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

# Study Design and Analytical Results Used to Evaluate Carry-Over Contamination by Volatile Organic Compounds in Surface- and Ground-Water Sampling Procedures

By Brandon L. Taglioli[1], Gregory C. Delzer[2], and John S. Zogorski[2]

Open-File Report 00-384

[1]South Dakota School of Mines and Technology Contract Student
[2]U.S. Geological Survey, Rapid City, S. Dak.

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

Bruce Babbitt, Secretary

**U.S. Geological Survey**

Charles G. Groat, Director



Rapid City, South Dakota: 2001

**For additional information write to:**

**District Chief**
**U.S. Geological Survey**
**1608 Mt. View Road**
**Rapid City, SD 57702**

**Copies of this report can be purchased from:**

**U.S. Geological Survey**
**Information Services**
**Box 25286**
**Denver, CO 80225-0286**

# FOREWORD

The mission of the U.S. Geological Survey (USGS) is to assess the quantity and quality of the earth resources of the Nation and to provide information that will assist resource managers and policymakers at Federal, State, and local levels in making sound decisions. Assessment of water-quality conditions and trends is an important part of this overall mission.

One of the greatest challenges faced by water-resources scientists is acquiring reliable information that will guide the use and protection of the Nation's water resources. That challenge is being addressed by Federal, State, interstate, and local water-resource agencies and by many academic institutions. These organizations are collecting water-quality data for a host of purposes that include: compliance with permits and water-supply standards; development of remediation plans for a specific contamination problem; operational decisions on industrial, wastewater, or water-supply facilities; and research on factors that affect water quality. An additional need for water-quality information is to provide a basis on which regional and national-level policy decisions can be based. Wise decisions must be based on sound information. As a society we need to know whether certain types of water-quality problems are isolated or ubiquitous, whether there are significant differences in conditions among regions, whether the conditions are changing over time, and why these conditions change from place to place and over time. The information can be used to help determine the efficacy of existing water-quality policies and to help analysts determine the need for and likely consequences of new policies.

To address these needs, the Congress appropriated funds in 1986 for the USGS to begin a pilot program in seven project areas to develop and refine the National Water-Quality Assessment (NAWQA) Program. In 1991, the USGS began full implementation of the program. The NAWQA Program builds upon an existing base of water-quality studies of the USGS, as well as those of other Federal, State, and local agencies. The objectives of the NAWQA Program are to:

- Describe current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers.
- Describe how water quality is changing over time.
- Improve understanding of the primary natural and human factors that affect water-quality conditions.

This information will help support the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies to protect, use, and enhance water resources.

The goals of the NAWQA Program are being achieved through ongoing and proposed investigations of 59 of the Nation's most important river basins and aquifer systems, which are referred to as Study Units. These Study Units are distributed throughout the Nation and cover a diversity of hydrogeologic settings. More than two-thirds of the Nation's freshwater use occurs within the 59 Study Units and more than two-thirds of the people served by public water-supply systems live within their boundaries.

National synthesis of data analysis, based on aggregation of comparable information obtained from the Study Units, is a major component of the program. This effort focuses on selected water-quality topics using nationally consistent information. Comparative studies will explain differences and similarities in observed water-quality conditions among study areas and will identify changes and trends and their causes. The first topics addressed by the national synthesis are pesticides, nutrients, volatile organic compounds, and aquatic biology. Discussions on these and other water-quality topics will be published in periodic summaries of the quality of the Nation's ground and surface water as the information becomes available.

This report is an element of the comprehensive body of information developed as part of the NAWQA Program. The program depends heavily on the advice, cooperation, and information from many Federal, State, interstate, Tribal, and local agencies and the public. The assistance and suggestions of all are greatly appreciated.

Robert M. Hirsch

Chief Hydrologist

# CONTENTS



## FIGURES



## TABLES

## CONVERSION FACTORS

| Multiply | By | To obtain |
|---|---|---|
| foot (ft) | 0.3048 | meter |
| mile (mi) | 1.609 | kilometer |

# Study Design and Analytical Results Used to Evaluate Carry-Over Contamination by Volatile Organic Compounds in Surface- and Ground-Water Sampling Procedures

*By* Brandon L. Taglioli, Gregory C. Delzer, *and* John S. Zogorski

## ABSTRACT

The study described in this report was designed to determine the magnitude, if any, of carry-over contamination of volatile organic compounds (VOCs) in environmental samples resulting from contaminated source solution used to clean the sampling equipment. In general, the study compared the presence of VOCs in environmental samples collected using clean samplers with environmental samples collected after the samplers had been exposed to small concentrations of VOCs during the routine decontamination process. This report documents the study design and presents analytical results from a total of five surface-water samples and six ground-water samples to evaluate carry-over contamination. Results indicate that the VOCs did not carry over from the source solution used to clean sampling equipment to surface-water and ground-water samples collected subsequently. However, additional evaluation of carry-over contamination of methylbenzene in ground-water samples may be warranted.

## INTRODUCTION

### Background

Prior to August 1997, some volatile organic compounds (VOCs) were detected frequently in the source solution used by the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program to collect VOC blank samples. This source solution (hereinafter termed non-nitrogen-purged VOC-grade water) was commercially available. Several of the VOCs present in the non-nitrogen-purged VOC-grade water and respective blank samples also were detected frequently in environmental samples at similar concentrations. These concentrations were generally small—near 0.1 µg/L (micrograms per liter). Notable VOCs detected in the blank samples, non-nitrogen-purged VOC-grade water, and environmental samples included 2-butanone, 1,3 and 1,4-dimethylbenzene, dithiocarbonic anhydride, ethylbenzene, methylbenzene, and 2-propanone.

Similar concentrations of VOCs in environmental samples and blank samples prepared using the non-nitrogen-purged VOC-grade water made it difficult to determine if the detections in the environmental sample were true environmental concentrations or carry-over contamination from the non-nitrogen-purged VOC-grade water used to clean the equipment. Therefore, a new higher quality source solution was prepared at the USGS National Water-Quality Laboratory (NWQL) in Denver, Colorado, and used as part of onsite cleaning protocols in August 1997 and thereafter. This source solution is a commercially available pesticide-grade water that has been purged with nitrogen gas to remove VOCs. This water is hereinafter termed nitrogen-purged VOC-grade water.

The study described in this report was designed to determine the magnitude, if any, of carry-over concentrations of VOCs present in the non-nitrogen-purged VOC-grade water used by the USGS to clean sampling equipment prior to August 1997. In general, the study compared the presence of VOCs in environmental samples collected using clean samplers with environmental samples collected after the samplers had been exposed to small concentrations of VOCs during the routine decontamination process. This study was completed between March and October 1998.

The purpose of this report is to document the study design and present analytical results of the study.

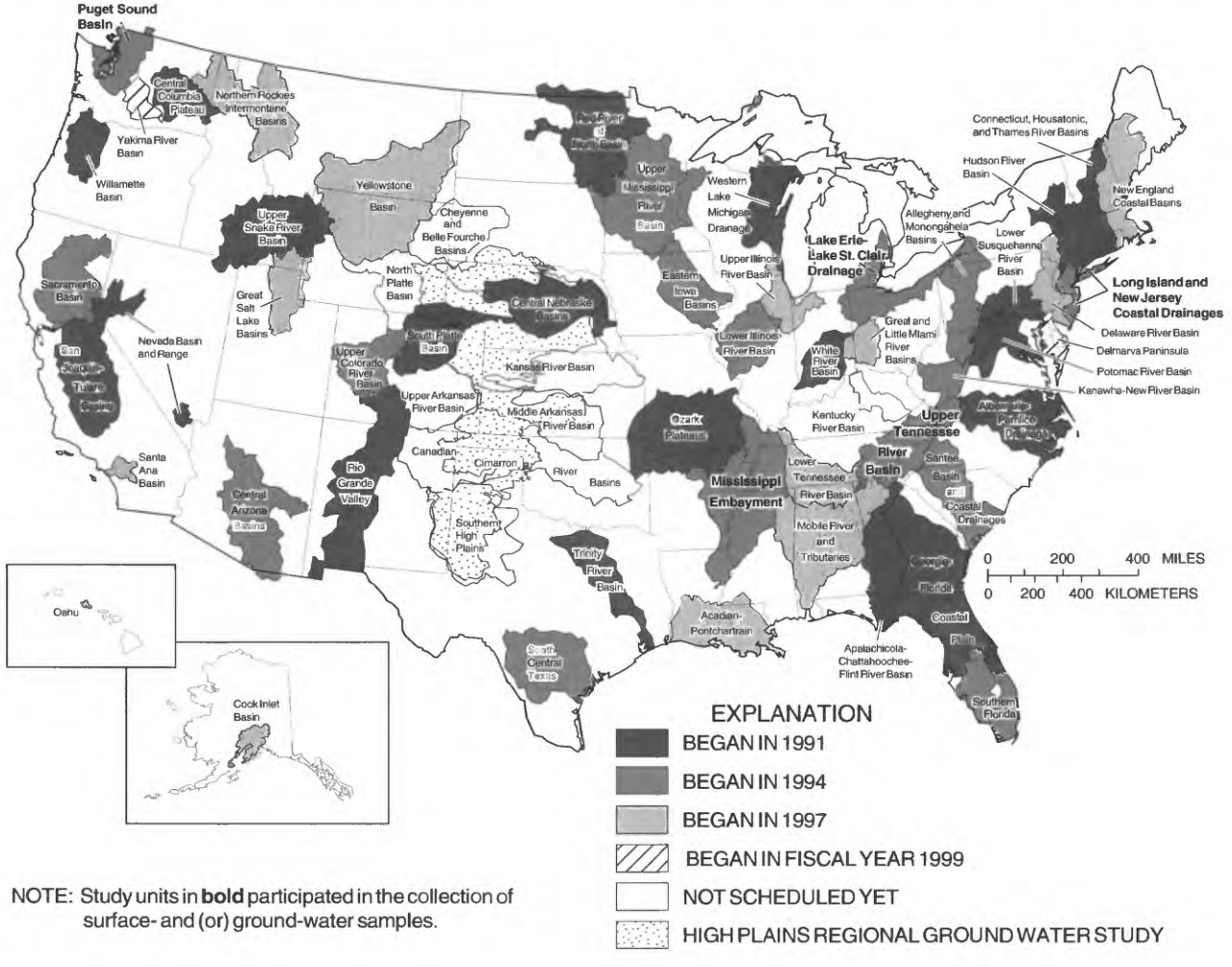
Results of this study will be used to further evaluate the quality of VOC data collected in the NAWQA Program.

## Acknowledgments

The authors acknowledge and thank the many people that assisted in this study. In particular, the authors appreciate the help of project personnel from five USGS NAWQA Study Units who collected surface- and (or) ground-water samples. These Study Units are the Lake Erie-Lake St. Clair Drainage (LERI), the Long Island and New Jersey Coastal Drainages (LINJ), the Mississippi Embayment (MISE), the Puget Sound Basin (PUGT), and the Upper Tennessee River Basin (UTEN), as shown in figure 1. The authors also thank the VOC section of the NWQL, who performed the laboratory analyses of VOC samples.

## STUDY DESIGN

This study was intended to determine if the non-nitrogen-purged VOC-grade water used during equipment-cleaning procedures prior to August 1997 contaminated subsequently collected surface- and ground-water samples. In addition, this study provides some insight about the ability of rinsing protocols to remove small concentrations of VOCs that may otherwise carry over from environmental sample to environmental sample. To make these determinations, the nitrogen-purged VOC-grade water currently used in equipment cleaning was spiked with as many as 87 VOCs to achieve a theoretical concentration of 0.1 µg/L for most VOCs. This spiked water is hereinafter termed spiked, nitrogen-purged VOC-grade water. Table 1 lists the 87 VOCs spiked into the nitrogen-purged VOC-grade water. The same analytes are included on the NWQL's low-level VOC method (schedule 2020) that is used in the NAWQA Program.




NOTE: Study units in **bold** participated in the collection of surface- and (or) ground-water samples.

**Figure 1.** Location of National Water-Quality Assessment Program Study Units and their proposed implementation dates (modified from Gilliom and others, 1995).

**Table 1.** Volatile organic compounds analyzed as part of the U.S. Geological Survey National Water-Quality Assessment Program

[Compounds are identified by the following: PCODE, U.S. Geological Survey parameter code; CAS number, Chemical Abstract Services number; IUPAC compound name, International Union of Pure and Applied Chemistry compound name]

| PCODE | CAS number | IUPAC compound name | PCODE | CAS number | IUPAC compound name |
|---|---|---|---|---|---|
| | | **Target Analytes** | | | |
| 34030 | 71-43-2 | Benzene ($C_6H_6$) | 34541 | 78-87-5 | 1,2-Dichloropropane ($C_3H_6Cl_2$) (propylene dichloride) |
| 32101 | 75-27-4 | Bromodichloromethane ($CHBrCl_2$) (dichlorobromomethane) | 34704 | 10061-01-5 | *cis*-1,3-Dichloropropene ($C_3H_4Cl_2$) ((Z)-1,3-dichloropropene) |
| 50002 | 593-60-2 | Bromoethene ($C_2H_3Br$) (vinyl bromide) | 34699 | 10061-02-6 | *trans*-1,3-Dichloropropene ($C_3H_4Cl_2$) ((E)-1,3-dichloropropene) |
| 34413 | 74-83-9 | Bromomethane ($CH_3Br$) (methyl bromide) | 77135 | 95-47-6 | 1,2-Dimethylbenzene ($C_8H_{10}$) (*o*-xylene) |
| 77342 | 104-51-8 | *n*-Butylbenzene ($C_{10}H_{14}$) (1-phenylbutane) | 85795 | 108-38-3 | 1,3-Dimethylbenzene ($C_8H_{10}$) (*m*-xylene) and |
| 34301 | 108-90-7 | Chlorobenzene ($C_6H_5Cl$) (monochlorobenzene) | | 106-42-3 | 1,4-Dimethylbenzene ($C_8H_{10}$) (*p*-xylene) |
| 34311 | 75-00-3 | Chloroethane ($C_2H_5Cl$) (ethyl chloride) | 77128 | 100-42-5 | Ethenylbenzene ($C_8H_8$) (styrene) |
| 39175 | 75-01-4 | Chloroethene ($C_2H_3Cl$) (vinyl chloride) | 50004 | 637-92-3 | 2-Ethoxy-2-methylpropane ($C_6H_{14}O$) (ethyl *tert*-butyl ether, ETBE) |
| 34418 | 74-87-3 | Chloromethane ($CH_3Cl$) (methyl chloride) | 34371 | 100-41-4 | Ethylbenzene ($C_8H_{10}$) (phenylethane) |
| 82625 | 96-12-8 | 1,2-Dibromo-3-chloropropane ($C_3H_5Br_2Cl$) (dibromochloropropane, DBCP) | 39702 | 87-68-3 | 1,1,2,3,4,4-Hexachloro-1,3-butadiene ($C_4Cl_6$) (hexachlorobutadiene) |
| 32105 | 124-48-1 | Dibromochloromethane ($CHBr_2Cl$) (chlorodibromomethane) | 34396 | 67-72-1 | 1,1,1,2,2,2-Hexachloroethane ($C_2Cl_6$) (carbon hexachloride) |
| 77651 | 106-93-4 | 1,2-Dibromoethane ($C_2H_4Br_2$) (ethylene dibromide, EDB) | 50005 | 994-05-8 | 2-Methoxy-2-methylbutane ($C_6H_{14}O$) (*tert*-amyl methyl ether, TAME) |
| 34536 | 95-50-1 | 1,2-Dichlorobenzene ($C_6H_4Cl_2$) (*o*-dichlorobenzene) | 78032 | 1634-04-4 | 2-Methoxy-2-methylpropane ($C_5H_{12}O$) (methyl *tert*-butyl ether, MTBE) |
| 34566 | 541-73-1 | 1,3-Dichlorobenzene ($C_6H_4Cl_2$) (*m*-dichlorobenzene) | 34010 | 108-88-3 | Methylbenzene ($C_7H_8$) (toluene) |
| 34571 | 106-46-7 | 1,4-Dichlorobenzene ($C_6H_4Cl_2$) (*p*-dichlorobenzene) | 77223 | 98-82-8 | (1-Methylethyl)benzene ($C_9H_{12}$) (isopropylbenzene) |
| 34668 | 75-71-8 | Dichlorodifluoromethane ($CCl_2F_2$) (CFC 12) | 34696 | 91-20-3 | Naphthalene ($C_{10}H_8$) (arrylonitrite) |
| 34496 | 75-34-3 | 1,1-Dichloroethane ($C_2H_4Cl_2$) (ethylidene chloride) | 81577 | 108-20-3 | 2,2'-Oxybis[propane] ($C_6H_{14}O$) (diisopropyl ether, DIPE) |
| 32103 | 107-06-2 | 1,2-Dichloroethane ($C_2H_4Cl_2$) (ethylene dichloride) | 34210[1] | 107-02-8 | 2-Propenal ($C_3H_4O$) (acrolein) |
| 34501 | 75-35-4 | 1,1-Dichloroethene ($C_2H_2Cl_2$) (vinylidene chloride) | 34215 | 107-13-1 | 2-Propenenitrile ($C_3H_3N$) |
| 77093 | 156-59-2 | *cis*-1,2-Dichloroethene ($C_2H_2Cl_2$) ((Z)-1,2-dichloroethene) | 77224 | 103-65-1 | *n*-Propylbenzene ($C_9H_{12}$) (1-phenylpropane) |
| 34546 | 156-60-5 | *trans*-1,2-Dichloroethene ($C_2H_2Cl_2$) ((E)-1,2-dichloroethene) | 34475 | 127-18-4 | Tetrachloroethene ($C_2Cl_4$) (perchloroethene, PCE) |
| 34423 | 75-09-2 | Dichloromethane ($CH_2Cl_2$) (methylene chloride) | 32102 | 56-23-5 | Tetrachloromethane ($CCl_4$) (carbon tetrachloride) |

