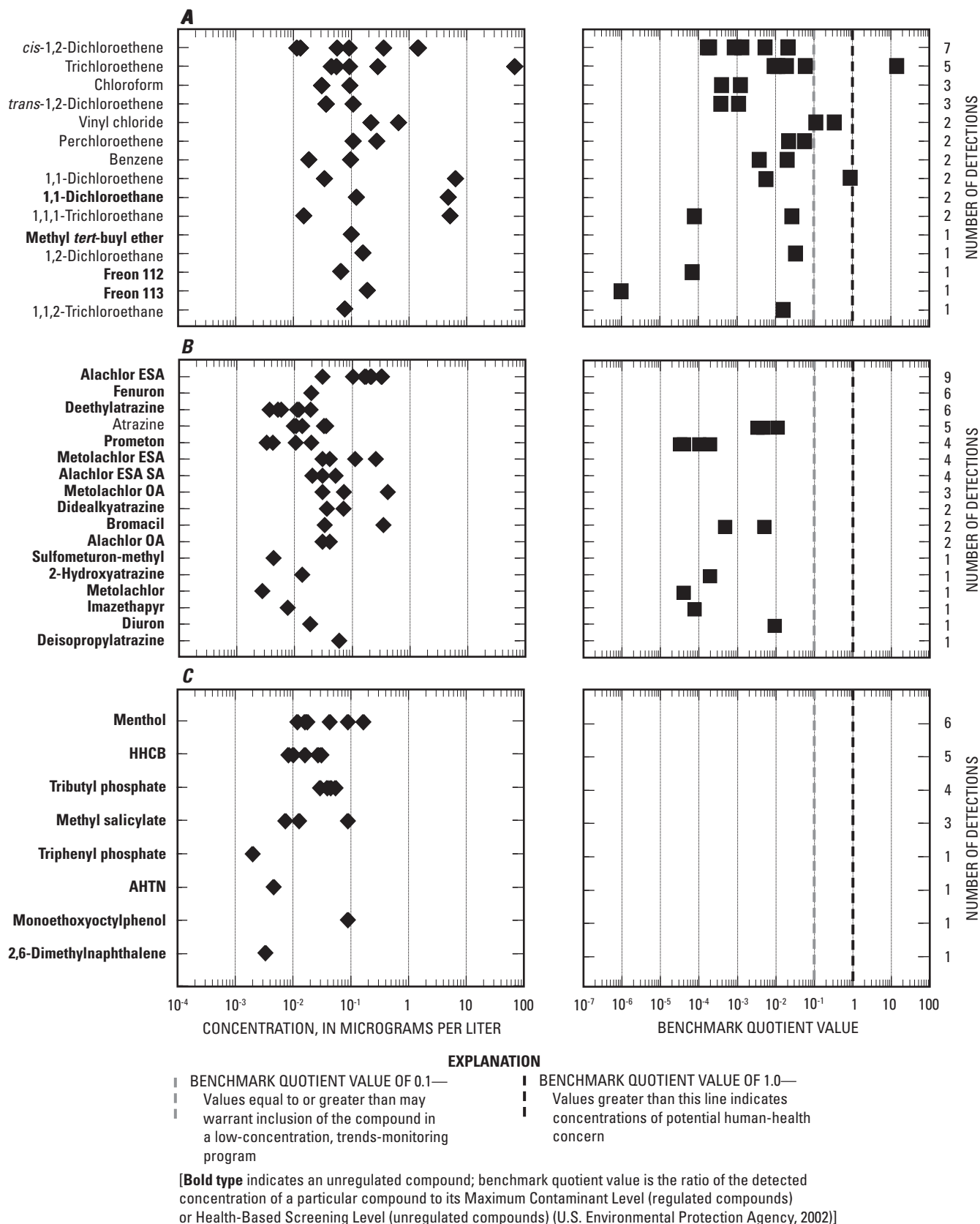


Figure 7. Anthropogenic organic compound concentrations, number of detections, and benchmark quotient values for source-water samples from the study for (A) volatile organic compounds, (B) pesticides, and (C) other anthropogenic organic compounds from 30 source-water wells in glacial aquifer and unconfined part of Prairie du Chien-Joran aquifer (see table 1), 2004.

Volatile Organic Compounds

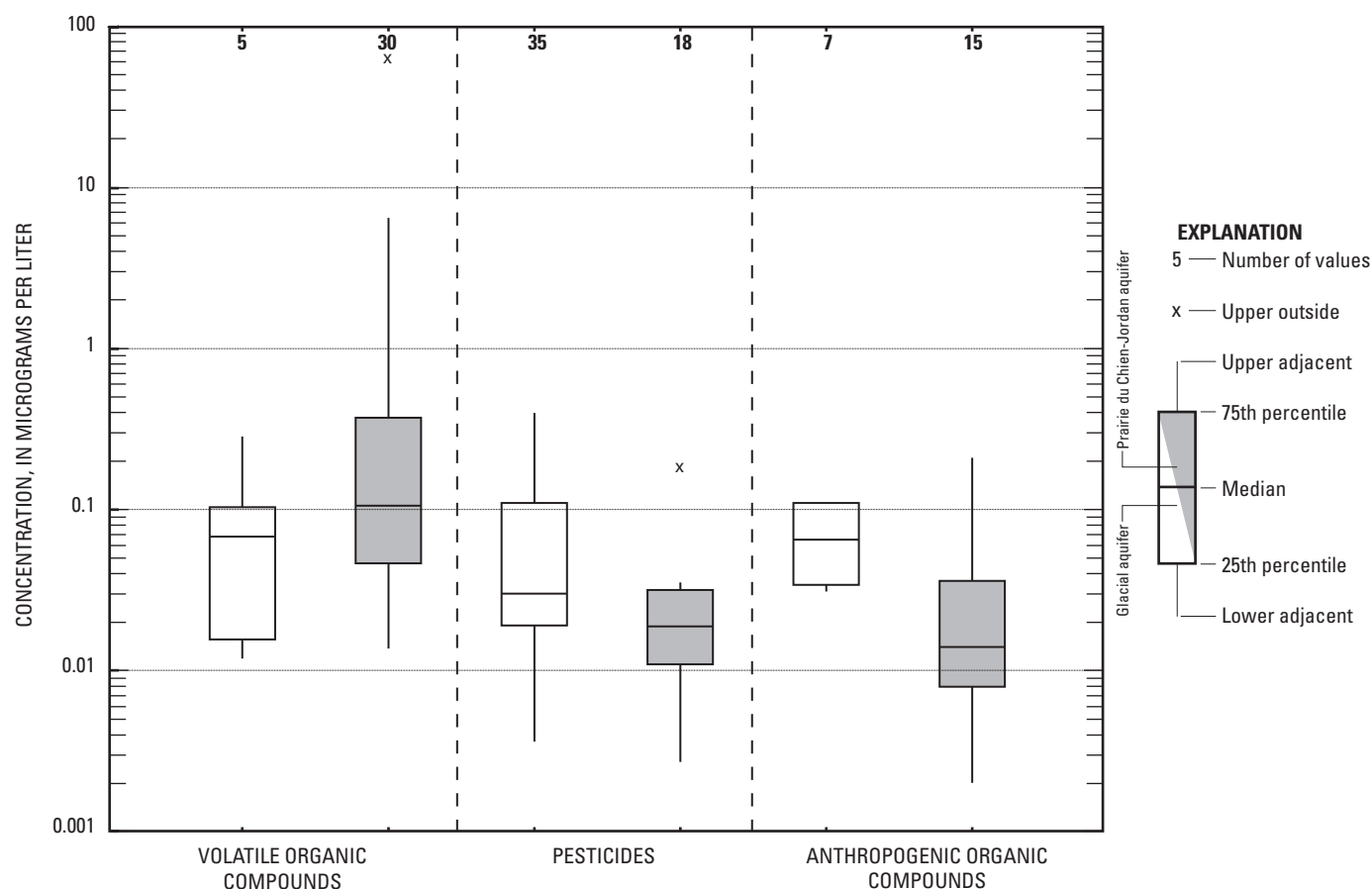
VOCs are carbon-containing compounds that readily evaporate at normal temperatures and pressures. VOCs are present in many commercial products including gasoline, paints, adhesives, solvents, wood preservatives, dry-cleaning agents, pesticides, cosmetics, correction fluids, and refrigerants. VOCs may leach to ground water from spills and leaks at or near land surface, from atmospheric dispersion to ground water, and through recharge of rainwater that contains VOCs sorbed from the atmosphere. Fifteen VOCs were detected in source-water samples (table 1, fig. 7). The compounds *cis*-1,2-dichloroethene, trichloroethene, chloroform, and *trans*-1,2-dichloroethene were the most frequently detected VOCs, each detected in 10 percent or more of the samples. These compounds may enter the hydrologic system from air emissions, discharges to surface water, and releases to land and from a variety of other anthropogenic sources (Ivahnenco and Barbash, 2004). Other frequently detected VOCs included vinyl chloride, perchloroethene, benzene, 1,1-dichloroethene, 1,1-dichloroethane, and 1,1,1-trichloroethane.