**Table 1.** Volatile organic compounds analyzed as part of the U.S. Geological Survey National Water-Quality Assessment Program–Continued

[Compounds are identified by the following: PCODE, U.S. Geological Survey parameter code; CAS number, Chemical Abstract Services number; IUPAC compound name, International Union of Pure and Applied Chemistry compound name]

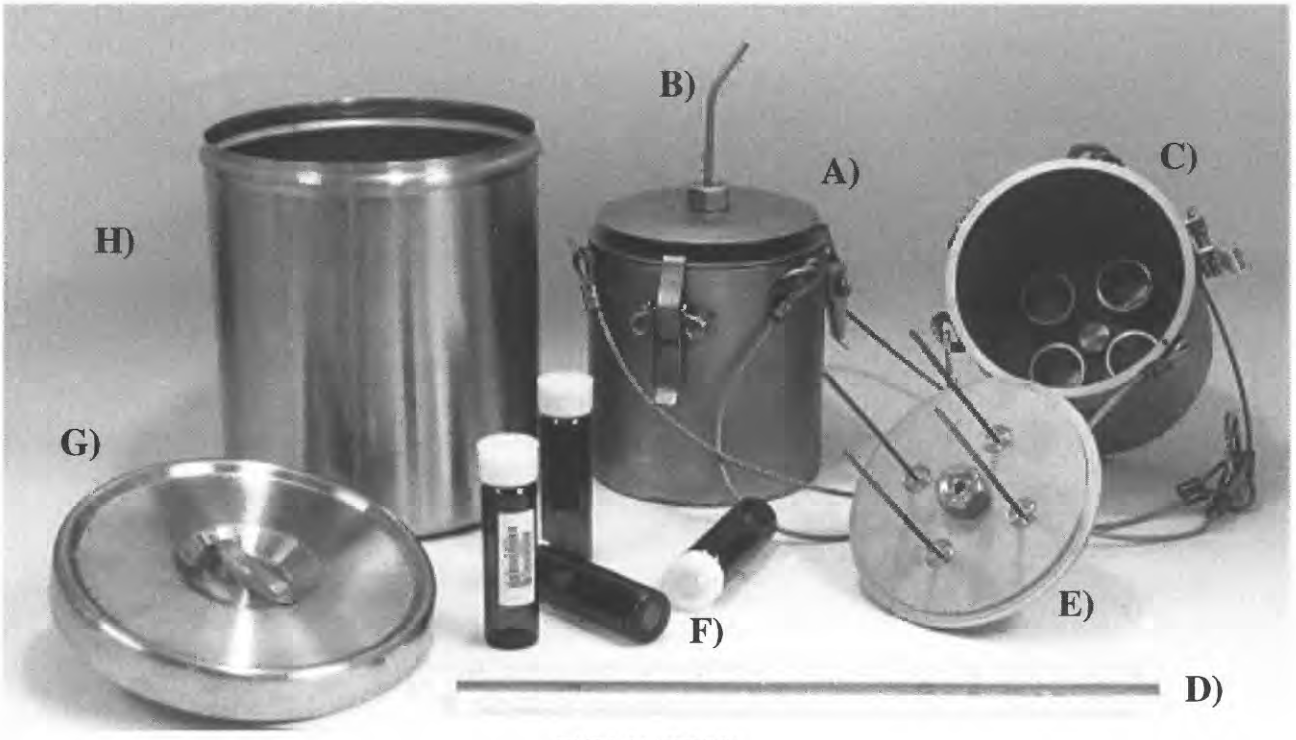
| PCODE | CAS number | IUPAC compound name | PCODE | CAS number | IUPAC compound name |
|---|---|---|---|---|---|
| | | **Target Analytes—Continued** | | | |
| 32104 | 75-25-2 | Tribromomethane ($CHBr_3$) (bromoform) | 39180 | 79-01-6 | 1,1,2-Trichloroethene ($C_2HCl_3$) (trichloroethylene, TCE) |
| 77652 | 76-13-1 | 1,1,2-Trichloro-1,2,2-trifluoroethane ($C_2Cl_3F_3$) (CFC 113) | 34488 | 75-69-4 | Trichlorofluoromethane ($CCl_3F$) (CFC 11) |
| 77613 | 87-61-6 | 1,2,3-Trichlorobenzene ($C_6H_3Cl_3$) | 32106 | 67-66-3 | Trichloromethane ($CHCl_3$) (chloroform) |
| 34551 | 120-82-1 | 1,2,4-Trichlorobenzene ($C_6H_3Cl_3$) | 77443 | 96-18-4 | 1,2,3-Trichloropropane ($C_3H_5Cl_3$) (allyl trichloride) |
| 34506 | 71-55-6 | 1,1,1-Trichloroethane ($C_2H_3Cl_3$) (methyl chloroform) | 77222 | 95-63-6 | 1,2,4-Trimethylbenzene ($C_9H_{12}$) (pseudocumene) |
| 34511 | 79-00-5 | 1,1,2-Trichloroethane ($C_2H_3Cl_3$) (vinyl trichloride) | | | |
| | | **Other Analytes** | | | |
| 81555 | 108-86-1 | Bromobenzene ($C_6H_5Br$) (phenyl bromide) | 77103 | 591-78-6 | 2-Hexanone ($C_6H_{12}O$) (butyl methyl ketone, MBK) |
| 77297 | 74-97-5 | Bromochloromethane ($CH_2BrCl$) (methylene chlorobromide) | 77424 | 74-88-4 | Iodomethane ($CH_3I$) (methyl iodide) |
| 81595 | 78-93-3 | 2-Butanone ($C_4H_8O$) (methyl ethyl ketone, MEK) | 77356 | 99-87-6 | 1-Isopropyl-4-methylbenzene ($C_{10}H_{14}$) (*p*-isopropyltoluene) |
| 77041 | 75-15-0 | Dithiocarbonic anhydride ($CS_2$) (carbon disulfide) | 81597 | 80-62-6 | Methyl 2-methyl-2-propenoate ($C_5H_8O_2$) (methyl methacrylate) |
| 77275 | 95-49-8 | 1-Chloro-2-methylbenzene ($C_7H_7Cl$) (*o*-chlorotoluene) | 78133 | 108-10-1 | 4-Methyl-2-pentanone ($C_6H_{12}O$) (isobutyl methyl ketone, MIK) |
| 77277 | 106-43-4 | 1-Chloro-4-methylbenzene ($C_7H_7Cl$) (*p*-chlorotoluene) | 81593 | 126-98-7 | 2-Methyl-2-propenenitrile ($C_4H_5N$) (methyl acrylonitrile) |
| 78109 | 107-05-1 | 3-Chloro-1-propene ($C_3H_5Cl$) (allyl chloride) | 49991 | 96-33-3 | Methyl-2-propenoate ($C_4H_6O_2$) (methyl acrylate) |
| 30217 | 74-95-3 | Dibromomethane ($CH_2Br_2$) (methylene bromide) | 77350 | 135-98-8 | (1-Methylpropyl)benzene ($C_{10}H_{14}$) (*sec*-butylbenzene) |
| 73547 | 110-57-6 | *trans*-1,4-Dichloro-2-butene ($C_4H_6Cl_2$) ((E)-1,4-dichloro-2-butene) | 81576 | 60-29-7 | 1,1'-Oxybisethane ($C_4H_{10}O$) (diethyl ether) |
| 77173 | 142-28-9 | 1,3-Dichloropropane ($C_3H_6Cl_2$) (trimethylene dichloride) | 81552 | 67-64-1 | 2-Propanone ($C_3H_6O$) (acetone) |
| 77170 | 594-20-7 | 2,2-Dichloropropane ($C_3H_6Cl_2$) | 77562 | 630-20-6 | 1,1,1,2-Tetrachloroethane ($C_2H_2Cl_4$) |
| 77168 | 563-58-6 | 1,1-Dichloropropene ($C_3H_4Cl_2$) | 34516 | 79-34-5 | 1,1,2,2-Tetrachloroethane ($C_2H_2Cl_4$) |
| 77353 | 98-06-6 | (1,1-Dimethylethyl)benzene ($C_{10}H_{14}$) (*tert*-butylbenzene) | 49999 | 488-23-3 | 1,2,3,4-Tetramethylbenzene ($C_{10}H_{14}$) (prehitene) |
| 81607 | 109-99-9 | 1,4-Epoxybutane ($C_4H_8O$) (tetrahydrofuran) | 50000 | 527-53-7 | 1,2,3,5-Tetramethylbenzene ($C_{10}H_{14}$) (isodurene) |
| 77220 | 611-14-3 | 1-Ethyl-2-methylbenzene ($C_9H_{12}$) (2-ethyltoluene) | 77221 | 526-73-8 | 1,2,3-Trimethylbenzene ($C_9H_{12}$) (hemimellitene) |
| 73570 | 97-63-2 | Ethyl 2-methyl-2-propenoate ($C_6H_{10}O_2$) (ethyl methacrylate) | 77226 | 108-67-8 | 1,3,5-Trimethylbenzene ($C_9H_{12}$) (mesitylene) |

[1]Not analyzed after April 30, 1998.

The analytes in table 1 are divided into two groups—target analytes (55 compounds) and other analytes (32 compounds). The compounds 1,3- and 1,4-dimethylbenzene are listed as individual target analytes in table 1; however, the NWQL reports the concentration sum of these two compounds because these isomers coelute and cannot be separated by the purge-and-trap gas chromatography/mass spectrometry method (Connor and others, 1998). NAWQA target analytes were selected because of their known human-health and (or) aquatic-life concern, or because of their high frequency of occurrence in surface water and ground water, or because of their potential for large-scale use in commerce (Bender and others, 1999). The "other analytes" were included on the NWQL's VOC schedule because they are analyzed as part of the U.S. Environmental Protection Agency's revised method for drinking-water samples (Connor and others, 1998). The NWQL discontinued analysis of 2-propenal as a VOC target analyte on April 30, 1998.

## SURFACE-WATER SAMPLES

Prior to August 1997, surface-water equipment was decontaminated according to procedures specified in Shelton (1997). These sampling procedures indicate that field-equipment blank samples are to be collected after equipment decontamination and immediately before the routine surface-water sample. After decontamination, the sampler (fig. 2) is rinsed three




EXPLANATION

A) ASSEMBLED VOC HAND SAMPLER EVALUATED FOR COLLECTION OF VOLATILE ORGANIC COMPOUNDS (VOCs) AND COMPONENT PARTS/RELATED ITEMS

B) REPLACEABLE AIR EXHAUST TUBE

C) INSIDE OF BODY OF VOC HAND SAMPLER SHOWING HOLDER FOR VOLATILE ORGANIC ANALYSIS (VOA) VIALS

D) ENGINEER'S SCALE FOR REFERENCE (APPROXIMATELY 12 INCHES IN LENGTH)

E) BOTTOM OF VOC HAND SAMPLER LID SHOWING REPLACEABLE FILLING PORTS

F) VOA VIALS

G) CANISTER LID

H) CANISTER USED TO PROCESS FIELD BLANKS

**Figure 2.** Volatile organic compound hand sampler used for collection of surface-water samples.

times with native water before collection of the surface-water sample. The surface-water phase of this study tests the assumption that this native-water rinsing process removes the residual contamination, if any, that may have resulted from the non-nitrogen-purged VOC-grade water used during decontamination procedures prior to August 1997.

## Sampling Procedures

A field-blank sample was first collected from spiked, nitrogen-purged VOC-grade water in a stainless-steel container using the VOC hand sampler (sample 1). The VOC hand sampler subsequently was rinsed three times with the native stream water. Then, a surface-water sample was collected from the stream (sample 2) with the VOC hand sampler while a hand-dipped sample was collected concurrently near the same stream location (sample 3). Halde and others (1999) indicate that hand dipping a sample is statistically the same as using the VOC hand sampler. Occasionally, sample 3 was collected with a separate (pre-cleaned) VOC hand sampler. Sample 3 is representative of a surface-water sample collected according to procedures specified in Shelton (1997). Concentrations of carry-over VOCs from decontamination procedures to environmental samples would be characterized primarily through comparison of sample 2 and sample 3.

Each of the three samples just mentioned was collected on five different occasions at four different surface-water sites (table 2). Two samples were collected from one site in the LERI Study Unit, one sample was collected from each of two different sites in the LINJ Study Unit, and one sample was collected from one site in the PUGT Study Unit.

## Analytical Results

The results of the analysis of field-blank samples containing spiked, nitrogen-purged VOC-grade water (sample 1) are listed in table 3. Detected VOC concentrations ranged from 0.0067 to 11.7 µg/L. All VOCs analyzed were detected in the samples from the LINJ and PUGT Study Units. The LERI Study Unit samples were spiked with a solution containing only 13 primary VOCs. However, this solution was contaminated with five additional VOCs. All 18 VOCs were detected.

The data for the VOC hand sampler that had been exposed to the spiked, nitrogen-purged VOC-grade water (sample 2) and the hand-dipped surface-water sample (sample 3) are listed in appendix 1. Seventy-six of the 87 VOCs analyzed were not detected in surface-water samples 2 and 3. Eleven VOCs—benzene; cis-1,2-dichloroethene; 1,2-dimethylbenzene; 1,3 and 1,4-dimethylbenzene; ethylbenzene; 2-methoxy-2-methylpropane; methylbenzene; 1,1,2-trichloroethene; trichloromethane; and 1,2,4-trimethylbenzene—were detected a total of 21 times in both sample 2 and sample 3 at similar concentrations (table 4). Three VOCs—benzene; chloromethane; and 1,2,4-trimethylbenzene—were detected at small concentrations (less than 0.015 µg/L) in sample 3 but not in sample 2. Furthermore, 2-methoxy-2-methylpropane was the only VOC detected in sample 2 and not in sample 3.

Figure 3 compares concentrations of 87 VOCs in samples collected using a VOC hand sampler, which was exposed to low levels of VOCs during the prior decontamination process, with concentrations in hand-dipped samples. In figure 3, VOC concentrations that were not detected were given a value of 0.001 µg/L for plotting purposes. Results indicate that the VOCs did not carry over from the spiked, nitrogen-purged VOC-grade water used to clean sampling equipment to surface-water samples collected subsequently.

**Table 2.** Summary of surface-water samples collected and used for evaluation of carry-over contamination

[VOC, volatile organic compound]

| Procedure sample number | Description | Total number of samples collected at four sites |
|---|---|---|
| 1 | Field-blank sample containing spiked, nitrogen-purged VOC-grade water using VOC hand sampler. | 5 |
| 2 | Environmental sample collected using the VOC hand sampler that had been exposed to the spiked, nitrogen-purged VOC-grade water and rinsed three times with native stream water. | 5 |
| 3 | Environmental sample collected by hand dipping a sample vial or using a separate VOC hand sampler concurrently with sample 2. | 5 |

**Table 3.** Concentrations of volatile organic compounds (VOCs) detected in spiked, nitrogen-purged VOC-grade water (sample 1) from three Study Units of the National Water-Quality Assessment Program

[All samples were spiked, nitrogen-purged VOC-grade water. IUPAC, International Union of Pure and Applied Chemistry; E, estimated; <, less than; NA, not analyzed]

| VOC (IUPAC compound name) | VOC concentrations in sample 1 from three Study Units (fig. 1) (micrograms per liter) | | | | |
|---|---|---|---|---|---|
| | Lake Erie-Lake St. Clair Drainage Study Unit | | Long Island and New Jersey Coastal Drainages Study Unit | | Puget Sound Basin Study Unit |
| | Site A | Site A[1] | Site A | Site B | Site A |
| | | Target Analytes | | | |
| Benzene | E 0.013 | E 0.022 | 0.152 | 0.155 | 0.170 |
| Bromodichloromethane | .104 | E .078 | .214 | .178 | .185 |
| Bromoethene | <.100 | <.100 | .240 | .279 | .362 |
| Bromomethane | <.148 | <.148 | E .418 | E .560 | E .260 |
| *n*-Butylbenzene | <.186 | <.186 | .403 | .524 | .548 |
| Chlorobenzene | <.028 | <.028 | .135 | .156 | .141 |
| Chloroethane | <.120 | <.120 | .316 | .375 | .449 |
| Chloroethene | <.112 | E .028 | .180 | .252 | .342 |
| Chloromethane | <.254 | <.254 | E .594 | E .800 | E .780 |
| 1,2-Dibromo-3-chloropropane | <.214 | <.214 | .989 | .857 | .653 |
| Dibromochloromethane | E .092 | E .066 | .801 | .703 | .651 |
| 1,2-Dibromoethane | <.036 | <.036 | .203 | .188 | .179 |
| 1,2-Dichlorobenzene | <.048 | <.048 | .213 | .194 | .153 |
| 1,3-Dichlorobenzene | <.054 | <.054 | .178 | .173 | .139 |
| 1,4-Dichlorobenzene | E .089 | .092 | .169 | .169 | .143 |
| Dichlorodifluoromethane | <.096 | <.096 | E .098 | E .170 | E .220 |
| 1,1-Dichloroethane | <.066 | <.066 | .257 | .228 | .280 |
| 1,2-Dichloroethane | E .100 | .097 | .660 | .496 | .548 |
| 1,1-Dichloroethene | E .052 | E .043 | .102 | .116 | .165 |
| *cis*-1,2-Dichloroethene | <.038 | <.038 | .158 | .152 | .168 |
| *trans*-1,2-Dichloroethene | <.032 | <.032 | .137 | .139 | .205 |
| Dichloromethane | <.382 | <.382 | 1.55 | 1.40 | 1.79 |
| 1,2-Dichloropropane | <.068 | <.068 | .268 | .235 | .254 |
| *cis*-1,3-Dichloropropene | <.092 | <.092 | .286 | .290 | .266 |
| *trans*-1,3-Dichloropropene | <.134 | <.134 | .437 | .470 | .421 |
| 1,2-Dimethylbenzene | <.064 | <.064 | .144 | .194 | .184 |
| 1,3 and 1,4-Dimethylbenzene | E .021 | E .015 | .295 | .391 | .377 |
| Ethenylbenzene | <.042 | <.042 | .152 | .173 | .143 |
| 2-Ethoxy-2-methylpropane | <.054 | <.054 | .134 | .161 | .168 |
| Ethylbenzene | E .081 | E .065 | .100 | .151 | .148 |

**Table 3.** Concentrations of volatile organic compounds (VOCs) detected in spiked, nitrogen-purged VOC-grade water (sample 1) from three Study Units of the National Water-Quality Assessment Program–Continued

[All samples were spiked, nitrogen-purged VOC-grade water. IUPAC, International Union of Pure and Applied Chemistry; E, estimated; <, less than; NA, not analyzed]

| VOC (IUPAC compound name) | VOC concentrations in sample 1 from three Study Units (fig. 1) (micrograms per liter) | | | | |
|---|---|---|---|---|---|
| | Lake Erie-Lake St. Clair Drainage Study Unit | | Long Island and New Jersey Coastal Drainages Study Unit | | Puget Sound Basin Study Unit |
| | Site A | Site A[1] | Site A | Site B | Site A |
| **Target Analytes—Continued** | | | | | |
| 1,1,2,3,4,4-Hexachloro-1,3-butadiene | <0.142 | <0.142 | 0.332 | 0.371 | 0.371 |
| 1,1,1,2,2,2- Hexachloroethane | <.362 | <.362 | 1.41 | 1.51 | 1.01 |
| 2-Methoxy-2-methylbutane | <.112 | <.112 | .308 | .364 | .331 |
| 2-Methoxy-2-methylpropane | .116 | E .100 | .394 | .377 | .448 |
| Methylbenzene | <.038 | E .036 | E .150 | .154 | .163 |
| (1-Methylethyl)benzene | <.032 | <.032 | .103 | .145 | .146 |
| Naphthalene | <.250 | <.250 | .837 | .925 | .748 |
| 2,2'-Oxybis[propane] | <.098 | <.098 | .361 | .330 | .387 |
| 2-Propenal | NA | NA | <250 | <250 | <250 |
| 2-Propenenitrile | <1.23 | <1.23 | E 9.59 | 7.61 | E 7.25 |
| *n*-Propylbenzene | <.042 | <.042 | .126 | .142 | .139 |
| Tetrachloroethene | E .057 | E .041 | .176 | .188 | E .410 |
| Tetrachloromethane | E .045 | E .032 | .342 | .402 | .255 |
| Tribromomethane | .103 | E .078 | .403 | .370 | .322 |
| 1,1,2-Trichloro-1,2,2-trifluoroethane | <.032 | <.032 | E .046 | E .059 | E .076 |
| 1,2,3-Trichlorobenzene | <.266 | <.266 | .932 | .981 | .805 |
| 1,2,4-Trichlorobenzene | <.188 | <.188 | .610 | .675 | .553 |
| 1,1,1-Trichloroethane | E .060 | E .052 | .124 | .126 | .165 |
| 1,1,2-Trichloroethane | <.064 | <.064 | .269 | .240 | .223 |
| 1,1,2-Trichloroethene | E .082 | E .065 | .133 | .139 | .168 |
| Trichlorofluoromethane | <.092 | <.092 | .126 | .145 | .220 |
| Trichloromethane | <.052 | <.052 | .208 | .178 | .198 |
| 1,2,3-Trichloropropane | <.070 | <.070 | .348 | .321 | .245 |
| 1,2,4-Trimethylbenzene | <.056 | E .007 | .190 | .230 | .193 |
| **Other Analytes** | | | | | |
| Bromobenzene | <.036 | <.036 | .164 | .181 | .131 |
| Bromochloromethane | <.044 | <.044 | .210 | .177 | .178 |
| 2-Butanone | <1.65 | <1.65 | 7.11 | 6.27 | 7.09 |
| Dithiocarbonic anhydride | <.080 | <.080 | .180 | .198 | E .340 |
| 1-Chloro-2-methylbenzene | <.042 | <.042 | .142 | .162 | .144 |
| 1-Chloro-4-methylbenzene | <.056 | <.056 | .188 | .202 | .186 |

**Table 3.** Concentrations of volatile organic compounds (VOCs) detected in spiked, nitrogen-purged VOC-grade water (sample 1) from three Study Units of the National Water-Quality Assessment Program–Continued

[All samples were spiked, nitrogen-purged VOC-grade water. IUPAC, International Union of Pure and Applied Chemistry; E, estimated; <, less than; NA, not analyzed]

| VOC (IUPAC compound name) | VOC concentrations in sample 1 from three Study Units (fig. 1) (micrograms per liter) | | | | |
|---|---|---|---|---|---|
| | Lake Erie-Lake St. Clair Drainage Study Unit | | Long Island and New Jersey Coastal Drainages Study Unit | | Puget Sound Basin Study Unit |
| | Site A | Site A[1] | Site A | Site B | Site A |
| **Other Analytes—Continued** | | | | | |
| 3-Chloro-1-propene | <0.196 | <0.196 | 0.228 | 0.243 | 0.355 |
| Dibromomethane | <.050 | <.050 | .226 | .190 | .189 |
| *trans*-1,4-Dichloro-2-butene | <.692 | <.692 | 3.72 | 2.81 | 2.21 |
| 1,3-Dichloropropane | <.116 | <.116 | .491 | .426 | .417 |
| 2,2-Dichloropropane | <.078 | <.078 | .172 | .180 | .236 |
| 1,1-Dichloropropene | <.026 | <.026 | E .091 | .097 | .148 |
| (1,1-Dimethylethyl)benzene | <.096 | <.096 | .285 | .282 | .341 |
| 1,4-Epoxybutane | <1.15 | <1.15 | E 2.68 | E 2.63 | E 2.68 |
| 1-Ethyl-2-methylbenzene | <.100 | <.100 | .296 | .352 | .296 |
| Ethyl 2-methyl-2-propenoate | <.278 | <.278 | .999 | 1.04 | .832 |
| 2-Hexanone | <.746 | <.746 | 3.04 | 2.78 | 2.92 |
| Iodomethane | <.076 | <.076 | E .320 | E .300 | E .310 |
| 1-Isopropyl-4-methylbenzene | <.110 | <.110 | .244 | .333 | .323 |
| Methyl 2-methyl-2-propenoate | <.350 | <.350 | 1.26 | 1.36 | 1.30 |
| 4-Methyl-2-pentanone | <.374 | <.374 | 1.52 | 1.20 | 1.31 |
| 2-Methyl-2-propenenitrile | <.570 | <.570 | 2.33 | 2.03 | 2.08 |
| Methyl-2-propenoate | <.612 | <.612 | 2.39 | 2.17 | 2.34 |
| (1-Methylpropyl)benzene | <.048 | <.048 | .106 | E .100 | .136 |
| 1,1'-Oxybisethane | <.170 | <.170 | .812 | .629 | .791 |
| 2-Propanone | 5.29 | <4.90 | 1.9 | 8.67 | 11.7 |
| 1,1,1,2-Tetrachloroethane | <.044 | <.044 | .176 | .178 | .164 |
| 1,1,2,2-Tetrachloroethane | <.132 | <.132 | .745 | .615 | .484 |
| 1,2,3,4-Tetramethylbenzene | <.230 | <.230 | .728 | .819 | .712 |
| 1,2,3,5-Tetramethylbenzene | <.240 | <.240 | .828 | .956 | .820 |
| 1,2,3-Trimethylbenzene | <.124 | <.124 | .470 | .509 | .453 |
| 1,3,5-Trimethylbenzene | <.044 | <.044 | .133 | .170 | .169 |

[1] Two samples from the same site were collected from the Lake Erie-Lake St. Clair Drainage Study Unit.

**Table 4.** Concentrations of volatile organic compounds (VOCs) detected in surface-water samples 2 and 3 from three Study Units of the National Water-Quality Assessment Program

[IUPAC, International Union of Pure and Applied Chemistry; ND, not detected; E, estimated]

| Study Unit (fig. 1) | | VOC (IUPAC compound name) | Concentrations (micrograms per liter) | |
|---|---|---|---|---|
| | | | Sample 2 | Sample 3 |
| Lake Erie-Lake St. Clair Drainage | Site A | *cis*-1,2-Dichloroethene | E 0.042 | E 0.042 |
| | | 1,1,2-Trichloroethene | E .120 | E .130 |
| | | Trichloromethane | E .026 | E .023 |
| | Site A[1] | *cis*-1,2-Dichloroethene | E .017 | E .022 |
| | | 2-Methoxy-2-methylpropane | E .190 | E .170 |
| | | Methylbenzene | E .056 | E .053 |
| | | 1,1,2-Trichloroethene | E .054 | E .058 |
| | | Trichloromethane | E .024 | E .025 |
| Long Island and New Jersey Coastal Drainages | Site A | Benzene | ND | E .011 |
| | | 2-Methoxy-2-methylpropane | E .11 | ND |
| | | 1,1,2-Trichloroethene | E .029 | E .029 |
| | | Trichloromethane | E .022 | E .021 |
| | Site B | Benzene | E .018 | E .018 |
| | | 1,2-Dimethylbenzene | E .014 | E .013 |
| | | 1,3 and 1,4-Dimethylbenzene | E .026 | E .029 |
| | | Ethylbenzene | E .009 | E .010 |
| | | 2-Methoxy-2-methylpropane | .400 | .402 |
| | | Methylbenzene | E .068 | E .068 |
| | | Trichloromethane | E .013 | E .013 |
| | | 1,2,4-Trimethylbenzene | ND | E .014 |
| Puget Sound Basin | Site A | Benzene | E .009 | E .009 |
| | | Chloromethane | ND | E .011 |
| | | Methylbenzene | E .039 | E .041 |
| | | Trichloromethane | E .041 | E .041 |
| | | 1,2,4-Trimethylbenzene | E .084 | .118 |

[1] Two samples from the same site were collected from the Lake Erie-Lake St. Clair Drainage Study Unit.

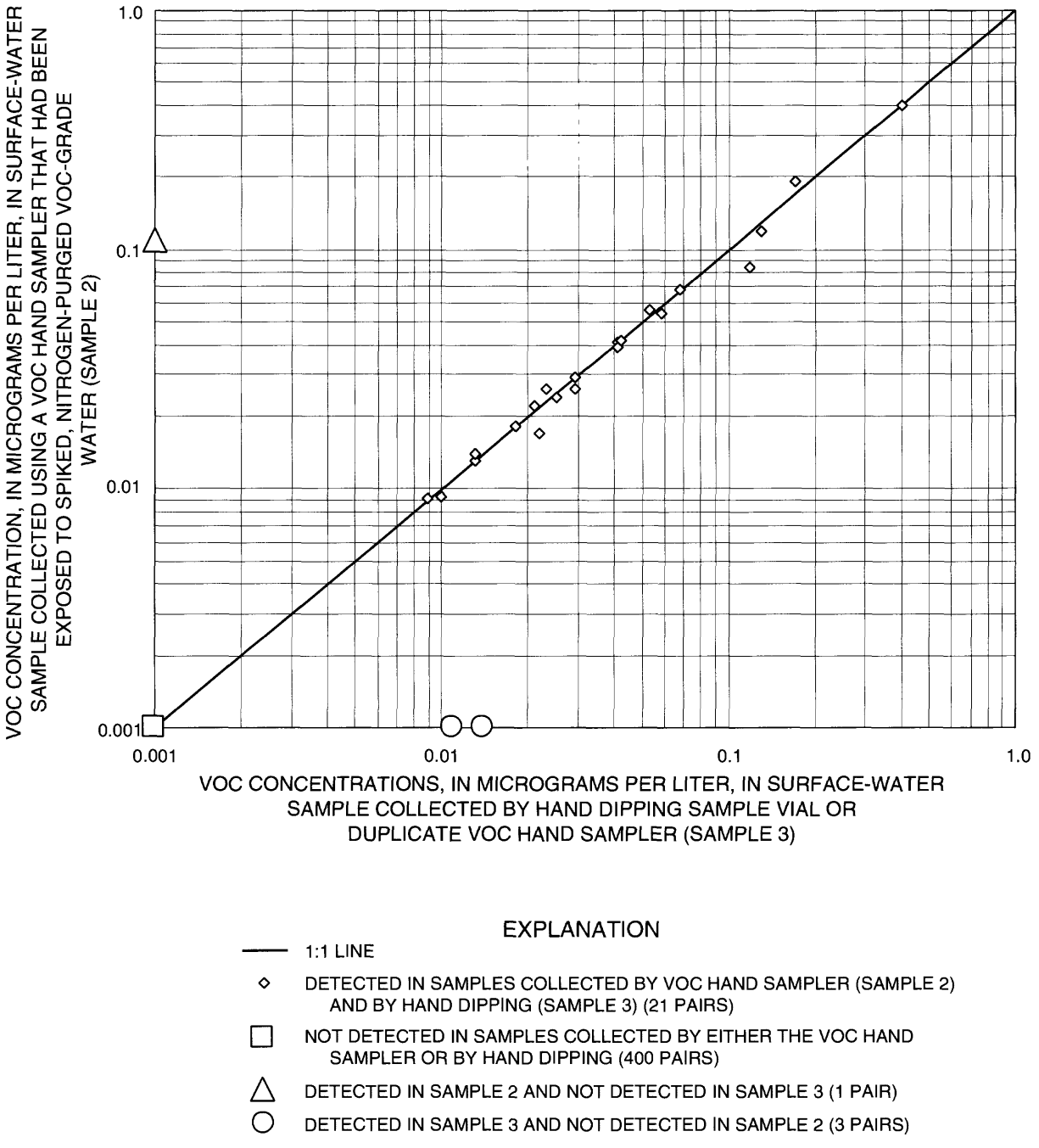



**Figure 3.** Comparison of concentrations of 87 volatile organic compounds (VOCs) in samples collected using a VOC hand sampler, which was exposed to low levels of VOCs during the prior decontamination process, with concentrations in hand-dipped samples.