Chloroform is one of many disinfection by-products (DBPs) typically produced during the disinfection of drinking water and wastewater. DBPs may enter the ground water from

recharge of treated wastewater, chlorinated or reclaimed water used to irrigate lawns and gardens, leakage from distribution lines for treated water and wastewater, spas, pools, leachate from septic-system drainfields, air emissions, and releases to the atmosphere (Thiros, 2000; Ivahnenco and Barbash, 2004). Detection of chloroform in ground water, along with other associated DBPs, provides a means for distinguishing between the inputs of chlorinated water and inputs of other chloroform sources to the environment (Ivahnenco and Barbash, 2004).

VOC concentrations in source water generally were less than human-health benchmarks (table 1, fig. 7). Of the 15 VOCs detected, human-health benchmarks were available for 13 compounds. BQmax values for these 13 compounds typically were several orders of magnitude less than 1.0, and three were greater than the 0.1 criteria (table 1, fig. 7). Trichloroethene, vinyl chloride, and 1,1-dichloroethene in one well likely are related to a known source of VOC contamination; the Twin Cities Army Ammunition Plant (TCAAP) located in Arden Hills, Minn. (City of New Brighton, 2008). Water from that well is treated to reduce VOC concentrations prior to being used as a source of public supply.

Results indicate that VOCs are of possible concern in specific areas and may warrant consideration for continued low-concentration trends monitoring. An MCL or HBSL has



Relating Study Results to Human-Health Benchmarks, Consumer Confidence Reports, and Source Water-Quality Assessments

Results from this study were compared to U.S. Environmental Protection Agency (USEPA) Maximum Contaminant Levels (MCLs) and U.S. Geological Survey (USGS) Health-Based Screening Levels (HBSLs) to evaluate the relevance of the findings to human health (Appendix 4).

The USGS began an interagency pilot effort in 1998 to communicate the significance of water-quality findings of the NAWQA Program in a human-health context. Historically, the USGS has assessed water-quality conditions by comparing water concentration data with human-health benchmarks such as established Federal or State drinking-water standards and guidelines. The drinking-water standards for regulated compounds are called Maximum Contaminant Levels (MCLs), which protect drinking-water quality by limiting the concentration of specific compounds delivered to any user of a public water system that can adversely affect public health (U.S. Environmental Protection Agency, 2002). However, drinking-water standards and guidelines do not exist for nearly one-half of the compounds analyzed by the NAWQA Program and other USGS studies. To provide a more complete understanding of the significance of water-quality data collected, existing Federal drinking-water standards and guidelines are supplemented by HBSL concentrations or ranges calculated for unregulated compounds (compounds without Federal drinking-water standards) monitored by the NAWQA Program using an approach that was developed collaboratively by the USGS, USEPA, New Jersey Department of Environmental Protection (NJDEP), and Oregon Health & Science University (OHSU) (Toccalino and others, 2003, 2004).

HBSLs are not regulatory standards and are not enforceable, and water systems are not required to monitor for any unregulated compounds for which HBSLs have been developed. HBSLs are estimates of benchmark concentrations that can be used as thresholds against which contaminant concentrations in water can be compared to evaluate water-quality data in a human-health context. HBSLs can be used as planning tools to help prioritize contaminants that may merit further study or monitoring and to provide an early indication of contaminant concentrations of human-health concern in water resources (Toccalino and others, 2005).

Appendix 4 provides descriptions of the human-health benchmarks that were used in this study.

To aid in evaluating water-quality data in the context of human health, benchmark quotient (BQ) values were calculated. A BQ value is the ratio of a measured concentration of a detected compound to its MCL (for a regulated compound) or HBSL (for an unregulated compound). For this study, the maximum concentration detected for each compound was used to calculate this ratio, called BQ_{max}. A BQ_{max} value greater than or equal to 1.0 was used to identify concentrations of potential human-health concern (hereafter referred to as concentrations of potential concern). A BQ_{max} value greater than or equal to 0.1 is used to identify compounds that may warrant inclusion in a low-concentration, trends-monitoring program; especially frequently occurring compounds (in this report, an anthropogenic organic compound detected in 10 percent or more of samples) also may warrant inclusion in such a monitoring program. Such monitoring can provide an early indication of contaminant levels that approach human-health benchmarks, and consequently, concentrations of concern (or potential concern for those compounds with HBSLs).

not been developed for methyl *tert*-butyl ether (MTBE) and 1,1-dichloroethane, and additional monitoring of these compounds may be warranted because they often were detected. VOCs were more frequently detected, and detected at higher concentrations, in the Prairie du Chien-Jordan aquifer compared to the glacial aquifer (fig. 8).

Pesticide Compounds

Pesticide compounds are used to control plants, insects, and other pests. They are applied primarily to cropland in rural areas but also for lawns, rights-of-way, and gardens in urban areas. Seventeen pesticide compounds were detected in source water (table 1, fig. 7). The number of individual pesticides detected was roughly the same as for VOCs. However, pesticides were detected more frequently (53 pesticide detections compared to 35 VOC detections, table 1). Pesticides generally were detected at lower concentrations than VOCs (table 1, fig. 7).

Of the pesticide compounds detected, most were triazine-parent and alachlor-parent pesticides and their breakdown products. Several reasons exist for the higher detection frequencies for triazine-parent and alachlor-parent compounds and their breakdown products compared to other pesticides. These reasons include widespread use, high mobility in sandy soils, and persistence in ground water (Kruger and others, 1995; Barbash and others, 1999). The half-life for atrazine in soils can be more than 100 days, and in ground water, atrazine and deethylatrazine can persist for almost 6 years and more than 25 years, respectively (Denver and Sandstrom, 1991; Gaus, 2000).

Concentrations of pesticides detected in the source water generally were low (less than 0.1 µg/L) (table 1, figs. 7 and 8). Of the 17 pesticides detected, human-health benchmarks were available for seven compounds. BQmax values for these seven pesticides typically were several orders of magnitude less than 1.0 and none were greater than 0.1 (table 1, fig. 7). Human-health benchmarks were not available for many of the pesticide compounds, and additional monitoring may be warranted on the basis of their frequencies of occurrence. Pesticides were more frequently detected, and detected at higher concentrations, in the glacial aquifer as compared to the Prairie du Chien-Jordan aquifer (fig. 8). This probably is because pesticides have widespread use on the landscape and are more easily transported to the shallow glacial aquifer.

Other Anthropogenic Organic Compounds

Eight other AOCs were detected in source water during this study. Of those, menthol, HHCB, tributyl phosphate, and methyl salicylate were each detected in 10 percent or more of the samples. Concentrations generally were low (0.21 µg/L or less) (table 1, fig. 7). A human-health benchmark was not available for any of the eight other AOCs detected. Additional monitoring may be warranted for several of the compounds

detected based on their frequent occurrence. Other AOCs were detected more frequently in the Prairie du Chien-Jordan aquifer but concentrations were higher in the glacial aquifer (fig. 8).

Comparison of Source and Finished Ground Water

In the second phase of sampling, 15 of the original 30 CWS sampled wells (seven in the glacial aquifer and eight in the Prairie du Chien-Jordan aquifer, figs. 4 and 5), those with the greatest number of AOC detections during the first phase, were re-sampled in August 2005. In addition, 14 corresponding finished-water samples were collected. Fourteen finished-water wells were sampled instead of 15 because two of the sampled CWS wells had potential to contain blended water. Only one-half as many wells were resampled during the second phase, resulting in a smaller number of samples. Consequently, the characterization of the occurrence of these compounds in source water and finished water is less well defined, so only a general comparison of these compounds in source water and finished water can be presented. In addition, of the 14 finished-water sampling sites, nine had potential to contain water that could be blended with water from one or more other wells. Five sites did not have the potential for blended water.

The CWS wells and associated finished water were not all sampled for the same AOCs. Five of the source-water CWS wells and associated finished water pairs were analyzed for VOCs, 6 pairs were analyzed for pesticides, and 12 pairs were sampled for other AOCs. Concentrations of each AOC detected in source water and the associated blended or non-blended finished water are presented in Appendix 5.

Volatile Organic Compounds

Five of the 30 original CWS wells were analyzed for VOCs. Seventeen VOCs were detected in either source water or finished water. Specifically, 13 and 12 VOC compounds were detected in source-water and finished-water samples, respectively (table 2, fig. 9). Four of the VOCs detected in finished water were common chlorination DBPs. For example, chloroform was detected in one source-water sample and in four finished-water samples. The DBPs typically detected in finished-water samples, but not in source-water samples, included bromodichloromethane, bromoform, and dibromochloromethane. In addition, DBP concentrations were greater in finished-water samples than in source-water samples in all but one case (fig. 9, Appendix 5). Most of the VOCs, except for the DBPs, were detected more frequently in source-water samples than in finished-water samples.

Maximum concentrations of detected VOCs ranged from E0.050 to 64 µg/L in source water and from E0.018 to E8.9 µg/L in finished water (table 2). Concentrations of most

VOCs detected in either source water or finished water were well below their human-health benchmarks, and as such, BQmax values typically were several orders of magnitude less than 1.0 (table 2, fig. 9). BQmax values for 1,1-dichloroethene, trichloroethene, and vinyl chloride were 0.10 or greater in samples of source water, and BQmax values for bromoform and trichloroethene were greater than 0.10 in some samples of finished water. Most of these detections are associated with one well that is part of a gradient-control system and a water-treatment system related to a known source of contamination (City of New Brighton, 2008). Water from wells in these systems is treated and routinely tested by the utilities prior to discharge to the municipal-supply distribution system.