## GROUND-WATER SAMPLES

Prior to August 1997, ground-water equipment was decontaminated according to procedures specified in Koterba and others (1995). These protocols indicate field-equipment blank samples are to be collected after applying decontamination procedures. Well-purge criteria are part of the process in collecting ground-water samples. The ground-water phase of this study tests the assumption that the purge process removes the residual contamination, if any, that may have resulted from the non-nitrogen-purged VOC-grade water used during decontamination procedures prior to August 1997.

### Sampling Procedures

For this study, the well was first purged according to Koterba and others (1995), and an environmental sample was collected using a previously cleaned pump (sample 1). This sample is representative of an environmental sample collected by NAWQA Study Units. The pump then was removed from the well, and sampling equipment was decontaminated as described by Koterba and others (1995). A field-blank sample then was collected using the spiked, nitrogen-purged VOC-grade water (sample 2). The exterior of the pump was rinsed with nitrogen-purged VOC-grade water, the pump was placed back in the well, and the well was purged using the same flow rate and amount of time as in the initial purge for sample 1. Current (2000) decontamination protocols do not require the normal sampling line from the flow-through chamber to the collection chamber to be rinsed during the purging process (fig. 4). As such, the third sample (sample 3) was collected from the purge/waste line, and sample 4 was collected from the collection

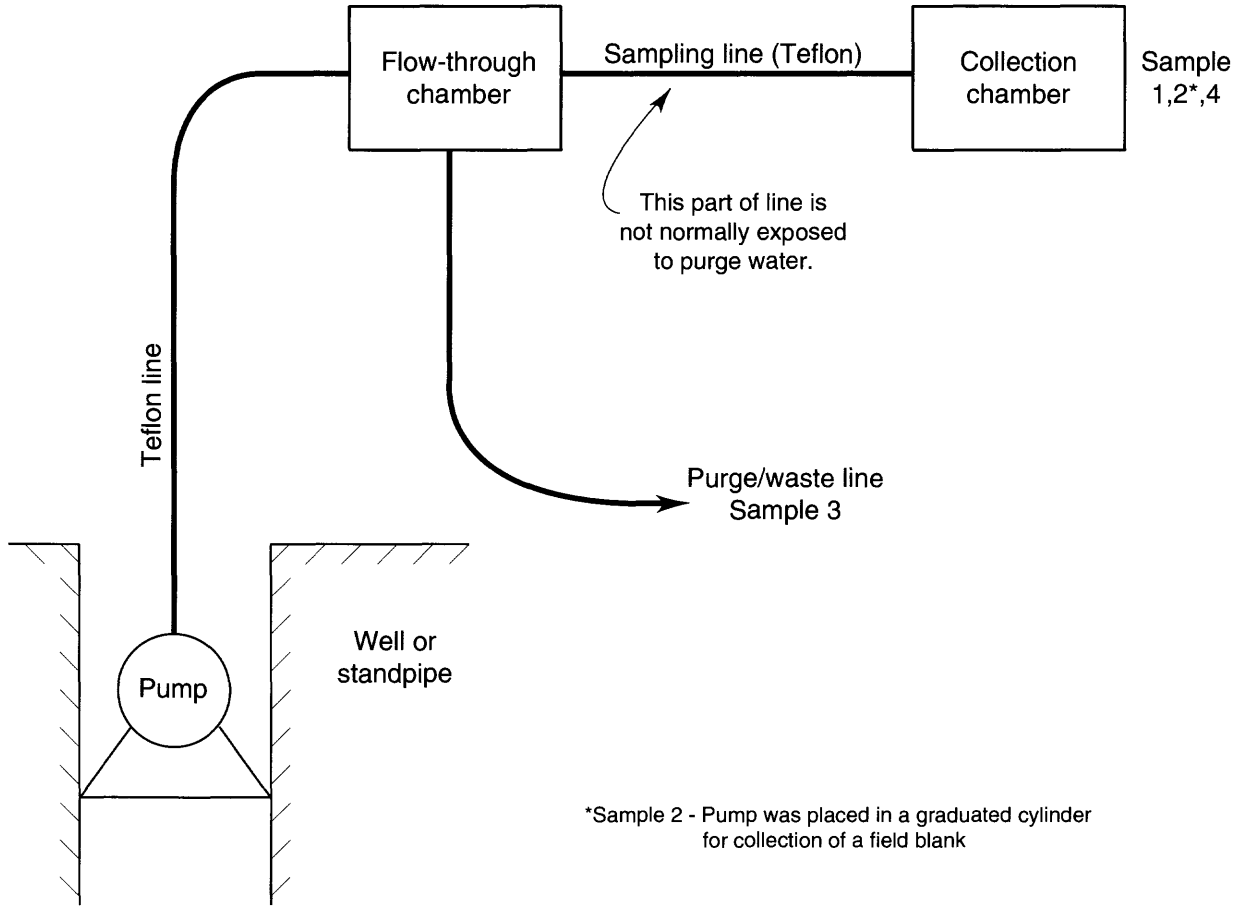



**Figure 4.** Typical ground-water sampling configuration.

chamber. Thus, the effect of not rinsing the normal sampling line would be characterized through comparison of sample 3 and sample 4. Concentrations of carry-over VOCs from decontamination procedures to environmental samples would be characterized primarily through comparison of sample 1 and sample 4. It is important to note, however, samples collected from the MISE Study Unit did not include a sample from the well-purge/waste line (sample 3). Also, samples collected from MISE used a 50-ft Teflon line for sampling well A and a 150-ft polyethylene line for sampling well B.

Except as noted above, each of the four samples just mentioned was collected at six different wells (table 5). Ground-water samples for this study were collected from two separate well locations at each of three participating Study Units. Two wells were sampled in the LINJ, MISE, and UTEN Study Units.

## Analytical Results

Detected concentrations in the spiked, nitrogen-purged VOC-grade water (sample 2) ranged from 0.022 to 27.6 µg/L (table 6). The data for the ground-water sample collected by NAWQA Study Units (sample 1), the ground-water sample collected from the waste line (sample 3), and the ground-water sample collected from the normal sampling location (collection chamber) (sample 4) are listed in appendix 2. Eighty-four of the 87 VOCs analyzed were not detected in ground-water samples 1, 3, or 4. All three samples from well A in the UTEN Study Unit had similar concentrations of trichloromethane (table 7). Also, none of the 87 VOCs listed in table 1 were detected in any of the three samples collected from well A in the LINJ Study Unit. These results indicate that the VOCs did not carry over from the source solution used to clean sampling equipment to ground-water samples collected subsequently. Excluding the UTEN trichloromethane data, three VOCs—methylbenzene, tetrachloroethene, and trichloromethane—were detected a total of six times in samples 3 and (or) 4 but not in sample 1. These three compounds may warrant further carry-over evaluation, especially methylbenzene that was found in sample 4 at three of the six sampled wells.

**Table 5.** Summary of ground-water samples collected and used for evaluation of carry-over contamination

| Procedure sample number | Description | Total number of samples collected from six wells |
|---|---|---|
| 1 | Ground-water sample collected from the collection chamber before ground-water equipment had been exposed to spiked, nitrogen-purged VOC-grade water. | 6 |
| 2 | Field-blank sample containing spiked, nitrogen-purged VOC-grade water. | 6 |
| 3 | Ground-water sample collected from the wasteline after ground-water equipment had been exposed to spiked, nitrogen-purged VOC-grade water. | 6 |
| 4 | Ground-water sample collected from the collection chamber after ground-water equipment had been exposed to spiked, nitrogen-purged VOC-grade water. | 6 |

**Table 6.** Concentrations of volatile organic compounds (VOCs) detected in ground-water sample 2 from three Study Units of the National Water-Quality Assessment Program

[All samples were spiked, nitrogen-purged VOC-grade water. IUPAC, International Union of Pure and Applied Chemistry; E, estimated; <, less than; NA, not analyzed]

| VOC (IUPAC compound name) | VOC concentrations in ground-water sample 2 from three Study Units (fig. 1) (micrograms per liter) | | | | | |
|---|---|---|---|---|---|---|
| | Long Island and New Jersey Coastal Drainages | | Mississippi Embayment | | Upper Tennessee River Basin | |
| | Well A | Well B | Well A | Well B | Well A | Well B |
| **Target Analytes** | | | | | | |
| Benzene | 0.169 | 0.176 | 0.138 | 0.13 | 0.128 | 0.135 |
| Bromodichloromethane | .182 | .185 | .155 | .148 | .165 | .163 |
| Bromoethene | .266 | .292 | .198 | .209 | .224 | .276 |
| Bromomethane | E .780 | E .820 | E .320 | E .490 | E .620 | E .720 |
| *n*-Butylbenzene | .390 | .426 | .314 | .118 | .308 | .340 |
| Chlorobenzene | .175 | .181 | .137 | .106 | .123 | .119 |
| Chloroethane | .311 | .344 | E .099 | .189 | .249 | .339 |
| Chloroethene | .224 | .252 | .168 | .189 | .177 | .252 |
| Chloromethane | E .440 | E .470 | E .430 | E .420 | E .350 | E .450 |
| 1,2-Dibromo-3-chloropropane | .779 | .820 | .776 | .686 | .644 | .624 |
| Dibromochloromethane | .665 | .684 | .632 | .566 | E .085 | .531 |
| 1,2-Dibromoethane | .184 | .187 | .171 | .156 | .136 | .160 |
| 1,2-Dichlorobenzene | .176 | .175 | .140 | E .088 | .118 | .139 |
| 1,3-Dichlorobenzene | .167 | .171 | .129 | E .068 | 1.16 | .120 |
| 1,4-Dichlorobenzene | .163 | .167 | .132 | E .069 | .128 | .116 |
| Dichlorodifluoromethane | E .080 | E .100 | E .073 | E .046 | E .100 | E .120 |
| 1,1-Dichloroethane | .249 | .260 | .192 | .194 | .219 | .236 |
| 1,2-Dichloroethane | .471 | .494 | .423 | .403 | .520 | .502 |
| 1,1-Dichloroethene | .104 | .120 | E .085 | E .083 | .098 | .120 |
| *cis*-1,2-Dichloroethene | .182 | .192 | .136 | .139 | .145 | .141 |
| *trans*-1,2-Dichloroethene | .163 | .175 | .118 | .119 | .135 | .179 |
| Dichloromethane | 1.37 | 1.48 | 1.16 | 1.20 | 1.36 | 1.43 |
| 1,2-Dichloropropane | .268 | .275 | .221 | .220 | .214 | .217 |
| *cis*-1,3-Dichloropropene | .261 | .279 | .248 | .229 | .209 | .216 |
| *trans*-1,3-Dichloropropene | .383 | .410 | .395 | .348 | .426 | .370 |
| 1,2-Dimethylbenzene | .210 | .213 | .172 | .127 | .147 | .147 |
| 1,3 and 1,4-Dimethylbenzene | .392 | .421 | .328 | .214 | .290 | .307 |
| Ethenylbenzene | .189 | .196 | .137 | .106 | .141 | .146 |
| 2-Ethoxy-2-methylpropane | .171 | .175 | .152 | .151 | .142 | .130 |
| Ethylbenzene | .159 | .169 | .132 | E .090 | .110 | .110 |

**Table 6.** Concentrations of volatile organic compounds (VOCs) detected in ground-water sample 2 from three Study Units of the National Water-Quality Assessment Program–Continued

[All samples were spiked, nitrogen-purged VOC-grade water. IUPAC, International Union of Pure and Applied Chemistry; E, estimated; <, less than; NA, not analyzed]

| VOC (IUPAC compound name) | VOC concentrations in ground-water sample 2 from three Study Units (fig. 1) (micrograms per liter) | | | | | |
|---|---|---|---|---|---|---|
| | Long Island and New Jersey Coastal Drainages | | Mississippi Embayment | | Upper Tennessee River Basin | |
| | Well A | Well B | Well A | Well B | Well A | Well B |
| **Target Analytes—Continued** | | | | | | |
| 1,1,2,3,4,4-Hexachloro-1,3-butadiene | 0.271 | 0.318 | 0.215 | E 0.077 | 0.232 | 0.259 |
| 1,1,1,2,2,2-Hexachloroethane | 1.32 | 1.42 | 1.24 | .852 | .949 | .982 |
| 2-Methoxy-2-methylbutane | .376 | .382 | .350 | .327 | .304 | .291 |
| 2-Methoxy-2-methylpropane | .667 | .675 | .369 | .525 | .658 | .685 |
| Methylbenzene | .173 | .183 | .202 | .185 | .129 | .129 |
| (1-Methylethyl)benzene | .146 | .156 | .103 | E .071 | .095 | .102 |
| Naphthalene | .579 | .882 | E 1.90 | E 1.20 | .949 | .758 |
| 2,2'-oxybis[propane] | .362 | .383 | .355 | .318 | .300 | .297 |
| 2-Propenal | NA | NA | NA | NA | NA | NA |
| 2-Propenenitrile | 4.38 | 4.5 | 5.17 | 4.79 | 5.40 | 5.80 |
| *n*-Propylbenzene | .133 | .147 | .113 | E .053 | E .089 | .097 |
| Tetrachloroethene | .314 | .346 | .218 | .130 | .243 | .268 |
| 1,1,2-Trichloroethene | .158 | .173 | .130 | .104 | .117 | .132 |
| Trichlorofluoromethane | .101 | .127 | E .089 | E .065 | .117 | .147 |
| Trichloromethane | .187 | .194 | .145 | .155 | .161 | .164 |
| 1,2,3-Trichloropropane | .685 | .754 | .234 | .506 | .665 | .669 |
| 1,2,4-Trimethylbenzene | .200 | .211 | .156 | .093 | .148 | .153 |
| Tetrachloromethane | .176 | .200 | .142 | .112 | .168 | .199 |
| Tribromomethane | .381 | .402 | .391 | .351 | .330 | .327 |
| 1,1,2-Trichloro-1,2,2-trifluoroethane | E .046 | E .057 | E .046 | E .022 | E .055 | E .054 |
| 1,2,3-Trichlorobenzene | .853 | .891 | .836 | .389 | .730 | .685 |
| 1,2,4-Trichlorobenzene | .588 | .601 | .556 | .233 | .493 | .474 |
| 1,1,1-Trichloroethane | .124 | .140 | .100 | .093 | .114 | .137 |
| 1,1,2-Trichloroethane | .232 | .236 | .224 | .202 | .201 | .203 |
| **Other Analytes** | | | | | | |
| Bromobenzene | .174 | .175 | .142 | .099 | .128 | .128 |
| Bromochloromethane | .187 | .178 | .146 | .147 | .162 | .156 |
| 2-Butanone | 6.98 | 6.96 | 18.40 | 9.52 | 6.75 | 6.43 |
| Dithiocarbonic anhydride | .187 | .212 | E .320 | E .140 | .165 | .219 |
| 1-Chloro-2-methylbenzene | .172 | .179 | .124 | E .074 | .116 | .122 |

**Table 6.** Concentrations of volatile organic compounds (VOCs) detected in ground-water sample 2 from three Study Units of the National Water-Quality Assessment Program–Continued

[All samples were spiked, nitrogen-purged VOC-grade water. IUPAC, International Union of Pure and Applied Chemistry; E, estimated; <, less than; NA, not analyzed]

| VOC (IUPAC compound name) | VOC concentrations in ground-water sample 2 from three Study Units (fig. 1) (micrograms per liter) | | | | | |
|---|---|---|---|---|---|---|
| | Long Island and New Jersey Coastal Drainages | | Mississippi Embayment | | Upper Tennessee River Basin | |
| | Well A | Well B | Well A | Well B | Well A | Well B |
| | Other Analytes—Continued | | | | | |
| 1-Chloro-4-methylbenzene | 0.202 | 0.210 | 0.154 | E 0.083 | 0.145 | 0.153 |
| 3-Chloro-1-propene | .245 | .284 | .216 | .235 | .269 | .260 |
| Dibromomethane | .187 | .188 | .176 | .160 | .161 | .177 |
| *trans*-1,4-Dichloro-2-butene | E 2.20 | E 2.50 | E 3.60 | E 3.40 | E 3.40 | E 3.30 |
| 1,3-Dichloropropane | .445 | .449 | .431 | .388 | .382 | .345 |
| 2,2-Dichloropropane | .100 | .121 | .132 | .117 | .140 | .174 |
| 1,1-Dichloropropene | .122 | .141 | .096 | E .071 | .094 | .113 |
| (1,1-Dimethylethyl)benzene | .275 | .301 | .236 | .135 | .216 | .236 |
| 1,4-Epoxybutane | 8.13 | 8.23 | <9.00 | E 6.40 | 6.54 | 6.63 |
| 1-Ethyl-2-methylbenzene | .317 | .331 | .267 | .149 | .222 | .231 |
| Ethyl 2-methyl-2-propenoate | .979 | 1.00 | .959 | .868 | .825 | .788 |
| 2-Hexanone | 2.73 | 2.72 | 2.98 | 2.74 | 2.35 | 2.21 |
| Iodomethane | E .360 | E .390 | E .28 | E .340 | E .290 | E .340 |
| 1-Isopropyl-4-methylbenzene | .278 | .302 | .221 | E .091 | .201 | .222 |
| Methyl 2-methyl-2-propenoate | 1.36 | 1.40 | 1.40 | 1.30 | 1.15 | 1.06 |
| 4-Methyl-2-pentanone | 1.30 | 1.32 | 1.41 | 1.27 | E .900 | 1.32 |
| 2-Methyl-2-propenenitrile | 2.22 | 2.24 | 2.24 | 2.10 | 1.95 | 1.75 |
| Methyl-2-propenoate | 5.77 | 5.87 | 2.45 | 4.72 | 5.29 | 5.12 |
| (1-Methylpropyl)benzene | .125 | .137 | .119 | E .044 | E .088 | .097 |
| 1,1'-Oxybisethane | .615 | .640 | .641 | .613 | .586 | .649 |
| 2-Propanone | 27.6 | 25.3 | 13.6 | 21.2 | E 26.0 | E 27.0 |
| 1,1,1,2-Tetrachloroethane | .172 | .175 | .130 | .126 | .141 | .136 |
| 1,1,2,2-Tetrachloroethane | .519 | .510 | .520 | .473 | .476 | .437 |
| 1,2,3,4-Tetramethylbenzene | .773 | .790 | E 1.00 | E .470 | .798 | .783 |
| 1,2,3,5-Tetramethylbenzene | .715 | .744 | .800 | .363 | .672 | .698 |
| 1,2,3-Trimethylbenzene | .446 | .461 | .380 | .216 | .348 | .351 |
| 1,3,5-Trimethylbenzene | .158 | .169 | .123 | E .068 | .110 | .117 |

**Table 7.** Concentrations of volatile organic compounds (VOCs) detected in ground-water samples 1, 3, and 4 from three Study Units of the National Water-Quality Assessment Program

[IUPAC, International Union of Pure and Applied Chemistry; ND, not detected; E, estimated; NA, not analyzed]

| Study Unit (fig. 1) | | VOC (IUPAC compound name) | Concentrations (micrograms per liter) | | |
|---|---|---|---|---|---|
| | | | Sample 1 | Sample 3 | Sample 4 |
| Mississippi Embayment | Well A | Methylbenzene | ND | NA | E 0.065 |
| | Well B[1] | Methylbenzene | ND | NA | E .044 |
| | Well B[1] | Tetrachloroethene | ND | NA | E .004 |
| Long Island and New Jersey Coastal Drainages | Well A | ND | ND | ND | ND |
| | Well B | Methylbenzene | ND | E 0.015 | ND |
| Upper Tennessee River Basin | Well A | Trichloromethane | E 0.015 | E .015 | E .014 |
| | Well B | Trichloromethane | ND | E .010 | ND |
| | | Methylbenzene | ND | E .022 | E .019 |

[1]A 150-ft polyethylene sample line was used. All other samples were collected using a Teflon sampling line.

## REFERENCES CITED


Bender, D.A., Zogorski, J.S., Halde, M.J., and Rowe, B.L., 1999, Selection procedure and salient information for volatile organic compounds emphasized in the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 99-182, 32 p.

Connor, B.F., Rose, D.L., Noriega, M.C., Murtagh, L.K., and Abney, S.R., 1998, Methods of analysis by the U.S. Geological Survey National Water-Quality Laboratory—determination of 86 volatile organic compounds in water by gas chromatography/mass spectrometry, including detections less than reporting limits: U.S. Geological Survey Open-File Report 97-829, 78 p.

Halde, M.J., Delzer, G.C., and Zogorski, J.S., 1999, Study design and analytical results used to evaluate a surface-water point sampler for volatile organic compounds: U.S. Geological Survey Open-File Report 98-651, 31 p.

Koterba, M.T., Wilde, F.D., and Lapham W.W., 1995, Ground-water data-collection protocols and procedures for the National Water-Quality Assessment Program—collection and documentation of water-quality samples and related data: U.S. Geological Survey Open-File Report 95-399, 113 p.

Shelton, L.R., 1997, Field guide for collecting samples for analysis of volatile organic compounds in stream water for the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 97-401, 14 p.

# APPENDICES

19 → 21

**Appendix 1.** Concentrations of volatile organic compounds (VOCs) in surface-water samples 2 and 3 from Lake Erie-Lake St. Clair Drainage, Long Island and New Jersey Coastal Drainages, and Puget Sound Basin Study Units

[Bold type indicates detected compounds and concentrations. IUPAC, International Union of Pure and Applied Chemistry; E, estimated; <, less than; NA, not analyzed]

| VOC (IUPAC compound name) | Concentrations, in micrograms per liter | | | |
|---|---|---|---|---|
| | Site A | | Site A[1] or Site B | |
| | Sample 2 | Sample 3 | Sample 2 | Sample 3 |
| **Lake Erie-Lake St. Clair Drainage Study Unit (fig. 1) Target Analytes** | | | | |
| Sample date | 5-9-98 | 5-9-98 | 6-3-98 | |
| Benzene | <0.064 | <0.064 | <0.064 | <0.064 |
| Bromodichloromethane | <.096 | <.096 | <.096 | <.096 |
| Bromoethene | <.200 | <.200 | <.200 | <.200 |
| Bromomethane | <.296 | <.296 | <.296 | <.296 |
| *n*-Butylbenzene | <.372 | <.372 | <.372 | <.372 |
| Chlorobenzene | <.056 | <.056 | <.056 | <.056 |
| Chloroethane | <.240 | <.240 | <.240 | <.240 |
| Chloroethene | <.224 | <.224 | <.224 | <.224 |
| Chloromethane | <.508 | <.508 | <.508 | <.508 |
| 1,2-Dibromo-3-chloropropane | <.428 | <.428 | <.428 | <.428 |
| Dibromochloromethane | <.364 | <.364 | <.364 | <.364 |
| 1,2-Dibromoethane | <.072 | <.072 | <.072 | <.072 |
| 1,2-Dichlorobenzene | <.096 | <.096 | <.096 | <.096 |
| 1,3-Dichlorobenzene | <.108 | <.108 | <.108 | <.108 |
| 1,4-Dichlorobenzene | <.100 | <.100 | <.100 | <.100 |
| Dichlorodifluoromethane | <.192 | <.192 | <.192 | <.192 |
| 1,1-Dichloroethane | <.132 | <.132 | <.132 | <.132 |
| 1,2-Dichloroethane | <.268 | <.268 | <.268 | <.268 |
| 1,1-Dichloroethene | <.088 | <.088 | <.088 | <.088 |
| **_cis_-1,2-Dichloroethene** | **E .042** | **E .042** | **E .017** | **E.022** |
| _trans_-1,2-Dichloroethene | <.064 | <.064 | <.064 | <.064 |
| Dichloromethane | <.764 | <.764 | <.764 | <.764 |
| 1,2-Dichloropropane | <.136 | <.136 | <.136 | <.136 |
| _cis_-1,3-Dichloropropene | <.184 | <.184 | <.184 | <.184 |
| _trans_-1,3-Dichloropropene | <.268 | <.268 | <.268 | <.268 |
| 1,2-Dimethylbenzene | <.128 | <.128 | <.128 | <.128 |
| 1,3 and 1,4-Dimethylbenzene | <.128 | <.128 | <.128 | <.128 |
| Ethenylbenzene | <.084 | <.084 | <.084 | <.084 |
| 2-Ethoxy-2-methylpropane | <.108 | <.108 | <.108 | <.108 |
| Ethylbenzene | <.060 | <.060 | <.060 | <.060 |
| 1,1,2,3,4,4-Hexachloro-1,3-butadiene | <.284 | <.284 | <.284 | <.284 |
| 1,1,1,2,2,2-Hexachloroethane | <.724 | <.724 | <.724 | <.724 |
| 2-Methoxy-2-methylbutane | <.224 | <.224 | <.224 | <.224 |
| **2-Methoxy-2-methylpropane** | <.224 | <.224 | **E .190** | **E .170** |
| **Methylbenzene** | <.076 | <.076 | **E .056** | **E .053** |

**Appendix 1.** Concentrations of volatile organic compounds (VOCs) in surface-water samples 2 and 3 from Lake Erie-Lake St. Clair Drainage, Long Island and New Jersey Coastal Drainages, and Puget Sound Basin Study Units—Continued

[Bold type indicates detected compounds and concentrations. IUPAC, International Union of Pure and Applied Chemistry; E, estimated; <, less than; NA, not analyzed]

| VOC (IUPAC compound name) | Concentrations, in micrograms per liter | | | |
|---|---|---|---|---|
| | Site A | | Site A[1] or Site B | |
| | Sample 2 | Sample 3 | Sample 2 | Sample 3 |
| **Lake Erie-Lake St. Clair Drainage Study Unit (fig. 1)—Continued** | | | | |
| **Target Analytes—Continued** | | | | |
| (1-Methylethyl)benzene | <0.064 | <0.064 | <0.064 | <0.064 |
| Naphthalene | <.500 | <.500 | <.500 | <.500 |
| 2,2'-Oxybis[propane] | <.196 | <.196 | <.196 | <.196 |
| 2-Propenal | NA | NA | NA | NA |
| 2-Propenenitrile | <2.45 | <2.45 | <2.45 | <2.45 |
| *n*-Propylbenzene | <.084 | <.084 | <.084 | <.084 |
| Tetrachloroethene | <.076 | <.076 | <.076 | <.076 |
| Tetrachloromethane | <.176 | <.176 | <.176 | <.176 |
| Tribromomethane | <.208 | <.208 | <.208 | <.208 |
| 1,1,2-Trichloro-1,2,2-trifluoroethane | <.064 | <.064 | <.064 | <.064 |
| 1,2,3-Trichlorobenzene | <.532 | <.532 | <.532 | <.532 |
| 1,2,4-Trichlorobenzene | <.376 | <.376 | <.376 | <.376 |
| 1,1,1-Trichloroethane | <.064 | <.064 | <.064 | <.064 |
| 1,1,2-Trichloroethane | <.128 | <.128 | <.128 | <.128 |
| **1,1,2-Trichloroethene** | **E .120** | **E .130** | **E .054** | **E .058** |
| Trichlorofluoromethane | <.184 | <.184 | <.184 | <.184 |
| **Trichloromethane** | **E .026** | **E .023** | **E .024** | **E .025** |
| 1,2,3-Trichloropropane | <.140 | <.140 | <.140 | <.140 |
| 1,2,4-Trimethylbenzene | <.112 | <.112 | <.112 | <.112 |
| **Other Analytes** | | | | |
| Bromobenzene | <.072 | <.072 | <.072 | <.072 |
| Bromochloromethane | <.088 | <.088 | <.088 | <.088 |
| 2-Butanone | <3.30 | <3.30 | <3.30 | <3.30 |
| Dithiocarbonic anhydride | <.160 | <.160 | <.160 | <.160 |
| 1-Chloro-2-methylbenzene | <.084 | <.084 | <.084 | <.084 |
| 1-Chloro-4-methylbenzene | <.112 | <.112 | <.112 | <.112 |
| 3-Chloro-1-propene | <.392 | <.392 | <.392 | <.392 |
| Dibromomethane | <.100 | <.100 | <.100 | <.100 |
| *trans*-1,4-Dichloro-2-butene | <1.38 | <1.38 | <1.38 | <1.38 |
| 1,3-Dichloropropane | <.232 | <.232 | <.232 | <.232 |
| 2,2-Dichloropropane | <.156 | <.156 | <.156 | <.156 |
| 1,1-Dichloropropene | <.052 | <.052 | <.052 | <.052 |
| (1,1-Dimethylethyl)benzene | <.192 | <.192 | <.192 | <.192 |
| 1,4-Epoxybutane | <2.30 | <2.30 | <2.30 | <2.30 |
| 1-Ethyl-2-methylbenzene | <.200 | <.200 | <.200 | <.200 |

**Appendix 1.** Concentrations of volatile organic compounds (VOCs) in surface-water samples 2 and 3 from Lake Erie-Lake St. Clair Drainage, Long Island and New Jersey Coastal Drainages, and Puget Sound Basin Study Units—Continued

[Bold type indicates detected compounds and concentrations. IUPAC, International Union of Pure and Applied Chemistry; E, estimated; <, less than; NA, not analyzed]

| VOC (IUPAC compound name) | Concentrations, in micrograms per liter | | | |
|---|---|---|---|---|
| | Site A | | Site A[1] or Site B | |
| | Sample 2 | Sample 3 | Sample 2 | Sample 3 |
| **Lake Erie-Lake St. Clair Drainage Study Unit (fig. 1)—Continued** | | | | |
| **Other Analytes—Continued** | | | | |
| Ethyl 2-methyl-2-propenoate | <0.556 | <0.556 | <0.556 | <0.556 |
| 2-Hexanone | <1.49 | <1.49 | <1.49 | <1.49 |
| Iodomethane | <.152 | <.152 | <.152 | <.152 |
| 1-Isopropyl-4-methylbenzene | <.220 | <.220 | <.220 | <.220 |
| Methyl 2-methyl-2-propenoate | <.700 | <.700 | <.700 | <.700 |
| 4-Methyl-2-pentanone | <.748 | <.748 | <.748 | <.748 |
| 2-Methyl-2-propenenitrile | <1.14 | <1.14 | <1.14 | <1.14 |
| Methyl-2-propenoate | <1.22 | <1.22 | <1.22 | <1.22 |
| (1-Methylpropyl)benzene | <.096 | <.096 | <.096 | <.096 |
| 1,1'-Oxybisethane | <.340 | <.340 | <.340 | <.340 |
| 2-Propanone | <9.81 | <9.81 | <9.81 | <9.81 |
| 1,1,1,2-Tetrachloroethane | <.088 | <.088 | <.088 | <.088 |
| 1,1,2,2-Tetrachloroethane | <.264 | <.264 | <.264 | <.264 |
| 1,2,3,4-Tetramethylbenzene | <.460 | <.460 | <.460 | <.460 |
| 1,2,3,5-Tetramethylbenzene | <.480 | <.480 | <.480 | <.480 |
| 1,2,3-Trimethylbenzene | <.248 | <.248 | <.248 | <.248 |
| 1,3,5-Trimethylbenzene | | <.088 | <.088 | <.088 |
| **Long Island and New Jersey Coastal Drainages Study Unit** | | | | |
| **Target Analytes** | | | | |
| Sample date | 3-17-98 | | 3-19-98 | |
| **Benzene** | <.064 | **E .011** | **E .018** | **E .018** |
| Bromodichloromethane | <.096 | <.096 | <.048 | <.048 |
| Bromoethene | <.200 | <.200 | <.100 | <.100 |
| Bromomethane | <.296 | <.296 | <.148 | <.148 |
| *n*-Butylbenzene | <.372 | <.372 | <.186 | <.186 |
| Chlorobenzene | <.056 | <.056 | <.028 | <.028 |
| Chloroethane | <.240 | <.240 | <.120 | <.120 |
| Chloroethene | <.224 | <.224 | <.112 | <.112 |
| Chloromethane | <.508 | <.508 | <.254 | <.254 |
| 1,2-Dibromo-3-chloropropane | <.428 | <.428 | <.214 | <.214 |
| Dibromochloromethane | <.364 | <.364 | <.182 | <.182 |
| 1,2-Dibromoethane | <.072 | <.072 | <.036 | <.036 |
| 1,2-Dichlorobenzene | <.096 | <.096 | <.048 | <.048 |
| 1,3-Dichlorobenzene | <.108 | <.108 | <.054 | <.054 |
| 1,4-Dichlorobenzene | <.100 | <.100 | <.050 | <.050 |