The DBPs bromoform and chloroform are routinely analyzed by the NWQL as part of the suite of VOCs. When samples of treated water are collected, they are treated with a dechlorination reagent to deactivate free bromine and chlorine, effectively stopping the formation of DBPs in the collected sample. Although bromine and chlorine may continue forming DBPs after collection and processing, this does not explain the large bromoform concentration (E8.9 µg/L) in the VOC sample shown in table 2. A similarly high bromoform concentration was measured in the replicate sample collected during the environmental sampling. DBPs also were present in other VOC-suite analyses of source water, but at much lower concentrations.

Results indicate that monitoring VOCs in source water does not necessarily identify the potential occurrence of VOCs in finished water. Some VOCs are removed during water treatment and some appear to be introduced to finished water as a result of disinfection. Eight of the 17 VOCs were detected in either the source-water samples or finished-water samples but not both. VOCs present in source-water samples, but not in finished-water samples, may be diluted to undetectable concentrations in the finished water by blending with other source water. Similarly, VOCs present in the finished-water samples, but not the source-water samples, may have been present in the source water from other wells or may be the result of disinfection processes.

Pesticide Compounds

Six of the original 30 CWS wells and six associated finished waters were re-sampled for pesticides in August 2005. Of the six finished waters sampled for pesticides, five potentially contained water blended from other wells. A total of 21 individual pesticide compounds were detected in either the source water or finished water. The most frequently detected compounds in both the source and the finished water were atrazine and breakdown products of triazine-based herbicides as well as breakdown products of alachlor and metolachlor. Generally, pesticides detected in source-water samples also were detected in corresponding finished water (table 2). However, seven pesticide compounds were detected in source-water samples but not in finished-water samples, and two

compounds were detected in finished-water samples but not in source-water samples.

Maximum concentrations of detected pesticides in source-water samples and in finished-water samples were similar and low, ranging from E0.009 to 0.54 µg/L in source water and from E0.006 to 0.62 µg/L in finished water (table 2, fig. 10). Concentrations of seven of the pesticides detected in source-water samples or in finished-water samples could be compared to human-health benchmarks, and BQmax values were several orders of magnitude less than 0.1. HBSLs were not available for many of the pesticide compounds, and the occurrence of these unregulated compounds in both source and finished water may warrant additional monitoring.

Results indicate that monitoring for pesticides in source water generally helps to identify the potential occurrence of pesticides in finished water and that water treatment used by the CWSs participating in this study does not substantially remove many pesticide compounds from finished water. However, these systems are not designed to remove these compounds, and blending of source waters makes it difficult to characterize how representative source water is of finished water. Pesticides present in source-water samples, but not in finished-water samples, may be diluted to undetectable concentrations in the finished water by blending with other source waters. Similarly, pesticide compounds present in the finished-water samples, but not the source-water samples, may have been present in the source water from other wells.

Other Anthropogenic Organic Compounds

Twelve of the 30 original CWS wells and associated finished water were re-sampled for other AOCs in August 2005. Seven of the finished-water samples could have contained water blended from more than one well (these samples do not sum to 12 because one of the finished-water samples could contain water from two source-water wells). A total of nine other AOCs were detected in source-water samples or in finished-water samples; however, none were detected frequently (table 2, fig. 11). Caffeine occurred most frequently but only in two of the source-water and finished-water samples. Seven compounds were detected in source-water samples, and four compounds were detected in finished-water samples. Five compounds were detected in only source-water samples, and two compounds were detected only in finished-water samples. Two compounds were detected in both source-water samples and finished-water samples (table 2, fig. 11, and Appendix 5).

Concentrations of other detected AOCs generally were low, with maximum concentrations ranging from E0.012 to E0.18 µg/L in the source water and from E0.011 to E0.065 µg/L in finished water (table 2, fig. 11). A human-health benchmark was not available for any of the nine other AOCs detected. Additional monitoring of some compounds may be warranted due to their occasional detection in source water and in finished water (table 2, Appendix 5).

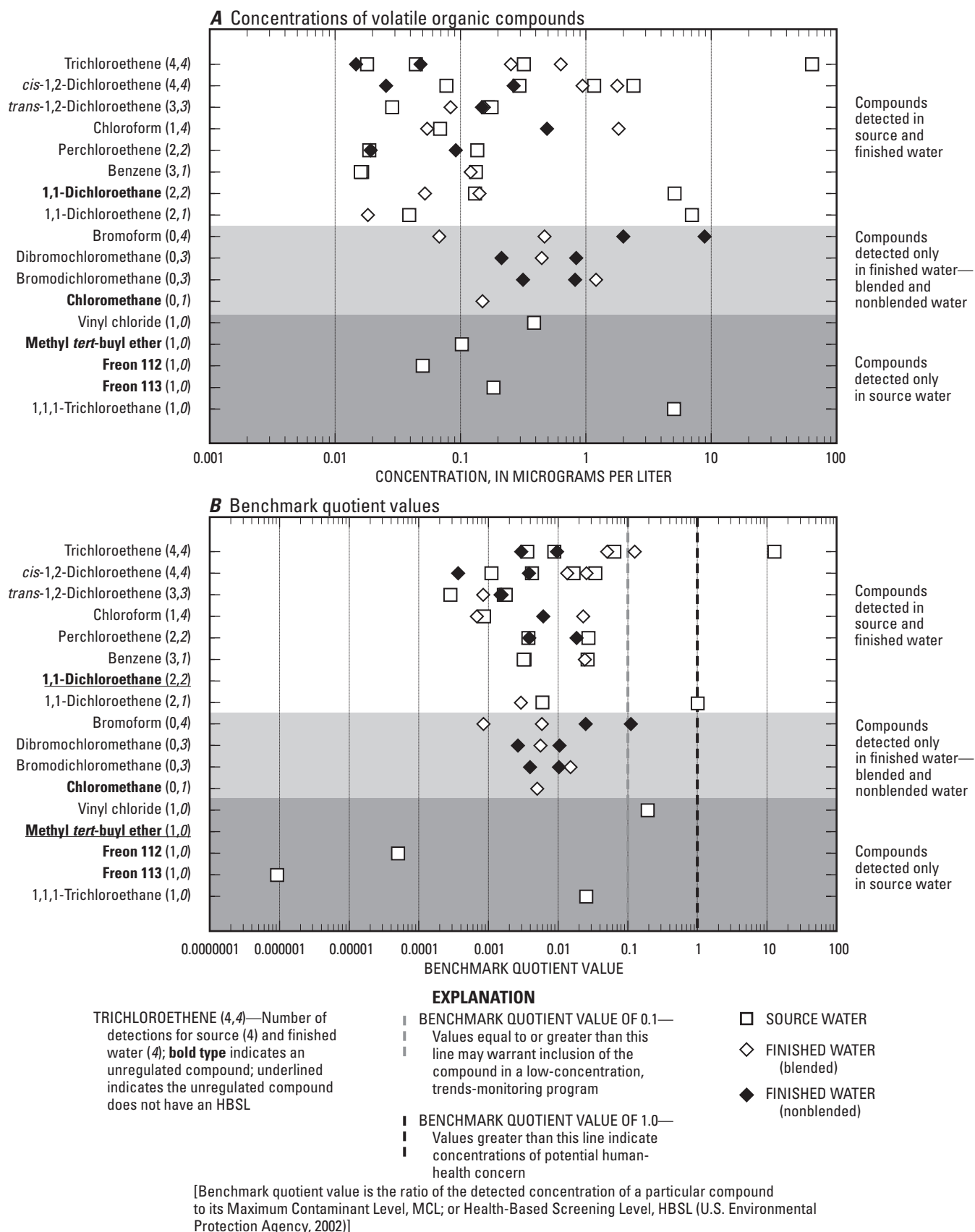


Figure 9. Detected volatile organic compounds showing (A) concentrations and number of detections, and (B) benchmark quotient values for source and associated finished water (blended and nonblended) in samples from study area, 2005.

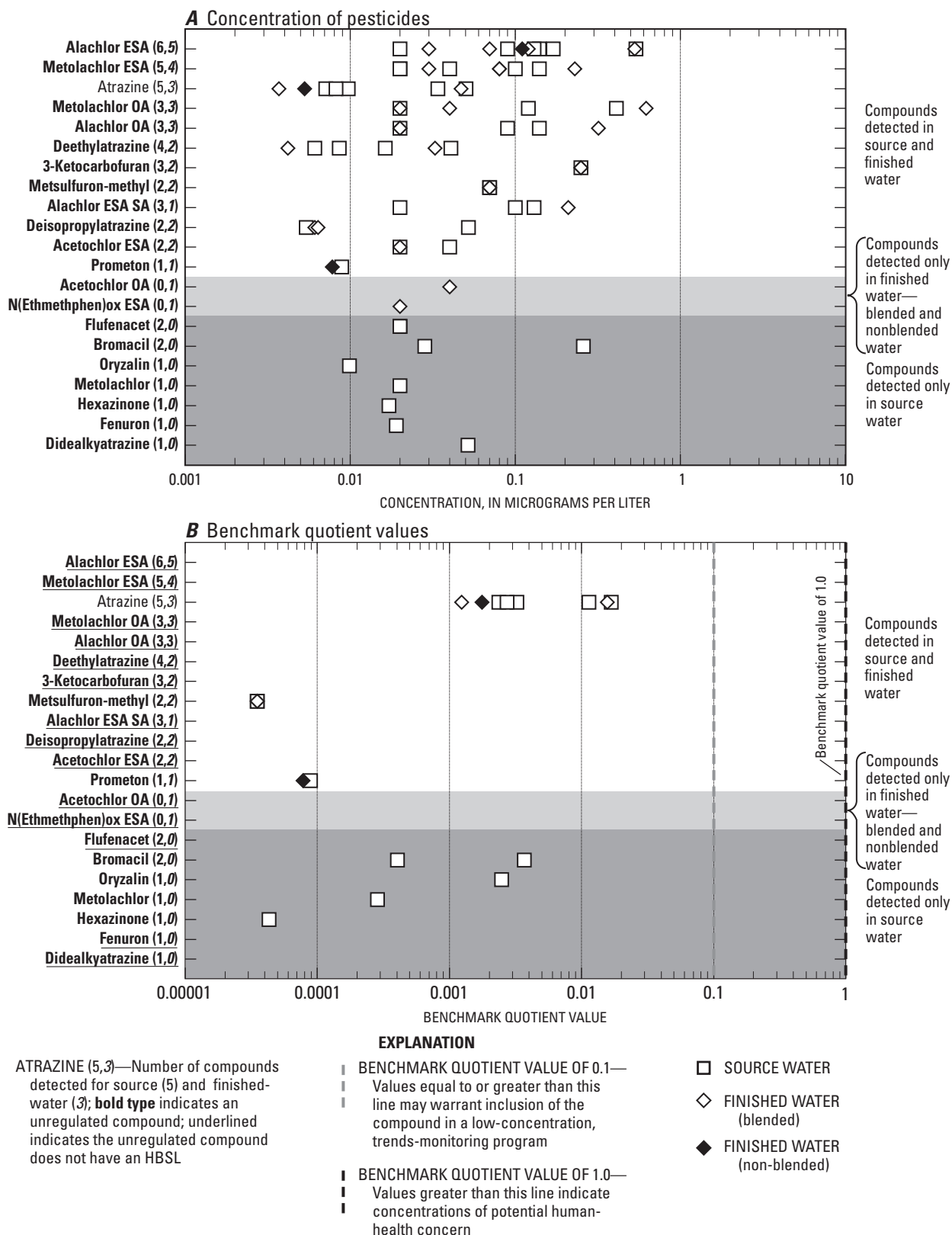


Figure 10. Detected pesticides showing (A) concentrations and number of detections, and (B) benchmark quotient values for source and associated finished water (blended and nonblended) in samples from study area, 2005.

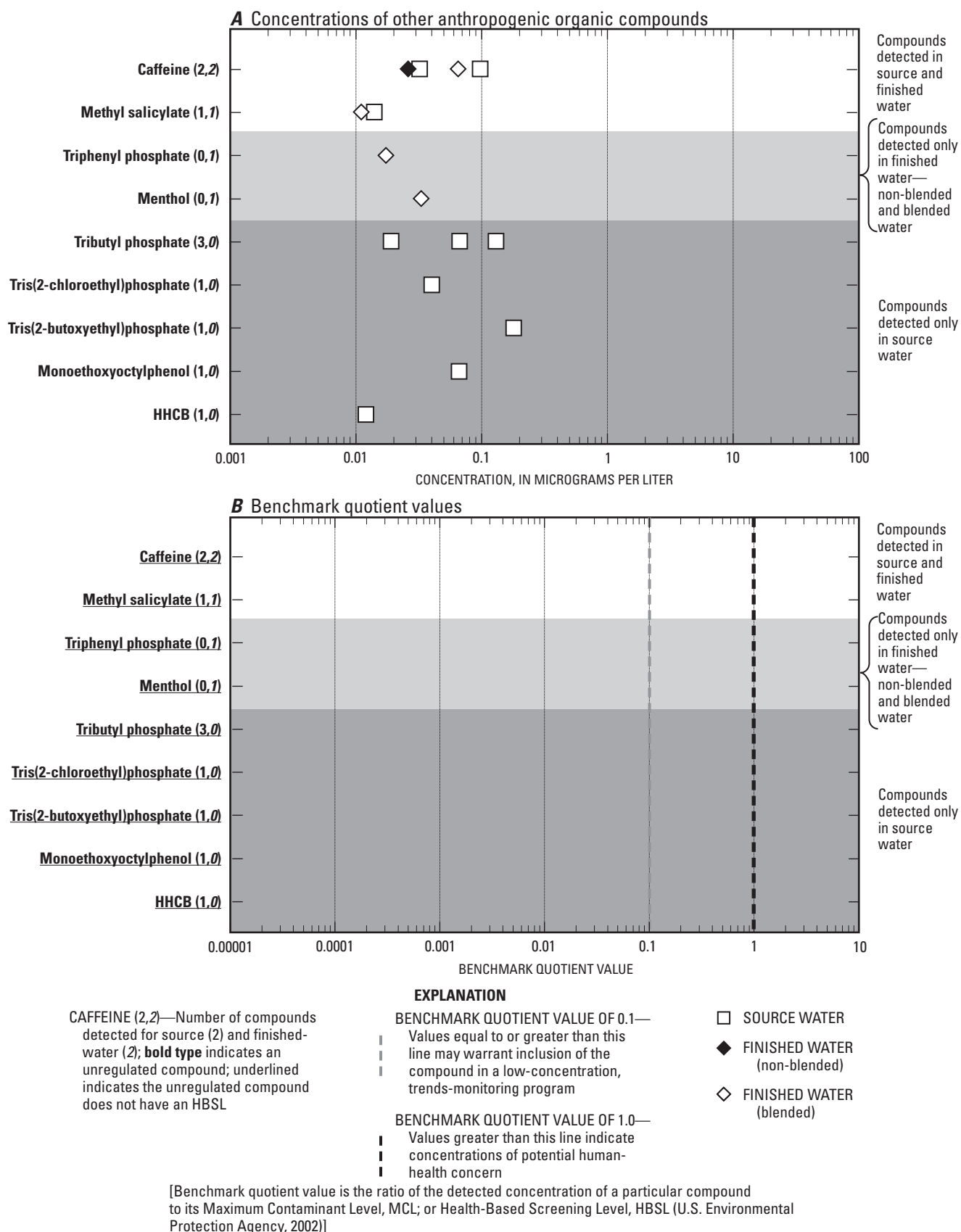


Figure 11. Detected other anthropogenic organic compounds showing (A) concentrations and number of detections, and (B) benchmark quotient values for source and associated finished-water (blended and nonblended) in samples from study area, 2005.

Results indicate that additional monitoring for other AOCs in source water is needed to better understand their potential occurrence in source water and in finished water. Blending of source water makes it difficult to characterize how representative source water is of finished water. Other AOCs present in source-water samples, but not in finished-water samples, may be diluted to undetectable concentrations in the finished water by blending with other source water. Similarly, other AOC compounds present in the finished-water samples, but not in the source-water samples, may have been present in the source water from other wells.

Study Implications Related to Hydrogeologic Setting, Land Use, and Aquifer Productivity

Water-quality results were compared to characterize differences between the aquifers. Of the 40 AOCs detected (a total of 110 individual detections) in source-water samples during phase-1 sampling, detections were more frequent in samples from the Prairie du Chien-Jordan aquifer than in samples from the glacial aquifer (fig. 8). Concentrations of AOC compounds detected in the source water generally were less than concentrations of potential concern (BQmax values greater than or equal to 1.0). Water-quality results from source-water samples were compared to characterize differences between aquifers. There were 30 detections of VOCs in samples from the Prairie du Chien-Jordan aquifer and 5 detections in samples from the glacial aquifer (fig. 8). Pesticide detections, however, were more frequent in samples from the glacial aquifer (35) than in samples from the Prairie du Chien-Jordan aquifer (18). Similar to results for VOCs, other AOCs were detected more frequently in samples from the Prairie du Chien-Jordan aquifer (15 times compared to 7 times in samples from the glacial aquifer) although the median of the concentrations was greater in samples from the glacial aquifer (fig. 8).

These data indicate that hydrogeologic and land-use settings, as well as the productivity of aquifers, play a role in the presence of AOCs in CWS wells. Greater numbers of compounds were detected in samples from the deeper Prairie du Chien-Jordan aquifer compared to samples from the glacial aquifer (Appendix 5). This may indicate that water pumped from wells in the deeper Prairie du Chien-Jordan aquifer integrates larger contributing areas and longer flow paths compared to water pumped from the glacial aquifer. In addition,

fracture flow and bedrock valleys incised in the Prairie du Chien-Jordan aquifer and filled with transmissive glacial drift and fracture flow also may enhance transport of anthropogenic compounds in the Prairie du Chien-Jordan aquifer relative to the glacial aquifer. In contrast, median AOC concentrations were greater in samples from the glacial aquifer, possibly because some of these compounds, like pesticides, are used extensively on the land surface and have a potential to reach ground water through a variety of primary uses and nonpoint applications that exert a greater effect on shallow aquifers. Other AOCs, on the other hand, may have more specific sources and (or) pathways to enter the environment, such as nonpoint source contamination.

VOCs detected in source water do not necessarily help to identify the potential occurrence of VOCs in finished water. Some VOCs are removed during water treatment, and some appear to be introduced to finished water as the result of disinfection. VOCs present in source-water samples, but not in finished-water samples, may be diluted to undetectable concentrations in the finished water by blending with other source water. Similarly, VOCs present in the finished-water samples, but not the source-water samples, may be present in the source water from other wells or may be the result of disinfection processes.