**Appendix 1.** Concentrations of volatile organic compounds (VOCs) in surface-water samples 2 and 3 from Lake Erie-Lake St. Clair Drainage, Long Island and New Jersey Coastal Drainages, and Puget Sound Basin Study Units—Continued

[Bold type indicates detected compounds and concentrations. IUPAC, International Union of Pure and Applied Chemistry; E, estimated; <, less than; NA, not analyzed]

| VOC (IUPAC compound name) | Concentrations, in micrograms per liter | | | |
|---|---|---|---|---|
| | Site A | | Site A[1] or Site B | |
| | Sample 2 | Sample 3 | Sample 2 | Sample 3 |
| **Long Island and New Jersey Coastal Drainages Study Unit Target Analytes—Continued** | | | | |
| Dichlorodifluoromethane | <0.192 | <0.192 | <0.096 | <0.096 |
| 1,1-Dichloroethane | <.132 | <.132 | <.066 | <.066 |
| 1,2-Dichloroethane | <.268 | <.268 | <.134 | <.134 |
| 1,1-Dichloroethene | <.088 | <.088 | <.044 | <.044 |
| *cis*-1,2-Dichloroethene | <.076 | <.076 | <.038 | <.038 |
| *trans*-1,2-Dichloroethene | <.064 | <.064 | <.032 | <.032 |
| Dichloromethane | <.764 | <.764 | <.382 | <.382 |
| 1,2-Dichloropropane | <.136 | <.136 | <.068 | <.068 |
| *cis*-1,3-Dichloropropene | <.184 | <.184 | <.092 | <.092 |
| *trans*-1,3-Dichloropropene | <.268 | <.268 | <.134 | <.134 |
| **1,2-Dimethylbenzene** | <.128 | <.128 | **E .014** | **E .013** |
| **1,3 and 1,4-Dimethylbenzene** | <.128 | <.128 | **E .026** | **E .029** |
| Ethenylbenzene | <.084 | <.084 | <.042 | <.042 |
| 2-Ethoxy-2-methylpropane | <.108 | <.108 | <.054 | <.054 |
| **Ethylbenzene** | <.060 | <.060 | **E .009** | **E .010** |
| 1,1,2,3,4,4-Hexachloro-1,3-butadiene | <.284 | <.284 | <.142 | <.142 |
| 1,1,1,2,2,2-Hexachloroethane | <.724 | <.724 | <.362 | <.362 |
| 2-Methoxy-2-methylbutane | <.224 | <.224 | <.112 | <.112 |
| **2-Methoxy-2-methylpropane** | **E .110** | <.224 | .400 | .402 |
| **Methylbenzene** | <.076 | <.079 | **E .068** | **E .068** |
| (1-Methylethyl)benzene | <.064 | <.064 | <.032 | <.032 |
| Naphthalene | <.500 | <.500 | <.250 | <.250 |
| 2,2'-Oxybis[propane] | <.196 | <.196 | <.098 | <.098 |
| 2-Propenal | <500 | <500 | <250 | <250 |
| 2-Propenenitrile | <2.45 | <2.45 | <1.23 | <1.23 |
| *n*-Propylbenzene | <.084 | <.084 | <.042 | <.042 |
| Tetrachloroethene | <.076 | <.076 | <.038 | <.038 |
| Tetrachloromethane | <.176 | <.176 | <.088 | <.088 |
| Tribromomethane | <.208 | <.208 | <.104 | <.104 |
| 1,1,2-Trichloro-1,2,2-trifluoroethane | <.064 | <.064 | <.032 | <.032 |
| 1,2,3-Trichlorobenzene | <.532 | <.532 | <.266 | <.266 |
| 1,2,4-Trichlorobenzene | <.376 | <.376 | <.188 | <.188 |
| 1,1,1-Trichloroethane | <.064 | <.064 | <.032 | <.032 |
| 1,1,2-Trichloroethane | <.128 | <.128 | <.064 | <.064 |
| **1,1,2-Trichloroethene** | **E .029** | **E .029** | <.038 | <.038 |

**Appendix 1.** Concentrations of volatile organic compounds (VOCs) in surface-water samples 2 and 3 from Lake Erie-Lake St. Clair Drainage, Long Island and New Jersey Coastal Drainages, and Puget Sound Basin Study Units—Continued

[Bold type indicates detected compounds and concentrations. IUPAC, International Union of Pure and Applied Chemistry; E, estimated; <, less than; NA, not analyzed]

| VOC (IUPAC compound name) | Concentrations, in micrograms per liter | | | |
|---|---|---|---|---|
| | Site A | | Site A[1] or Site B | |
| | Sample 2 | Sample 3 | Sample 2 | Sample 3 |
| **Long Island and New Jersey Coastal Drainages Study Unit Target Analytes—Continued** | | | | |
| Trichlorofluoromethane | <0.184 | <0.184 | <0.092 | <0.092 |
| **Trichloromethane** | **E .022** | **E .021** | **E .013** | **E .013** |
| 1,2,3-Trichloropropane | <.140 | <.140 | <.070 | <.070 |
| **1,2,4-Trimethylbenzene** | <.112 | <.112 | <.056 | **E .014** |
| **Other Analytes** | | | | |
| Bromobenzene | <.072 | <.072 | <.036 | <.036 |
| Bromochloromethane | <.088 | <.088 | <.044 | <.044 |
| 2-Butanone | <3.30 | <3.30 | <1.65 | <1.65 |
| Dithiocarbonic anhydride | <.160 | <.160 | <.080 | <.080 |
| 1-Chloro-2-methylbenzene | <.084 | <.084 | <.042 | <.042 |
| 1-Chloro-4-methylbenzene | <.112 | <.112 | <.056 | <.056 |
| 3-Chloro-1-propene | <.392 | <.392 | <.196 | <.196 |
| Dibromomethane | <.100 | <.100 | <.050 | <.050 |
| *trans*-1,4-Dichloro-2-butene | <1.38 | <1.38 | <.692 | <.692 |
| 1,3-Dichloropropane | <.232 | <.232 | <.116 | <.116 |
| 2,2-Dichloropropane | <.156 | <.156 | <.078 | <.078 |
| 1,1-Dichloropropene | <.052 | <.052 | <.026 | <.026 |
| (1,1-Dimethylethyl)benzene | <.192 | <.192 | <.096 | <.096 |
| 1,4-Epoxybutane | <2.30 | <2.30 | <1.15 | <1.15 |
| 1-Ethyl-2-methylbenzene | <.200 | <.200 | <.100 | <.100 |
| Ethyl 2-methyl-2-propenoate | <.556 | <.556 | <.278 | <.278 |
| 2-Hexanone | <1.49 | <1.49 | <.746 | <.746 |
| Iodomethane | <.152 | <.152 | <.076 | <.076 |
| 1-Isopropyl-4-methylbenzene | <.220 | <.220 | <.110 | <.110 |
| Methyl 2-methyl-2-propenoate | <.700 | <.700 | <.350 | <.350 |
| 4-Methyl-2-pentanone | <.748 | <.748 | <.374 | <.374 |
| 2-Methyl-2-propenenitrile | <1.14 | <1.14 | <.570 | <.570 |
| Methyl-2-propenoate | <1.22 | <1.22 | <.612 | <.612 |
| (1-Methylpropyl)benzene | <.096 | <.096 | <.048 | <.048 |
| 1,1'-Oxybisethane | <.340 | <.340 | <.170 | <.170 |
| 2-Propanone | <9.81 | <9.81 | <4.90 | <4.90 |
| 1,1,1,2-Tetrachloroethane | <.088 | <.088 | <.044 | <.044 |
| 1,1,2,2-Tetrachloroethane | <.264 | <.264 | <.132 | <.132 |
| 1,2,3,4-Tetramethylbenzene | <.460 | <.460 | <.230 | <.230 |
| 1,2,3,5-Tetramethylbenzene | <.480 | <.480 | <.240 | <.240 |

**Appendix 1.** Concentrations of volatile organic compounds (VOCs) in surface-water samples 2 and 3 from Lake Erie-Lake St. Clair Drainage, Long Island and New Jersey Coastal Drainages, and Puget Sound Basin Study Units—Continued

[Bold type indicates detected compounds and concentrations. IUPAC, International Union of Pure and Applied Chemistry; E, estimated; <, less than; NA, not analyzed]

| VOC (IUPAC compound name) | Concentrations, in micrograms per liter | | | |
|---|---|---|---|---|
| | Site A | | Site A[1] or Site B | |
| | Sample 2 | Sample 3 | Sample 2 | Sample 3 |
| | **Long Island and New Jersey Coastal Drainages Study Unit Other Analytes—Continued** | | | |
| 1,2,3-Trimethylbenzene | <0.248 | <0.248 | <0.124 | <0.124 |
| 1,3,5-Trimethylbenzene | <.088 | <.088 | <.044 | <.044 |
| | **Puget Sound Basin Study Unit Target Analytes** | | | |
| Sample date | 4-6-98 | | | |
| **Benzene** | **E .0091** | **E .0089** | NA | NA |
| Bromodichloromethane | <.048 | <.048 | NA | NA |
| Bromoethene | <.100 | <.100 | NA | NA |
| Bromomethane | <.148 | <.148 | NA | NA |
| *n*-Butylbenzene | <.186 | <.186 | NA | NA |
| Chlorobenzene | <.028 | <.028 | NA | NA |
| Chloroethane | <.120 | <.120 | NA | NA |
| Chloroethene | <.112 | <.112 | NA | NA |
| **Chloromethane** | <.254 | **E.011** | NA | NA |
| 1,2-Dibromo-3-chloropropane | <.214 | <.214 | NA | NA |
| Dibromochloromethane | <.182 | <.182 | NA | NA |
| 1,2-Dibromoethane | <.036 | <.036 | NA | NA |
| 1,2-Dichlorobenzene | <.048 | <.048 | NA | NA |
| 1,3-Dichlorobenzene | <.054 | <.054 | NA | NA |
| 1,4-Dichlorobenzene | <.050 | <.050 | NA | NA |
| Dichlorodifluoromethane | <.096 | <.096 | NA | NA |
| 1,1-Dichloroethane | <.066 | <.066 | NA | NA |
| 1,2-Dichloroethane | <.134 | <.134 | NA | NA |
| 1,1-Dichloroethene | <.044 | <.044 | NA | NA |
| *cis*-1,2-Dichloroethene | <.038 | <.038 | NA | NA |
| *trans*-1,2-Dichloroethene | <.032 | <.032 | NA | NA |
| Dichloromethane | <.382 | <.382 | NA | NA |
| 1,2-Dichloropropane | <.068 | <.068 | NA | NA |
| *cis*-1,3-Dichloropropene | <.092 | <.092 | NA | NA |
| *trans*-1,3-Dichloropropene | <.134 | <.134 | NA | NA |
| 1,2-Dimethylbenzene | <.064 | <.064 | NA | NA |
| 1,3 and 1,4-Dimethylbenzene | <.064 | <.064 | NA | NA |
| Ethenylbenzene | <.042 | <.042 | NA | NA |
| 2-Ethoxy-2-methylpropane | <.054 | <.054 | NA | NA |
| Ethylbenzene | <.030 | <.030 | NA | NA |

**Appendix 1.** Concentrations of volatile organic compounds (VOCs) in surface-water samples 2 and 3 from Lake Erie-Lake St. Clair Drainage, Long Island and New Jersey Coastal Drainages, and Puget Sound Basin Study Units—Continued

[Bold type indicates detected compounds and concentrations. IUPAC, International Union of Pure and Applied Chemistry; E, estimated; <, less than; NA, not analyzed]

| VOC (IUPAC compound name) | Concentrations, in micrograms per liter | | | |
|---|---|---|---|---|
| | Site A | | Site A[1] or Site B | |
| | Sample 2 | Sample 3 | Sample 2 | Sample 3 |
| | **Puget Sound Basin Study Unit—Continued** | | | |
| | **Target Analytes—Continued** | | | |
| 1,1,2,3,4,4-Hexachloro-1,3-butadiene | <0.142 | <0.142 | NA | NA |
| 1,1,1,2,2,2-Hexachloroethane | <.362 | <.362 | NA | NA |
| 2-Methoxy-2-methylbutane | <.112 | <.112 | NA | NA |
| 2-Methoxy-2-methylpropane | <.112 | <.112 | NA | NA |
| **Methylbenzene** | **E .039** | **E .041** | NA | NA |
| (1-Methylethyl)benzene | <.032 | <.032 | NA | NA |
| Naphthalene | <.250 | <.250 | NA | NA |
| 2,2'-Oxybis[propane] | <.098 | <.098 | NA | NA |
| 2-Propenal | <250 | <250 | NA | NA |
| 2-Propenenitrile | <1.23 | <1.23 | NA | NA |
| *n*-Propylbenzene | <.042 | <.042 | NA | NA |
| Tetrachloroethene | <.038 | <.038 | NA | NA |
| Tetrachloromethane | <.088 | <.088 | NA | NA |
| Tribromomethane | <.104 | <.104 | NA | NA |
| 1,1,2-Trichloro-1,2,2-trifluoroethane | <.032 | <.032 | NA | NA |
| 1,2,3-Trichlorobenzene | <.266 | <.266 | NA | NA |
| 1,2,4-Trichlorobenzene | <.188 | <.188 | NA | NA |
| 1,1,1-Trichloroethane | <.032 | <.032 | NA | NA |
| 1,1,2-Trichloroethane | <.064 | <.064 | NA | NA |
| 1,1,2-Trichloroethene | <.038 | <.038 | NA | NA |
| Trichlorofluoromethane | <.092 | <.092 | NA | NA |
| **Trichloromethane** | **E .041** | **E .041** | NA | NA |
| 1,2,3-Trichloropropane | <.070 | <.070 | NA | NA |
| **1,2,4-Trimethylbenzene** | **E .084** | .118 | NA | NA |
| | **Other Analytes** | | | |
| Bromobenzene | <.036 | <.036 | NA | NA |
| Bromochloromethane | <.044 | <.044 | NA | NA |
| 2-Butanone | <1.65 | <1.65 | NA | NA |
| Dithiocarbonic anhydride | <.080 | <.080 | NA | NA |
| 1-Chloro-2-methylbenzene | <.042 | <.042 | NA | NA |
| 1-Chloro-4-methylbenzene | <.056 | <.056 | NA | NA |
| 3-Chloro-1-propene | <.196 | <.196 | NA | NA |
| Dibromomethane | <.050 | <.050 | NA | NA |
| *trans*-1,4-Dichloro-2-butene | <.692 | <.692 | NA | NA |
| 1,3-Dichloropropane | <.116 | <.116 | NA | NA |

**Appendix 1.** Concentrations of volatile organic compounds (VOCs) in surface-water samples 2 and 3 from Lake Erie-Lake St. Clair Drainage, Long Island and New Jersey Coastal Drainages, and Puget Sound Basin Study Units—Continued

[Bold type indicates detected compounds and concentrations. IUPAC, International Union of Pure and Applied Chemistry; E, estimated; <, less than; NA, not analyzed]

| VOC (IUPAC compound name) | Concentrations, in micrograms per liter | | | |
|---|---|---|---|---|
| | Site A | | Site A[1] or Site B | |
| | Sample 2 | Sample 3 | Sample 2 | Sample 3 |
| | **Puget Sound Basin Study Unit—Continued** | | | |
| | **Other Analytes—Continued** | | | |
| 2,2-Dichloropropane | <0.078 | <0.078 | NA | NA |
| 1,1-Dichloropropene | <.026 | <.026 | NA | NA |
| (1,1-Dimethylethyl)benzene | <.096 | <.096 | NA | NA |
| 1,4-Epoxybutane | <1.15 | <1.15 | NA | NA |
| 1-Ethyl-2-methylbenzene | <.100 | <.100 | NA | NA |
| Ethyl 2-methyl-2-propenoate | <.278 | <.278 | NA | NA |
| 2-Hexanone | <.746 | <.746 | NA | NA |
| Iodomethane | <.076 | <.076 | NA | NA |
| 1-Isopropyl-4-methylbenzene | <.110 | <.110 | NA | NA |
| Methyl 2-methyl-2-propenoate | <.350 | <.350 | NA | NA |
| 4-Methyl-2-pentanone | <.374 | <.374 | NA | NA |
| 2-Methyl-2-propenenitrile | <.570 | <.570 | NA | NA |
| Methyl-2-propenoate | <.612 | <.612 | NA | NA |
| (1-Methylpropyl)benzene | <.048 | <.048 | NA | NA |
| 1,1'-Oxybisethane | <.170 | <.170 | NA | NA |
| 2-Propanone | <4.90 | <4.90 | NA | NA |
| 1,1,1,2-Tetrachloroethane | <.044 | <.044 | NA | NA |
| 1,1,2,2-Tetrachloroethane | <.132 | <.132 | NA | NA |
| 1,2,3,4-Tetramethylbenzene | <.230 | <.230 | NA | NA |
| 1,2,3,5-Tetramethylbenzene | <.240 | <.240 | NA | NA |
| 1,2,3-Trimethylbenzene | <.124 | <.124 | NA | NA |
| 1,3,5-Trimethylbenzene | <.044 | <.044 | NA | NA |

[1]Two samples from the same site were collected from the Lake Erie-Lake St. Clair Drainage Study Unit.