Pesticide compounds detected in source-water samples generally were detected in corresponding finished-water samples (Appendix 5). Results indicate that monitoring for pesticides in source water helps to identify potential occurrence of pesticides in finished water and that water treatment may not remove many of the pesticide compounds. Blending of source water, however, makes it difficult to characterize how representative source water is of finished water. Pesticide compounds detected in source-water samples, but not in finished-water samples, may be diluted to undetectable concentrations in the finished water by blending with other source water. Similarly, pesticide compounds present in finished-water samples, but not in source-water samples, may have been introduced from other wells.

Other AOCs detected in source-water samples also generally help to identify the potential occurrence of other AOCs in finished-water samples and consequently that water treatment may not remove many of the compounds from finished water. Like for pesticides, blending of source water makes it difficult to characterize how representative source water is of finished water. Although HBSLs are not available for some other detected and unregulated AOCs, additional monitoring may be warranted due to their frequent occurrence in source water and presence in finished water.

Summary

In 1991, the U.S. Geological Survey (USGS) began the National Water-Quality Assessment (NAWQA) Program to collect and interpret water-quality information and to make this information available to help address and prioritize issues related to managing and protecting the Nation's water resources. In 2001, the NAWQA Program began its second decade of intensive assessment activities. During its second decade, the NAWQA Program returned to 42 of the original river basin and aquifer study areas to build on the initial assessments and to establish links between sources, transport, and the potential effects of contaminants on humans and aquatic ecosystems. This was accomplished through focused studies. One assessment activity focused on characterizing the quality of major rivers and aquifers used as a source of supply to large community water systems (CWSs). This activity, called a Source Water-Quality Assessment (SWQA), was intended to complement drinking-water monitoring required by Federal, State, and local programs, which focused primarily on post-treatment compliance monitoring.

This report summarizes results from ground-water SWQAs of two important water-supply aquifers—the unconfined part of the glacial aquifer system and the unconfined part of the Prairie du Chien-Jordan aquifer system underlying the Greater Twin Cities metropolitan areas in Minnesota and Wisconsin. Ground-water SWQAs consisted of two sampling phases. The first phase focused on determining the occurrence of 265 (258 are included in this report) anthropogenic organic compounds (AOCs) in the source water of 30 of the largest producing CWS wells in the study area. Forty individual AOCs were detected. AOCs monitored during the first phase included volatile organic compounds (VOCs), pesticides, and other AOCs. The second phase focused on those AOCs that occurred most frequently during the first phase of sampling and characterized their occurrence in source water as well as in the associated finished water of 14 of the CWS wells prior to distribution.

During the first phase of sampling in November and December 2004, concentrations of AOCs detected in the source water generally were low (defined in this report as concentrations less than 1.0 microgram per liter) and generally were less than human-health benchmarks, which include U.S. Environmental Protection Agency Maximum Contaminant Levels for regulated compounds and USGS Health-Based Screening Levels for unregulated compounds. Fifteen VOCs were detected. The compounds *cis*-1,2-dichloroethene, trichloroethene, chloroform, and *trans*-1,2-dichloroethene were the most frequently detected VOC compounds, each being detected in at least 10 percent of the samples. Concentrations of VOCs in source water were low. Seventeen pesticide

compounds were detected in source water. Pesticides generally were detected at lower concentrations than VOCs, and most were derived from atrazine and alachlor and their breakdown products. Human-health benchmarks were available for seven of these compounds. Maximum benchmark quotients for these pesticides typically were several orders of magnitude less than 1.0. Eight other AOCs were detected in the source-water samples, and concentrations generally were low.

During the second phase of sampling, 15 of the original 30 CWS wells, those with the greatest number of AOC detections, were re-sampled along with associated finished water in 2005. Thirteen and 12 VOCs were detected in the source-water and finished-water samples, respectively. Most of the VOCs, except for disinfection by-products, were detected more frequently in source-water samples than in finished-water samples. Disinfection by-products generally had higher concentrations in finished water than in source water. Concentrations of most VOCs detected in either source water or finished water were well below their human-health benchmarks. Twenty-one pesticide compounds were detected in either source water or finished water. The most frequently detected compounds in both the source and the finished water were atrazine and its breakdown products and the breakdown products of alachlor and metolachlor. In general pesticides, if detected in source water, also were detected in the corresponding finished water. Concentrations of detected pesticides in source-water and finished-water samples were low. Concentrations of seven of the pesticides detected in source or finished waters could be compared to human-health benchmarks, and concentrations generally were several orders of magnitude less than the benchmark quotients. Nine other AOCs were detected in the source-water and (or) finished-water samples. Caffeine occurred most frequently but in only two of the source- and finished-water samples. Concentrations of other detected AOCs were low. A human-health benchmark was not available for any of the nine other AOCs detected. Results indicate that monitoring for pesticides in source water generally reflects the occurrence of pesticides in finished water but that this is not necessarily true of VOCs. Additional monitoring is needed to better understand the occurrence of other AOCs in source and finished waters.

Water-quality results were compared to characterize differences between the two aquifers. VOC and other AOC detections were more frequent in the Prairie du Chien-Jordan aquifer compared to the glacial aquifer. However, pesticide detections were more frequent in the glacial aquifer compared to the Prairie du Chien-Jordan aquifer. On the basis of results from this study, the hydrogeologic setting, land use, and aquifer productivity seem to play an important role in the detection of AOCs in CWS wells.

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Appendixes

Appendix 1. Volatile organic compounds analyzed in this study, 2004–05.

[CASR, Chemical Abstracts Service Registry; µg/L, micrograms per liter; shading represents compound detected in source or finished water in this study; **bold type** indicates unregulated compound for which no Federal and (or) State drinking-water standards have been established; --, none]

Regulated or unregulated compound	CASR number	Minimum reporting level (µg/L)	Remarks
1,1,1,2-Tetrachloroethane	630–20–6	0.03	--
1,1,1-Trichloroethane	71–55–6	.032	--
1,1,2,2-Tetrachloroethane	79–34–5	.08	--
1,1,2-Trichloro-1,2,2-trifluoroethane	76–13–1	.038	Also known as Freon 113.
1,1,2-Trichloroethane	79–00–5	.04	--
1,1-Dichloroethane	75–34–3	.035	Used to make other chemicals; solvent.
1,1-Dichloroethene	75–35–4	.024	--
1,1-Dichloropropene	563–58–6	.026	--
1,2,3,4-Tetramethylbenzene	488–23–3	.14	--
1,2,3,5-Tetramethylbenzene	527–53–7	.14	--
1,2,3-Trichlorobenzene	87–61–6	.18	--
1,2,3-Trichloropropane	96–18–4	.18	--
1,2,3-Trimethylbenzene	526–73–8	.06	--
1,2,4-Trichlorobenzene	120–82–1	.12	--
1,2,4-Trimethylbenzene	95–63–6	.056	Used in foam insulation, paints, and thinners.
1,2-Dibromo-3-chloropropane	96–12–8	.51	--
1,2-Dibromoethane	106–93–4	.036	--
1,2-Dichlorobenzene	95–50–1	.048	--
1,2-Dichloroethane	107–06–2	.13	--
1,2-Dichloropropane	78–87–5	.029	--
1,3,5-Trimethylbenzene	108–67–8	.044	--
1,3-Dichlorobenzene	541–73–1	.03	--
1,3-Dichloropropane	142–28–9	.06	--
1,4-Dichlorobenzene	106–46–7	.034	--
1-Ethyl-2-methylbenzene	611–14–3	.06	Also known as <i>o</i> -ethyl toluene.
2,2-Dichloropropane	594–20–7	.05	--
2-Chlorotoluene	95–49–8	.04	--
2-Hexanone	591–78–6	.4	--
3-Chloropropene	107–05–1	.5	--
4-Chlorotoluene	106–43–4	.05	--
4-Methyl-2-pentanone	108–10–1	.37	Used as a solvent, used in paints, varnishes, and lacquers.
Acetone ¹	67–64–1	6	Occurs naturally; manufactured chemical is used to make plastics and other chemicals; a solvent.
Acrylonitrile	107–13–1	.8	--
Benzene	71–43–2	.021	--
Bromobenzene	108–86–1	.028	--
Bromochloromethane	74–97–5	.12	--
Bromodichloromethane	75–27–4	.028	Also known as dichlorobromomethane; by-product when chlorine is added to water-supply systems.

Appendix 1. Volatile organic compounds analyzed in this study, 2004–05.—Continued

[CASR, Chemical Abstracts Service Registry; µg/L, micrograms per liter; shading represents compound detected in source or finished water in this study; **bold type** indicates unregulated compound for which no Federal and (or) State drinking-water standards have been established; --, none]

Regulated or unregulated compound	CASR number	Minimum reporting level (µg/L)	Remarks
Bromoform	75–25–2	0.1	By-product when chlorine is added to water-supply systems.
Bromomethane	74–83–9	.26	--
Carbon disulfide	75–15–0	.038	Occurs naturally; manufactured chemical is used as a solvent in industrial processes.
Carbon tetrachloride	56–23–5	.06	Used as a solvent in dry cleaning; used in fire extinguishers. Also known as tetrachloromethane.
Chlorobenzene	108–90–7	.028	--
Chloroethane	75–00–3	.12	Gasoline additive; used in cellulose, dyes, and medical drugs.
Chloroform	67–66–3	.024	Also known as trichloromethane, by-product when chlorine is added to water-supply systems; used as a solvent.
Chloromethane	74–87–3	.17	Used as a chemical intermediate and in agricultural chemicals (methyl chloride).
<i>cis</i> -1,2-Dichloroethene	156–59–2	.024	Used as a solvent for waxes and resins; used as a refrigerant.
<i>cis</i>-1,3-Dichloropropene	10061–01–5	.05	--
Dibromochloromethane	124–48–1	.1	Also known as chlorodibromomethane; by-product when chlorine is added to water-supply systems.
Dibromomethane	74–95–3	.05	--
Dichlorodifluoromethane	75–71–8	.18	Also known as Freon 112.
Diethyl ether	60–29–7	.08	--
Diisopropyl ether	108–20–3	.1	--
Ethylbenzene	100–41–4	.03	Used in the production of synthetic rubber; a solvent.
Ethyl methacrylate	97–63–2	.18	--
Ethyl <i>tert</i>-butyl ether	637–92–3	.03	Also known as ETBE.
Hexachlorobutadiene	87–68–3	.14	--
Hexachloroethane	67–72–1	.14	--
Iodomethane	74–88–4	.5	Also known as methyl iodide.
Isopropylbenzene	98–82–8	.038	
<i>m</i> - and <i>p</i> -Xylene	<i>m</i> =108–38–3 <i>p</i> =106–42–3	.06	Occurs naturally in petroleum; manufactured chemical is used in chemical processes and pesticides.
Methyl acrylate	96–33–3	1	--
Methyl acrylonitrile	126–98–7	.4	--
Methylene chloride	75–09–2	.06	Also known as dichloromethane.
Methyl ethyl ketone	78–93–3	2	Occurs naturally; manufactured chemical is used in paints and coatings; cleaning agent; exhaust from cars and trucks. Also known as 2-butanone.
Methyl methacrylate	80–62–6	.2	--
Methyl <i>tert</i>-butyl ether	1634–04–4	.1	Also known as MTBE. Gasoline additive.
Naphthalene	91–20–3	.52	Used in the making of polyvinyl chloride (PVC) plastics, moth repellents, and toilet deodorant blocks.
<i>n</i> -Butylbenzene	104–51–8	.12	--
<i>n</i> -Propylbenzene	103–65–1	.042	--

Appendix 1. Volatile organic compounds analyzed in this study, 2004–05.—Continued

[CASR, Chemical Abstracts Service Registry; µg/L, micrograms per liter; shading represents compound detected in source or finished water in this study; **bold type** indicates unregulated compound for which no Federal and (or) State drinking-water standards have been established; --, none]

Regulated or unregulated compound	CASR number	Minimum reporting level (µg/L)	Remarks
<i>o</i> -Xylene	95–47–6	0.038	Used in the production of plastics, dyes, and insecticides.
Perchloroethene	127–18–4	.03	Also known as tetrachloroethene and PCE; primarily used as dry cleaning agent.
<i>p</i>-Isopropyltoluene	99–87–6	.08	Also known as 4-isopropyl-1-methylbenzene.
<i>sec</i>-Butylbenzene	135–98–8	.06	--
<i>tert</i>-Amyl methyl ether	994–05–8	.04	--
<i>tert</i>-Butylbenzene	98–06–6	.06	--
Tetrahydrofuran	109–99–9	1	Industrial solvent and chemical intermediate.
Toluene ¹	108–88–3	.02	--
<i>trans</i>-1,2-Dichloroethene	156–60–5	.032	--
<i>trans</i>-1,3-Dichloropropene	10061–02–6	.09	--
<i>trans</i>-1,4-Dichloro-2-butene	110–57–6	.7	--
Trichloroethene	79–01–6	.038	Also known as TCE; solvent.
Trichlorofluoromethane	75–69–4	.08	Used in refrigeration and air conditioning; foam blowing agents.
Vinyl bromide	593–60–2	.1	Also known as bromoethene.
Vinyl chloride	75–01–4	.08	--

¹Results not included in this report.

Appendix 2. Pesticide compounds analyzed in this study, 2004–05.

[CASR, Chemical Abstracts Service Registry; µg/L, micrograms per liter; shading represents compound detected in source water or finished water in this study; **bold type** indicates unregulated compound for which no Federal and (or) State drinking-water standards have been established; --, none]

Regulated or unregulated compound	CASR number	Minimum reporting level (µg/L)		Remarks
1-Naphthol	90–15–3	0.0882		--
2,4–D	94–75–7	.038	Herbicide.	
2,4–D methyl ester	1928–38–7	.016		--
2,4–DB	94–82–6	.02		--
2,6-Diethylaniline	579–66–8	.006		--
2-Chloro-2,6-diethylacetanilide	6967–29–9	.005		--
2-Ethyl-6-methylaniline	24549–06–2	.0045		--
2-Hydroxyatrazine (OIET)	2163–68–0	.032	Breakdown product of triazines; also referred to as 2-hydroxy-4-isopropylamino-6-ethylamino- <i>s</i> -triazine.	
3(4-Chlorophenyl)-1-methyl urea	5352–88–5	.036		--
3,4-Dichloroaniline	95–76–1	.0045	Herbicide.	
3-Hydroxycarbofuran	16655–82–6	.008		--
3-Ketocarbofuran	16709–30–1	.02		--
4-Chloro-2-methylphenol	1570–64–5	.0057		--
Acetochlor	34256–82–1	.006	Herbicide.	
Acetochlor ESA	187011–11–3	.02		--
Acetochlor OA	--	.02		--
Acifluorfen	50594–66–6	.028		--
Alachlor	15972–60–8	.005	Herbicide.	
Alachlor ESA	14039–15–7	.02		--
Alachlor ESA SA	--	.02		--
Alachlor OA	140939–14–6	.02		--
Aldicarb	116–06–3	.04		--
Aldicarb sulfone	1646–88–4	.018		--
Aldicarb sulfoxide	1646–87–3	.022		--
Atrazine	1912–24–9	.007	Herbicide.	
Azinphos-methyl	86–50–0	.05		--
Azinphos-methyl-oxon	961–22–8	.07		--
Bendiocarb	22781–23–3	.02		--
Benfluralin	1861–40–1	.01	Herbicide.	
Benomyl	17804–35–2	.022		--
Bensulfuron-methyl	83055–99–6	.018		--
Bentazon	25057–89–0	.012	Herbicide.	
Bromacil	314–40–9	.018	Herbicide.	
Bromoxynil	1689–84–5	.028		--
Carbaryl	63–25–2	.018		--
Carbofuran	1563–66–2	.016		--

Appendix 2. Pesticide compounds analyzed in this study, 2004–05.—Continued

[CASR, Chemical Abstracts Service Registry; µg/L, micrograms per liter; shading represents compound detected in source water or finished water in this study; **bold type** indicates unregulated compound for which no Federal and (or) State drinking-water standards have been established; --, none]

Regulated or unregulated compound	CASR number	Minimum reporting level (µg/L)	Remarks
Chloramben, methyl ester	7286–84–2	0.024	--
Chlorimuron-ethyl	90982–32–4	.032	--
Chlorothalonil	1897–45–6	.035	--
Chlorpyrifos	2921–88–2	.005	Herbicide.
Chlorpyrifos, oxygen analog	5598–15–2	.0562	--
<i>cis</i> -Permethrin	54774–45–7	.006	--
Clopyralid	1702–17–6	.024	--
Cycloate	1134–23–2	.014	--
Cyfluthrin	68359–37–5	.008	--
Cypermethrin	52315–07–8	.0086	--
Dacthal	1861–32–1	.003	--
Dacthal monoacid	887–54–7	.028	--
Deethylatrazine (CIAT)	6190–65–4	.006	Breakdown product of triazines; also referred to as 2-chloro-4-isopropylamino-6-amino- <i>s</i> -triazine.
Deisopropylatrazine (CEAT)	1007–28–9	.08	Breakdown product of triazines; also referred to as 2-chloro-6-ethylamino-4-amino- <i>s</i> -triazine.
Desulfinylfipronil	--	.012	--
Desulfinylfipronil amide	--	.029	--
Diazinon	333–41–5	.005	Insecticide.
Diazinon, oxygen analog	962–58–3	.006	--
Dicamba	1918–00–9	.036	--
Dichlorprop	120–36–5	.028	--
Dichlorvos	62–73–7	.0118	--
Dicrotophos	141–66–2	.0843	--
Didealkylatrazine (CAAT)	3397–62–4	.022	Breakdown product of triazines; also referred to as chlordiamino- <i>s</i> -triazine.
Dieldrin	60–57–1	.009	--
Dimethoate	60–51–5	.0061	--
Dinoseb	88–85–7	.038	--
Diphenamid	957–51–7	.01	--
Diuron	330–54–1	.014	--
Ethion	563–12–2	.004	--
Ethion monoxon	17356–42–2	.002	--
Fenamiphos	22224–92–6	.029	--
Fenamiphos sulfone	31972–44–8	.0491	--
Fenamiphos sulfoxide	31972–43–7	.0387	--
Fenuron	101–42–8	.018	--
Fipronil	120068–37–3	.016	--
Fipronil sulfide	120067–83–6	.013	--