**Appendix 2.** Concentrations of volatile organic compounds (VOCs) in ground-water samples 1, 3, and 4 from the Long Island and New Jersey Coastal Drainages, the Mississippi Embayment, and the Upper Tennessee River Basin Study Units

[Bold type indicates detected compounds and concentrations. IUPAC, International Union of Pure and Applied Chemistry; E, estimated; <, less than; NA, not analyzed]

| VOC (IUPAC compound name) | Concentrations, in micrograms per liter | | | | | |
|---|---|---|---|---|---|---|
| | Well A | | | Well B | | |
| | Sample 1 | Sample 3 | Sample 4 | Sample 1 | Sample 3 | Sample 4 |
| **Long Island and New Jersey Coastal Drainages Study Unit (fig. 1)** | | | | | | |
| **Target Analytes** | | | | | | |
| Sample date | 8-11-98 | | | 8-11-98 | | |
| Benzene | <0.100 | <0.100 | <0.100 | <0.100 | <0.100 | <0.100 |
| Bromodichloromethane | <.048 | <.048 | <.048 | <.048 | <.048 | <.048 |
| Bromoethene | <.100 | <.100 | <.100 | <.100 | <.100 | <.100 |
| Bromomethane | <.148 | <.148 | <.148 | <.148 | <.148 | <.148 |
| *n*-Butylbenzene | <.186 | <.186 | <.186 | <.186 | <.186 | <.186 |
| Chlorobenzene | <.028 | <.028 | <.028 | <.028 | <.028 | <.028 |
| Chloroethane | <.120 | <.120 | <.120 | <.120 | <.120 | <.120 |
| Chloroethene | <.112 | <.112 | <.112 | <.112 | <.112 | <.112 |
| Chloromethane | <.254 | <.254 | <.254 | <.254 | <.254 | <.254 |
| 1,2-Dibromo-3-chloropropane | <.214 | <.214 | <.214 | <.214 | <.214 | <.214 |
| Dibromochloromethane | <.182 | <.182 | <.182 | <.182 | <.182 | <.182 |
| 1,2-Dibromoethane | <.036 | <.036 | <.036 | <.036 | <.036 | <.036 |
| 1,2-Dichlorobenzene | <.048 | <.048 | <.048 | <.048 | <.048 | <.048 |
| 1,3-Dichlorobenzene | <.054 | <.054 | <.054 | <.054 | <.054 | <.054 |
| 1,4-Dichlorobenzene | <.050 | <.050 | <.050 | <.050 | <.050 | <.050 |
| Dichlorodifluoromethane | <.138 | <.138 | <.138 | <.138 | <.138 | <.138 |
| 1,1-Dichloroethane | <.066 | <.066 | <.066 | <.066 | <.066 | <.066 |
| 1,2-Dichloroethane | <.134 | <.134 | <.134 | <.134 | <.134 | <.134 |
| 1,1-Dichloroethene | <.044 | <.044 | <.044 | <.044 | <.044 | <.044 |
| *cis*-1,2-Dichloroethene | <.038 | <.038 | <.038 | <.038 | <.038 | <.038 |
| *trans*-1,2-Dichloroethene | <.032 | <.032 | <.032 | <.032 | <.032 | <.032 |
| Dichloromethane | <.382 | <.382 | <.382 | <.382 | <.382 | <.382 |
| 1,2-Dichloropropane | <.068 | <.068 | <.068 | <.068 | <.068 | <.068 |
| *cis*-1,3-Dichloropropene | <.092 | <.092 | <.092 | <.092 | <.092 | <.092 |
| *trans*-1,3-Dichloropropene | <.134 | <.134 | <.134 | <.134 | <.134 | <.134 |
| 1,2-Dimethylbenzene | <.064 | <.064 | <.064 | <.064 | <.064 | <.064 |
| 1,3 and 1,4-Dimethylbenzene | <.064 | <.064 | <.064 | <.064 | <.064 | <.064 |
| Ethenylbenzene | <.042 | <.042 | <.042 | <.042 | <.042 | <.042 |
| 2-Ethoxy-2-methylpropane | <.054 | <.054 | <.054 | <.054 | <.054 | <.054 |
| Ethylbenzene | <.030 | <.030 | <.030 | <.030 | <.030 | <.030 |
| 1,1,2,3,4,4-Hexachloro-1,3-butadiene | <.142 | <.142 | <.142 | <.142 | <.142 | <.142 |
| 1,1,1,2,2,2-Hexachloroethane | <.362 | <.362 | <.362 | <.362 | <.362 | <.362 |
| 2-Methoxy-2-methylbutane | <.112 | <.112 | <.112 | <.112 | <.112 | <.112 |
| 2-Methoxy-2-methylpropane | <.166 | <.166 | <.166 | <.166 | <.166 | <.166 |
| **Methylbenzene** | <.054 | <.054 | <.054 | <.054 | **E .015** | <.054 |

**Appendix 2.** Concentrations of volatile organic compounds (VOCs) in ground-water samples 1, 3, and 4 from the Long Island and New Jersey Coastal Drainages, the Mississippi Embayment, and the Upper Tennessee River Basin Study Units—Continued

[Bold type indicates detected compounds and concentrations. IUPAC, International Union of Pure and Applied Chemistry; E, estimated; <, less than; NA, not analyzed]

| VOC (IUPAC compound name) | Concentrations, in micrograms per liter | | | | | |
|---|---|---|---|---|---|---|
| | Well A | | | Well B | | |
| | Sample 1 | Sample 3 | Sample 4 | Sample 1 | Sample 3 | Sample 4 |
| **Long Island and New Jersey Coastal Drainages Study Unit (fig. 1)—Continued** | | | | | | |
| **Target Analytes—Continued** | | | | | | |
| (1-Methylethyl)benzene | <0.032 | <0.032 | <0.032 | <0.032 | <0.032 | <0.032 |
| Naphthalene | <.250 | <.250 | <.250 | <.250 | <.250 | <.250 |
| 2,2'-Oxybis[propane] | <.098 | <.098 | <.098 | <.098 | <.098 | <.098 |
| 2-Propenal | NA | NA | NA | NA | NA | NA |
| 2-Propenenitrile | <1.23 | <1.23 | <1.23 | <1.23 | <1.23 | <1.23 |
| *n*-Propylbenzene | <.042 | <.042 | <.042 | <.042 | <.042 | <.042 |
| Tetrachloroethene | <.102 | <.102 | <.102 | <.102 | <.102 | <.102 |
| Tetrachloromethane | <.088 | <.088 | <.088 | <.088 | <.088 | <.088 |
| Tribromomethane | <.104 | <.104 | <.104 | <.104 | <.104 | <.104 |
| 1,1,2-Trichloro-1,2,2-trifluoroethane | <.032 | <.032 | <.032 | <.032 | <.032 | <.032 |
| 1,2,3-Trichlorobenzene | <.266 | <.266 | <.266 | <.266 | <.266 | <.266 |
| 1,2,4-Trichlorobenzene | <.188 | <.188 | <.188 | <.188 | <.188 | <.188 |
| 1,1,1-Trichloroethane | <.032 | <.032 | <.032 | <.032 | <.032 | <.032 |
| 1,1,2-Trichloroethane | <.064 | <.064 | <.064 | <.064 | <.064 | <.064 |
| 1,1,2-Trichloroethene | <.038 | <.038 | <.038 | <.038 | <.038 | <.038 |
| Trichlorofluoromethane | <.092 | <.092 | <.092 | <.092 | <.092 | <.092 |
| Trichloromethane | <.052 | <.052 | <.052 | <.052 | <.052 | <.052 |
| 1,2,3-Trichloropropane | <.162 | <.162 | <.162 | <.162 | <.162 | <.162 |
| 1,2,4-Trimethylbenzene | <.056 | <.056 | <.056 | <.056 | <.056 | <.056 |
| **Other Analytes** | | | | | | |
| Bromobenzene | <.036 | <.036 | <.036 | <.036 | <.036 | <.036 |
| Bromochloromethane | <.044 | <.044 | <.044 | <.044 | <.044 | <.044 |
| 2-Butanone | <1.65 | <1.65 | <1.65 | <1.65 | <1.65 | <1.65 |
| Dithiocarbonic anhydride | <.370 | <.370 | <.370 | <.370 | <.370 | <.370 |
| 1-Chloro-2-methylbenzene | <.042 | <.042 | <.042 | <.042 | <.042 | <.042 |
| 1-Chloro-4-methylbenzene | <.056 | <.056 | <.056 | <.056 | <.056 | <.056 |
| 3-Chloro-1-propene | <.196 | <.196 | <.196 | <.196 | <.196 | <.196 |
| Dibromomethane | <.050 | <.050 | <.050 | <.050 | <.050 | <.050 |
| *trans*-1,4-Dichloro-2-butene | <.692 | <.692 | <.692 | <.692 | <.692 | <.692 |
| 1,3-Dichloropropane | <.116 | <.116 | <.116 | <.116 | <.116 | <.116 |
| 2,2-Dichloropropane | <.078 | <.078 | <.078 | <.078 | <.078 | <.078 |
| 1,1-Dichloropropene | <.026 | <.026 | <.026 | <.026 | <.026 | <.026 |
| (1,1-Dimethylethyl)benzene | <.096 | <.096 | <.096 | <.096 | <.096 | <.096 |
| 1,4-Epoxybutane | <8.79 | <8.79 | <8.79 | <8.79 | <8.79 | <8.79 |
| 1-Ethyl-2-methylbenzene | <.100 | <.100 | <.100 | <.100 | <.100 | <.100 |

**Appendix 2.** Concentrations of volatile organic compounds (VOCs) in ground-water samples 1, 3, and 4 from the Long Island and New Jersey Coastal Drainages, the Mississippi Embayment, and the Upper Tennessee River Basin Study Units—Continued

[Bold type indicates detected compounds and concentrations. IUPAC, International Union of Pure and Applied Chemistry; E, estimated; <, less than; NA, not analyzed]

| VOC (IUPAC compound name) | Concentrations, in micrograms per liter | | | | | |
|---|---|---|---|---|---|---|
| | Well A | | | Well B | | |
| | Sample 1 | Sample 3 | Sample 4 | Sample 1 | Sample 3 | Sample 4 |
| **Long Island and New Jersey Coastal Drainages Study Unit (fig. 1)—Continued** | | | | | | |
| **Other Analytes—Continued** | | | | | | |
| Ethyl 2-methyl-2-propenoate | <0.278 | <0.278 | <0.278 | <0.278 | <0.278 | <0.278 |
| 2-Hexanone | <.746 | <.746 | <.746 | <.746 | <.746 | <.746 |
| Iodomethane | <.208 | <.208 | <.208 | <.208 | <.208 | <.208 |
| 1-Isopropyl-4-methylbenzene | <.110 | <.110 | <.110 | <.110 | <.110 | <.110 |
| Methyl 2-methyl-2-propenoate | <.350 | <.350 | <.350 | <.350 | <.350 | <.350 |
| 4-Methyl-2-pentanone | <.374 | <.374 | <.374 | <.374 | <.374 | <.374 |
| 2-Methyl-2-propenenitrile | <.570 | <.570 | <.570 | <.570 | <.570 | <.570 |
| Methyl-2-propenoate | <1.36 | <1.36 | <1.36 | <1.36 | <1.36 | <1.36 |
| (1-Methylpropyl)benzene | <.048 | <.048 | <.048 | <.048 | <.048 | <.048 |
| 1,1'-Oxybisethane | <.170 | <.170 | <.170 | <.170 | <.170 | <.170 |
| 2-Propanone | <4.90 | <4.90 | <4.90 | <4.90 | <4.90 | <4.90 |
| 1,1,1,2-Tetrachloroethane | <.044 | <.044 | <.044 | <.044 | <.044 | <.044 |
| 1,1,2,2-Tetrachloroethane | <.132 | <.132 | <.132 | <.132 | <.132 | <.132 |
| 1,2,3,4-Tetramethylbenzene | <.230 | <.230 | <.230 | <.230 | <.230 | <.230 |
| 1,2,3,5-Tetramethylbenzene | <.240 | <.240 | <.240 | <.240 | <.240 | <.240 |
| 1,2,3-Trimethylbenzene | <.124 | <.124 | <.124 | <.124 | <.124 | <.124 |
| 1,3,5-Trimethylbenzene | <.044 | <.044 | <.044 | <.044 | <.044 | <.044 |
| **Mississippi Embayment Study Unit (fig. 1)** | | | | | | |
| **Target Analytes** | | | | | | |
| Sample date | 9-10-98 | | | 9-10-98 | | |
| Benzene | <.100 | NA | <.100 | <.100 | NA | <.100 |
| Bromodichloromethane | <.048 | NA | <.048 | <.048 | NA | <.048 |
| Bromoethene | <.100 | NA | <.100 | <.100 | NA | <.100 |
| Bromomethane | <.150 | NA | <.150 | <.150 | NA | <.150 |
| *n*-Butylbenzene | <.190 | NA | <.190 | <.190 | NA | <.190 |
| Chlorobenzene | <.028 | NA | <.028 | <.028 | NA | <.028 |
| Chloroethane | <.120 | NA | <.120 | <.120 | NA | <.120 |
| Chloroethene | <.110 | NA | <.110 | <.110 | NA | <.110 |
| Chloromethane | <.250 | NA | <.250 | <.250 | NA | <.250 |
| 1,2-Dibromo-3-chloropropane | <.210 | NA | <.210 | <.210 | NA | <.210 |
| Dibromochloromethane | <.180 | NA | <.180 | <.180 | NA | <.180 |
| 1,2-Dibromoethane | <.036 | NA | <.036 | <.036 | NA | <.036 |
| 1,2-Dichlorobenzene | <.048 | NA | <.048 | <.048 | NA | <.048 |
| 1,3-Dichlorobenzene | <.054 | NA | <.054 | <.054 | NA | <.054 |
| 1,4-Dichlorobenzene | <.050 | NA | <.050 | <.050 | NA | <.050 |

**Appendix 2.** Concentrations of volatile organic compounds (VOCs) in ground-water samples 1, 3, and 4 from the Long Island and New Jersey Coastal Drainages, the Mississippi Embayment, and the Upper Tennessee River Basin Study Units—Continued