Appendix 2. Pesticide compounds analyzed in this study, 2004–05.—Continued

[CASR, Chemical Abstracts Service Registry; µg/L, micrograms per liter; shading represents compound detected in source water or finished water in this study; **bold type** indicates unregulated compound for which no Federal and (or) State drinking-water standards have been established; --, none]

Regulated or unregulated compound	CASR number	Minimum reporting level (µg/L)	Remarks
Fipronil sulfone	120068–36–2	0.024	--
Flufenacet	142459–58–3	.02	--
Flumetsulam	98967–40–9	.04	--
Fluometuron	2164–17–2	.016	--
Fonofos	944–22–9	.003	--
Fonofos, oxygen analog	944–21–8	.0029	--
Hexazinone	51235–04–2	.0129	--
Imazaquin	81335–37–7	.036	--
Imazethapyr	81335–77–5	.038	Herbicide.
Imidacloprid	138261–41–3	.02	Insecticide.
Iprodione	36734–19–7	.387	--
Isofenphos	25311–71–1	.0034	--
Linuron	330–55–2	.014	--
Malaoxon	1634–78–2	.0298	--
Malathion	121–75–5	.027	Insecticide.
MCPA	94–74–6	.03	Herbicide.
MCPB	94–81–5	.01	Herbicide.
Metalaxyl	57837–19–1	.0051	--
Methidathion	950–37–8	.0058	--
Methiocarb	2032–65–7	.01	--
Methomyl	16752–77–5	.02	--
Metolachlor	51218–45–2	.006	--
Metolachlor ESA	--	.02	--
Metolachlor OA	152019–73–3	.02	--
Metribuzin	21087–64–9	.006	--
Metsulfuron methyl	74223–64–6	.025	--
Myclobutanil	88671–89–0	.008	--
N(Ethmethphen)ox ESA	--	.02	--
Neburon	555–37–3	.012	--
Nicosulfuron	111991–09–4	.04	--
Norflurazon	27314–13–2	.02	--
Oryzalin	19044–88–3	.012	Herbicide.
Oxamyl	23135–22–0	.03	--
Paraoxon-methyl	950–35–6	.0299	--
Parathion-methyl	298–00–0	.015	--
Pendimethalin	40487–42–1	.022	--
Phorate	298–02–2	.011	--
Phorate oxygen analog	2600–69–3	.1048	--

Appendix 2. Pesticide compounds analyzed in this study, 2004–05.—Continued

[CASR, Chemical Abstracts Service Registry; µg/L, micrograms per liter; shading represents compound detected in source water or finished water in this study; **bold type** indicates unregulated compound for which no Federal and (or) State drinking-water standards have been established; --, none]

Regulated or unregulated compound	CASR number	Minimum reporting level (µg/L)		Remarks
Phosmet	732–11–6	0.0079		--
Phosmet oxon	3735–33–9	.0511		--
Picloram	2/1/1918	.032	Herbicide.	
Prometon	1610–18–0	.01	Herbicide.	
Prometryn	7287–19–6	.0054		--
Propham	122–42–9	.03		--
Propiconazole	60207–90–1	.01		--
Propoxur	114–26–1	.008		--
Propyzamide	23950–58–5	.004		--
Siduron	1982–49–6	.02		--
Simazine	122–34–9	.005	Herbicide.	
Sulfometuron-methyl	74222–97–2	.038		--
Tebuthiuron	34014–18–1	.016	Herbicide.	
Terbacil	5902–51–2	.016		--
Terbufos	13071–79–9	.017		--
Terbufos oxygen analog sulfone	56070–15–6	.0676		--
Terbuthylazine	5915–41–3	.0102		--
Tribenuron-methyl	101200–48–0	.0088		--
Triclopyr	55335–06–3	.026		--
Trifluralin	1582–09–8	.009		--

Appendix 3. Other anthropogenic organic compounds analyzed in this study, 2004–05.

[CASR, Chemical Abstracts Service Registry; µg/L, micrograms per liter; shading represents compound detected in source water or finished water in this study; **bold type** indicates unregulated compound for which no Federal and (or) State drinking-water standards have been established; --, none]

Regulated or unregulated compound	CASR number	Minimum reporting level (µg/L)	Remarks
1-Methylnaphthalene	90–12–0	0.5	Used in the manufacture of PVC, pharmaceuticals, and insecticides.
2,6-Dimethylnaphthalene	581–42–0	.5	--
2-Methylnaphthalene	91–57–6	.5	Used in the manufacture of PVC, pharmaceuticals, and insecticides.
3- <i>beta</i> -Coprostanol	360–68–9	2	Human and animal waste indicator.
3-Methyl-1(H)-indole	83–34–1	1	Also known as Skatole.
3- <i>tert</i> -Butyl-4-hydroxy anisole (BHA)	25013–16–5	5	--
4-Cumylphenol	599–64–4	1	--
4-Nonylphenol (total) ¹	84852–15–3	5	Used as a surfactant in detergents.
4- <i>n</i> -Octylphenol	1806–26–4	1	--
4- <i>tert</i> -Octylphenol	140–66–9	1	--
5-Methyl-1H-benzotriazole	136–85–6	2	--
Acetophenone	98–86–2	.5	--
Acetyl hexamethyl tetrahydronaphthalene (AHTN)	21145–77–7	.5	--
Anthracene	120–12–7	.5	--
Anthraquinone	84–65–1	.5	--
Benzo[a]pyrene	50–32–8	.5	--
Benzophenone ¹	119–61–9	.5	--
<i>beta</i> -Sitosterol	83–46–5	2	Eukaryotic sterol.
<i>beta</i> -Stigmastanol	19466–47–8	2	Plant sterol; hormone to lower cholesterol.
Bisphenol A	80–05–7	1	--
Caffeine	58–08–2	.012	Stimulant found in coffee and tea.
Camphor	76–22–2	.5	Widely used as a plasticizer in celluloid and lacquers.
Carbazole	86–74–8	.5	--
Cholesterol	57–88–5	2	Sterol found in human and animal body tissue and fat.
Cotinine	486–56–6	1	--
<i>d</i> -Limonene	5989–27–5	.5	--
Fluoranthene	206–44–0	.5	--
Hexahydrohexamethylcyclopentabenzopyran (HHCB)	1222–05–5	.5	--
Indole	120–72–9	.5	Fertilizer; stimulates root growth.
Isoborneol	124–76–5	.5	--
Isophorone ¹	78–59–1	.5	--
Isoquinoline	119–65–3	.5	--
Menthol	89–78–1	.5	--

Appendix 3. Other anthropogenic organic compounds analyzed in this study, 2004–05.—Continued

[CASR, Chemical Abstracts Service Registry; µg/L, micrograms per liter; shading represents compound detected in source water or finished water in this study; **bold type** indicates unregulated compound for which no Federal and (or) State drinking-water standards have been established; —, none]

Regulated or unregulated compound	CASR number	Minimum reporting level (µg/L)	Remarks
Methyl salicylate	119–36–8	0.5	--
N,N,-diethy- <i>meta</i> -toluamide (DEET) ¹	134–62–3	.5	Insect repellant.
Nonylphenol, diethoxy- (total)	26027–38–2	5	--
Octylphenol, diethoxy-	26636–32–8	1	Grouped as ethoxyoctylphenol.
Octylphenol, monoethoxy-	26636–32–8	1	Grouped as ethoxyoctylphenol.
<i>p</i> -Cresol	106–44–5	1	Wood preservative; cleaning agent; solvent.
Pentachlorophenol	87–86–5	2	--
Phenanthrene	85–01–8	.5	--
Phenol ¹	108–95–2	.5	--
Pyrene	129–00–0	.5	--
Tributyl phosphate	126–73–8	.5	--
Triclosan	3380–34–5	1	--
Triethyl citrate (ethyl citrate)	77–93–0	.5	--
Triphenyl phosphate	115–86–6	.5	--
Tris(2-butoxyethyl)phosphate	78–51–3	.5	--
Tris(2-chloroethyl)phosphate (TCEP)	115–96–8	.5	Used as a flame retardant in plastics and foams.
Tris(dichloroisopropyl)phosphate (TCPP)	13674–87–8	.5	Used as a flame retardant in plastics and foams.

¹Results not included in this report.

Appendix 4. Descriptions of human-health benchmarks related to drinking water.

[Maximum Contaminant Levels (MCLs) (Federal and State) are enforceable standards; Health-Based Screening Levels (HBSLs) are not enforceable guidelines; USGS, U.S. Geological Survey; USEPA, U.S. Environmental Protection Agency; OW, Office of Water]

Human-health benchmark	Acronym	Agency	Description	References
Maximum Contaminant Level	MCL	USEPA (OW)	Legally enforceable standard that sets the maximum permissible level of a contaminant in water that is delivered to any user of a public water system. MCLs are set as close as feasible to Maximum Contaminant Level Goals (MCLGs). An MCLG is the maximum level of a contaminant in drinking water at which no known or anticipated adverse effect on the health of persons would occur, and which allows an adequate margin of safety. MCLGs are non-enforceable public health goals that take into account the best available technology, treatment techniques, cost considerations, expert judgment, and public comments.	U.S. Environmental Protection Agency, 2008.
Health-Based Screening Level	HBSL	USGS	Benchmark concentrations of contaminants in water that may be of potential concern for human health, if exceeded. HBSLs are non-enforceable benchmarks that were developed by the USGS in collaboration with USEPA and others using USEPA methodologies for establishing drinking-water guidelines and the most current, USEPA peer-reviewed, publicly available human-health toxicity information.	Toccalino and others, 2003 and 2006.

Appendix 5. Comparison between source and associated finished water for anthropogenic organic compounds detected during this study, 2005.

[E, estimated value; ND, no detection; µg/L, micrograms per liter; **bold type** indicates unregulated compound for which no Federal and (or) State drinking-water standards have been established; * indicates blended water; PDCJ, Prairie du Chien-Jordan aquifer; GLAC, glacial aquifer]

Aquifer	Detected anthropogenic organic compound (regulated or unregulated)	Source-water concentration (µg/L)	Finished-water concentration (blended and nonblended) (µg/L)
Volatile organic compounds			
PDJC	1,1,1-Trichloroethane	5.066	ND*
PDJC	1,1,2-Trichloro-1,2,2-trifluoroethane (Freon-113)	E.184	ND*
PDJC	1,1-Dichloroethane	.131	0.142*
PDJC	1,1-Dichloroethane	5.110	ND*
PDJC	1,1-Dichloroethane	ND	E.052*
PDJC	1,1-Dichloroethene	E.039	ND*
PDJC	1,1-Dichloroethene	7.018	ND*
PDJC	1,1-Dichloroethene	ND	E.018*
PDJC	Benzene	E.016	ND
PDJC	Benzene	E.016	ND*
PDJC	Benzene	.133	.121*
PDJC	Bromodichloromethane ¹	ND	.316
GLAC	Bromodichloromethane ¹	ND	.825
PDJC	Bromodichloromethane ¹	ND	1.206*
PDJC	Bromoform ¹	ND	E.068*
GLAC	Bromoform ¹	ND	E.470*
PDJC	Bromoform ¹	ND	E2.000
GLAC	Bromoform ¹	ND	E8.900
PDJC	Chloroform ¹	E.069	ND*
PDJC	Chloroform ¹	ND	E.054*
PDJC	Chloroform ¹	ND	.491
GLAC	Chloroform ¹	ND	.492
PDJC	Chloroform ¹	ND	1.828*
PDJC	Chloromethane	ND	E.150*
PDJC	<i>cis</i> -1,2-Dichloroethene	E.077	.944*
PDJC	<i>cis</i> -1,2-Dichloroethene	.296	.266
PDJC	<i>cis</i> -1,2-Dichloroethene	1.166	ND*
PDJC	<i>cis</i> -1,2-Dichloroethene	2.401	1.789*
GLAC	<i>cis</i> -1,2-Dichloroethene	ND	E.026
PDJC	Dibromochloromethane ¹	ND	.213
PDJC	Dibromochloromethane ¹	ND	.445*
GLAC	Dibromochloromethane ¹	ND	.841
GLAC	Dichlorodifluoromethane (Freon-112)	E.050	ND
GLAC	Methyl <i>tert</i>-butyl ether (MTBE)	.103	ND
PDJC	Perchloroethene	E.019	E.019
PDJC	Perchloroethene	E.136	ND*
GLAC	Perchloroethene	ND	E.092
PDJC	<i>trans</i> -1,2-Dichloroethene	E.029	ND*
PDJC	<i>trans</i> -1,2-Dichloroethene	.167	.154*
PDJC	<i>trans</i> -1,2-Dichloroethene	.177	.149
PDJC	<i>trans</i> -1,2-Dichloroethene	ND	E.084*

Appendix 5. Comparison between source and associated finished water for anthropogenic organic compounds detected during this study, 2005.—Continued

[E, estimated value; ND, no detection; µg/L, micrograms per liter; **bold type** indicates unregulated compound for which no Federal and (or) State drinking-water standards have been established; * indicates blended water; PDCJ, Prarie du Chien-Jordan aquifer; GLAC, glacial aquifer]

Aquifer	Detected anthropogenic organic compound (regulated or unregulated)	Source-water concentration (µg/L)	Finished-water concentration (blended and nonblended) (µg/L)
Volatile organic compounds—Continued			
PDJC	Trichloroethene	E0.018	E.015
PDJC	Trichloroethene	E.044	.631*
PDJC	Trichloroethene	.322	.253*
PDJC	Trichloroethene	63.970	ND*
GLAC	Trichloroethene	ND	E.048
PDJC	Vinyl chloride	.387	ND*
Pesticides			
PDJC	3-Ketocarbofuran	E0.250	E0.250*
PDJC	3-Ketocarbofuran	E.250	ND*
PDJC	3-Ketocarbofuran	E.250	ND*
GLAC	3-Ketocarbofuran	ND	E.250*
GLAC	Acetochlor ESA	.020	ND*
GLAC	Acetochlor ESA	.040	ND*
PDJC	Acetochlor ESA	ND	.020*
PDJC	Acetochlor OA	ND	.040*
PDJC	Alachlor ESA	.020	.070*
GLAC	Alachlor ESA	.090	.030*
GLAC	Alachlor ESA	.130	.110
PDJC	Alachlor ESA	.140	.120*
GLAC	Alachlor ESA	.170	² .530*
GLAC	Alachlor ESA	.540	² .530*
PDJC	Alachlor ESA SA	.020	ND*
GLAC	Alachlor ESA SA	.100	² .210*
GLAC	Alachlor ESA SA	.130	² .210*
PDJC	Alachlor OA	.020	.020*
GLAC	Alachlor OA	.090	² .320*
GLAC	Alachlor OA	.140	² .320*
PDJC	Alachlor OA	ND	.020*
GLAC	Atrazine	E.007	E.004*
GLAC	Atrazine	0.008	E.005
PDJC	Atrazine	.010	ND*
PDJC	Atrazine	.034	.047*
PDJC	Atrazine	.050	ND*
PDJC	Bromacil	.028	ND*
GLAC	Bromacil	.258	ND
PDJC	Deethylatrazine (CIAT)	E.006	ND*
GLAC	Deethylatrazine (CIAT)	E.009	E.004*
PDJC	Deethylatrazine (CIAT)	E.016	ND*
PDJC	Deethylatrazine (CIAT)	.041	.033*
PDJC	Deisopropylatrazine (CEAT)	E.005	E.006*
GLAC	Deisopropylatrazine (CEAT)	E.052	E.006*

Appendix 5. Comparison between source and associated finished water for anthropogenic organic compounds detected during this study, 2005.—Continued

[E, estimated value; ND, no detection; µg/L, micrograms per liter; **bold type** indicates unregulated compound for which no Federal and (or) State drinking-water standards have been established; * indicates blended water; PDCJ, Prairie du Chien-Jordan aquifer; GLAC, glacial aquifer]

Aquifer	Detected anthropogenic organic compound (regulated or unregulated)	Source-water concentration (µg/L)	Finished-water concentration (blended and nonblended) (µg/L)
Pesticides—Continued			
GLAC	Didealkyatrazine (CAAT)	E0.052	ND*
PDJC	Fenuron	.019	ND*
PDJC	Flufenacet	.020	ND*
GLAC	Flufenacet	.020	ND*
PDJC	Hexazinone	.017	ND*
PDJC	Metolachlor	.020	ND*
PDJC	Metolachlor ESA	.020	0.080*
PDJC	Metolachlor ESA	.020	.080*
GLAC	Metolachlor ESA	.040	² .230*
GLAC	Metolachlor ESA	.100	² .230*
GLAC	Metolachlor ESA	.140	.030*
GLAC	Metolachlor OA	.020	ND*
GLAC	Metolachlor OA	.120	² .620*
GLAC	Metolachlor OA	.410	² .620*
PDJC	Metolachlor OA	ND	.020*
PDJC	Metolachlor OA	ND	.040*
PDJC	Metsulfuron methyl	E.070	E.070*
PDJC	Metsulfuron methyl	E.070	ND*
GLAC	Metsulfuron methyl	ND	E.070*
PDJC	N(Ethmethphen)ox ESA	ND	0.020*
GLAC	Oryzalin	E.010	ND*
GLAC	Prometon	E.009	E.008
Other anthropogenic organic compounds			
GLAC	Caffeine	E0.032	E0.026
GLAC	Caffeine	E.097	E.065*
GLAC	Monoethoxyoctylphenol	E.066	ND
PDJC	Hexahydrohexamethylcyclopentabenzopyran (HHCB)	E.012	ND
GLAC	Menthol	ND	E.033*
GLAC	Methyl salicylate	E.014	E.011*
GLAC	Tributyl phosphate	E.019	ND*
PDJC	Tributyl phosphate	E.067	ND
GLAC	Tributyl phosphate	E.130	ND
PDJC	Triphenyl phosphate	ND	E.017*
GLAC	Tris(2-butoxyethyl)phosphate	E.180	ND
GLAC	Tris(2-chloroethyl)phosphate (TCEP)	E.040	ND

¹Disinfection by-product (DBP).

²One finished-water sample was collected that was paired with two source-water samples due to blending. The same finished-water concentration is shown for both source-water samples.

Tornes, Stark, Hoard, and Smith—**Anthropogenic Organic Compounds in Ground Water and Finished Water of Community Water Systems in the Greater Twin Cities Metropolitan Area, Minnesota and Wisconsin, 2004–05**—Scientific Investigations Report 2007–5273