[Bold type indicates detected compounds and concentrations. IUPAC, International Union of Pure and Applied Chemistry; E, estimated; <, less than; NA, not analyzed]

| VOC (IUPAC compound name) | Concentrations, in micrograms per liter | | | | | |
|---|---|---|---|---|---|---|
| | Well A | | | Well B | | |
| | Sample 1 | Sample 3 | Sample 4 | Sample 1 | Sample 3 | Sample 4 |
| | **Mississippi Embayment Study Unit (fig. 1) Target Analytes** | | | | | |
| Dichlorodifluoromethane | <0.140 | NA | <0.140 | <0.140 | NA | <0.140 |
| 1,1-Dichloroethane | <.066 | NA | <.066 | <.066 | NA | <.066 |
| 1,2-Dichloroethane | <.130 | NA | <.130 | <.130 | NA | <.130 |
| 1,1-Dichloroethene | <.044 | NA | <.044 | <.044 | NA | <.044 |
| *cis*-1,2-Dichloroethene | <.038 | NA | <.038 | <.038 | NA | <.038 |
| *trans*-1,2-Dichloroethene | <.032 | NA | <.032 | <.032 | NA | <.032 |
| Dichloromethane | <.380 | NA | <.380 | <.380 | NA | <.380 |
| 1,2-Dichloropropane | <.068 | NA | <.068 | <.068 | NA | <.068 |
| *cis*-1,3-Dichloropropene | <.090 | NA | <.090 | <.090 | NA | <.090 |
| *trans*-1,3-Dichloropropene | <.130 | NA | <.130 | <.130 | NA | <.130 |
| 1,2-Dimethylbenzene | <.060 | NA | <.060 | <.060 | NA | <.060 |
| 1,3 and 1,4-Dimethylbenzene | <.060 | NA | <.060 | <.060 | NA | <.060 |
| Ethenylbenzene | <.042 | NA | <.042 | <.042 | NA | <.042 |
| 2-Ethoxy-2-methylpropane | <.054 | NA | <.054 | <.054 | NA | <.054 |
| Ethylbenzene | <.030 | NA | <.030 | <.030 | NA | <.030 |
| 1,1,2,3,4,4-Hexachloro-1,3-butadiene | <.140 | NA | <.140 | <.140 | NA | <.140 |
| 1,1,1,2,2,2-Hexachloroethane | <.360 | NA | <.360 | <.360 | NA | <.360 |
| 2-Methoxy-2-methylbutane | <.110 | NA | <.110 | <.110 | NA | <.110 |
| 2-Methoxy-2-methylpropane | <.170 | NA | <.170 | <.170 | NA | <.170 |
| **Methylbenzene** | <.050 | NA | **E .065** | <.050 | NA | **E.044** |
| (1-Methylethyl)benzene | <.032 | NA | <.032 | <.032 | NA | <.032 |
| Naphthalene | <.250 | NA | <.250 | <.250 | NA | <.250 |
| 2,2'-Oxybis[propane] | <.098 | NA | <.098 | <.098 | NA | <.098 |
| 2-Propenal | NA | NA | NA | NA | NA | NA |
| 2-Propenenitrile | <1.20 | NA | <1.20 | <1.20 | NA | <1.20 |
| *n*-Propylbenzene | <.042 | NA | <.042 | <.042 | NA | <.042 |
| **Tetrachloroethene** | <.100 | NA | <.100 | <.100 | NA | **E.0041** |
| Tetrachloromethane | <.088 | NA | <.088 | <.088 | NA | <.088 |
| Tribromomethane | <.100 | NA | <.100 | <.100 | NA | <.100 |
| 1,1,2-Trichloro-1,2,2-trifluoroethane | <.032 | NA | <.032 | <.032 | NA | <.032 |
| 1,2,3-Trichlorobenzene | <.270 | NA | <.270 | <.270 | NA | <.270 |
| 1,2,4-Trichlorobenzene | <.190 | NA | <.190 | <.190 | NA | <.190 |
| 1,1,1-Trichloroethane | <.032 | NA | <.032 | <.032 | NA | <.032 |
| 1,1,2-Trichloroethane | <.064 | NA | <.064 | <.064 | NA | <.064 |
| 1,1,2-Trichloroethene | <.038 | NA | <.038 | <.038 | NA | <.038 |

**Appendix 2.** Concentrations of volatile organic compounds (VOCs) in ground-water samples 1, 3, and 4 from the Long Island and New Jersey Coastal Drainages, the Mississippi Embayment, and the Upper Tennessee River Basin Study Units—Continued

[Bold type indicates detected compounds and concentrations. IUPAC, International Union of Pure and Applied Chemistry; E, estimated; <, less than; NA, not analyzed]

| VOC (IUPAC compound name) | Concentrations, in micrograms per liter | | | | | |
|---|---|---|---|---|---|---|
| | Well A | | | Well B | | |
| | Sample 1 | Sample 3 | Sample 4 | Sample 1 | Sample 3 | Sample 4 |
| **Mississippi Embayment Study Unit (fig. 1)—Continued** | | | | | | |
| **Target Analytes—Continued** | | | | | | |
| Trichlorofluoromethane | <0.090 | NA | <0.090 | <0.090 | NA | <0.090 |
| Trichloromethane | <.052 | NA | <.052 | <.052 | NA | <.052 |
| 1,2,3-Trichloropropane | <.160 | NA | <.160 | <.160 | NA | <.160 |
| 1,2,4-Trimethylbenzene | <.056 | NA | <.056 | <.056 | NA | <.056 |
| **Other Analytes** | | | | | | |
| Bromobenzene | <.036 | NA | <.036 | <.036 | NA | <.036 |
| Bromochloromethane | <.044 | NA | <.044 | <.044 | NA | <.044 |
| 2-Butanone | <1.60 | NA | <1.60 | <1.60 | NA | <1.60 |
| Dithiocarbonic anhydride | <.370 | NA | <.370 | <.370 | NA | <.370 |
| 1-Chloro-2-methylbenzene | <.042 | NA | <.042 | <.042 | NA | <.042 |
| 1-Chloro-4-methylbenzene | <.056 | NA | <.056 | <.056 | NA | <.056 |
| 3-Chloro-1-propene | <.200 | NA | <.200 | <.200 | NA | <.200 |
| Dibromomethane | <.050 | NA | <.050 | <.050 | NA | <.050 |
| *trans*-1,4-Dichloro-2-butene | <.700 | NA | <.700 | <.700 | NA | <.700 |
| 1,3-Dichloropropane | <.120 | NA | <.120 | <.120 | NA | <.120 |
| 2,2-Dichloropropane | <.078 | NA | <.078 | <.078 | NA | <.078 |
| 1,1-Dichloropropene | <.026 | NA | <.026 | <.026 | NA | <.026 |
| (1,1-Dimethylethyl)benzene | <.100 | NA | <.100 | <.100 | NA | <.100 |
| 1,4-Epoxybutane | <9.00 | NA | <9.00 | <9.00 | NA | <9.00 |
| 1-Ethyl-2-methylbenzene | <.100 | NA | <.100 | <.100 | NA | <.100 |
| Ethyl 2-methyl-2-propenoate | <.280 | NA | <.280 | <.280 | NA | <.280 |
| 2-Hexanone | <.700 | NA | <.700 | <.700 | NA | <.700 |
| Iodomethane | <.210 | NA | <.210 | <.210 | NA | <.210 |
| 1-Isopropyl-4-methylbenzene | <.110 | NA | <.110 | <.110 | NA | <.110 |
| Methyl 2-methyl-2-propenoate | <.350 | NA | <.350 | <.350 | NA | <.350 |
| 4-Methyl-2-pentanone | <.370 | NA | <.370 | <.370 | NA | <.370 |
| 2-Methyl-2-propenenitrile | <.570 | NA | <.570 | <.570 | NA | <.570 |
| Methyl-2-propenoate | <1.40 | NA | <1.40 | <1.40 | NA | <1.40 |
| (1-Methylpropyl)benzene | <.048 | NA | <.048 | <.048 | NA | <.048 |
| 1,1'-Oxybisethane | <.170 | NA | <.170 | <.170 | NA | <.170 |
| 2-Propanone | <5.00 | NA | <5.00 | <5.00 | NA | <5.00 |
| 1,1,1,2-Tetrachloroethane | <.044 | NA | <.044 | <.044 | NA | <.044 |
| 1,1,2,2-Tetrachloroethane | <.130 | NA | <.130 | <.130 | NA | <.130 |
| 1,2,3,4-Tetramethylbenzene | <.230 | NA | <.230 | <.230 | NA | <.230 |
| 1,2,3,5-Tetramethylbenzene | <.200 | NA | <.200 | <.200 | NA | <.200 |

**Appendix 2.** Concentrations of volatile organic compounds (VOCs) in ground-water samples 1, 3, and 4 from the Long Island and New Jersey Coastal Drainages, the Mississippi Embayment, and the Upper Tennessee River Basin Study Units—Continued

[Bold type indicates detected compounds and concentrations. IUPAC, International Union of Pure and Applied Chemistry; E, estimated; <, less than; NA, not analyzed]

| VOC (IUPAC compound name) | Concentrations, in micrograms per liter | | | | | |
|---|---|---|---|---|---|---|
| | Well A | | | Well B | | |
| | Sample 1 | Sample 3 | Sample 4 | Sample 1 | Sample 3 | Sample 4 |
| **Mississippi Embayment Study Unit (fig. 1)—Continued** | | | | | | |
| **Other Analytes—Continued** | | | | | | |
| 1,2,3-Trimethylbenzene | <0.120 | NA | <0.120 | <0.120 | NA | <0.120 |
| 1,3,5-Trimethylbenzene | <.044 | NA | <.044 | <.044 | NA | <.044 |
| **Upper Tennessee River Basin Study Unit (fig. 1)** | | | | | | |
| **Target Analytes** | | | | | | |
| Sample date | 7-28-98 | | | 7-29-98 | | |
| Benzene | <.100 | <.100 | <.100 | <.100 | <.100 | <.100 |
| Bromodichloromethane | <.048 | <.048 | <.048 | <.048 | <.048 | <.048 |
| Bromoethene | <.100 | <.100 | <.100 | <.100 | <.100 | <.100 |
| Bromomethane | <.148 | <.148 | <.148 | <.148 | <.148 | <.148 |
| *n*-Butylbenzene | <.186 | <.186 | <.186 | <.186 | <.186 | <.186 |
| Chlorobenzene | <.028 | <.028 | <.028 | <.028 | <.028 | <.028 |
| Chloroethane | <.120 | <.120 | <.120 | <.120 | <.120 | <.120 |
| Chloroethene | <.112 | <.112 | <.112 | <.112 | <.112 | <.112 |
| Chloromethane | <.254 | <.254 | <.254 | <.254 | <.254 | <.254 |
| 1,2-Dibromo-3-chloropropane | <.214 | <.214 | <.214 | <.214 | <.214 | <.214 |
| Dibromochloromethane | <.182 | <.182 | <.182 | <.182 | <.182 | <.182 |
| 1,2-Dibromoethane | <.036 | <.036 | <.036 | <.036 | <.036 | <.036 |
| 1,2-Dichlorobenzene | <.048 | <.048 | <.048 | <.048 | <.048 | <.048 |
| 1,3-Dichlorobenzene | <.054 | <.054 | <.054 | <.054 | <.054 | <.054 |
| 1,4-Dichlorobenzene | <.050 | <.050 | <.050 | <.050 | <.050 | <.050 |
| Dichlorodifluoromethane | <.138 | <.138 | <.138 | <.138 | <.138 | <.138 |
| 1,1-Dichloroethane | <.066 | <.066 | <.066 | <.066 | <.066 | <.066 |
| 1,2-Dichloroethane | <.134 | <.134 | <.134 | <.134 | <.134 | <.134 |
| 1,1-Dichloroethene | <.044 | <.044 | <.044 | <.044 | <.044 | <.044 |
| *cis*-1,2-Dichloroethene | <.038 | <.038 | <.038 | <.038 | <.038 | <.038 |
| *trans*-1,2-Dichloroethene | <.032 | <.032 | <.032 | <.032 | <.032 | <.032 |
| Dichloromethane | <.382 | <.382 | <.382 | <.382 | <.382 | <.382 |
| 1,2-Dichloropropane | <.068 | <.068 | <.068 | <.068 | <.068 | <.068 |
| *cis*-1,3-Dichloropropene | <.092 | <.092 | <.092 | <.092 | <.092 | <.092 |
| *trans*-1,3-Dichloropropene | <.134 | <.134 | <.134 | <.134 | <.134 | <.134 |
| 1,2-Dimethylbenzene | <.064 | <.064 | <.064 | <.064 | <.064 | <.064 |
| 1,3 and 1,4-Dimethylbenzene | <.064 | <.064 | <.064 | <.064 | <.064 | <.064 |
| Ethenylbenzene | <.042 | <.042 | <.042 | <.042 | <.042 | <.042 |
| 2-Ethoxy-2-methylpropane | <.054 | <.054 | <.054 | <.054 | <.054 | <.054 |
| Ethylbenzene | <.030 | <.030 | <.030 | <.030 | <.030 | <.030 |

**Appendix 2.** Concentrations of volatile organic compounds (VOCs) in ground-water samples 1, 3, and 4 from the Long Island and New Jersey Coastal Drainages, the Mississippi Embayment, and the Upper Tennessee River Basin Study Units—Continued

[Bold type indicates detected compounds and concentrations. IUPAC, International Union of Pure and Applied Chemistry; E, estimated; <, less than; NA, not analyzed]

| VOC (IUPAC compound name) | Concentrations, in micrograms per liter | | | | | |
|---|---|---|---|---|---|---|
| | Well A | | | Well B | | |
| | Sample 1 | Sample 3 | Sample 4 | Sample 1 | Sample 3 | Sample 4 |
| **Upper Tennessee River Basin Study Unit (fig. 1)—Continued** | | | | | | |
| **Target Analytes—Continued** | | | | | | |
| 1,1,2,3,4,4-Hexachloro-1,3-butadiene | <0.142 | <0.142 | <0.142 | <0.142 | <0.142 | <0.142 |
| 1,1,1,2,2,2-Hexachloroethane | <.362 | <.362 | <.362 | <.362 | <.362 | <.362 |
| 2-Methoxy-2-methylbutane | <.112 | <.112 | <.112 | <.112 | <.112 | <.112 |
| 2-Methoxy-2-methylpropane | <.166 | <.166 | <.166 | <.166 | <.166 | <.166 |
| **Methylbenzene** | <.054 | <.054 | <.054 | <.054 | **E .022** | **E .019** |
| (1-Methylethyl)benzene | <.032 | <.032 | <.032 | <.032 | <.032 | <.032 |
| Naphthalene | <.250 | <.250 | <.250 | <.250 | <.250 | <.250 |
| 2,2'-Oxybis[propane] | <.098 | <.098 | <.098 | <.098 | <.098 | <.098 |
| 2-Propenal | NA | NA | NA | NA | NA | NA |
| 2-Propenenitrile | <1.23 | <1.23 | <1.23 | <1.23 | <1.23 | <1.23 |
| *n*-Propylbenzene | <.042 | <.042 | <.042 | <.042 | <.042 | <.042 |
| Tetrachloroethene | <.102 | <.102 | <.102 | <.102 | <.102 | <.102 |
| Tetrachloromethane | <.088 | <.088 | <.088 | <.088 | <.088 | <.088 |
| Tribromomethane | <.104 | <.104 | <.104 | <.104 | <.104 | <.104 |
| 1,1,2-Trichloro-1,2,2-trifluoroethane | <.032 | <.032 | <.032 | <.032 | <.032 | <.032 |
| 1,2,3-Trichlorobenzene | <.266 | <.266 | <.266 | <.266 | <.266 | <.266 |
| 1,2,4-Trichlorobenzene | <.188 | <.188 | <.188 | <.188 | <.188 | <.188 |
| 1,1,1-Trichloroethane | <.032 | <.032 | <.032 | <.032 | <.032 | <.032 |
| 1,1,2-Trichloroethane | <.064 | <.064 | <.064 | <.064 | <.064 | <.064 |
| 1,1,2-Trichloroethene | <.038 | <.038 | <.038 | <.038 | <.038 | <.038 |
| Trichlorofluoromethane | <.092 | <.092 | <.092 | <.092 | <.092 | <.092 |
| **Trichloromethane** | **E .015** | **E .015** | **E .014** | <.052 | **E .010** | <.052 |
| 1,2,3-Trichloropropane | <.162 | <.162 | <.162 | <.162 | <.162 | <.162 |
| 1,2,4-Trimethylbenzene | <.056 | <.056 | <.056 | <.056 | <.056 | <.056 |
| **Other Analytes** | | | | | | |
| Bromobenzene | <.036 | <.036 | <.036 | <.036 | <.036 | <.036 |
| Bromochloromethane | <.044 | <.044 | <.044 | <.044 | <.044 | <.044 |
| 2-Butanone | <1.65 | <1.65 | <1.65 | <1.65 | <1.65 | <1.65 |
| Dithiocarbonic anhydride | <.370 | <.370 | <.370 | <.370 | <.370 | <.370 |
| 1-Chloro-2-methylbenzene | <.042 | <.042 | <.042 | <.042 | <.042 | <.042 |
| 1-Chloro-4-methylbenzene | <.056 | <.056 | <.056 | <.056 | <.056 | <.056 |
| 3-Chloro-1-propene | <.196 | <.196 | <.196 | <.196 | <.196 | <.196 |
| Dibromomethane | <.050 | <.050 | <.050 | <.050 | <.050 | <.050 |
| *trans*-1,4-Dichloro-2-butene | <.692 | <.692 | <.692 | <.692 | <.692 | <.692 |
| 1,3-Dichloropropane | <.116 | <.116 | <.116 | <.116 | <.116 | <.116 |

**Appendix 2.** Concentrations of volatile organic compounds (VOCs) in ground-water samples 1, 3, and 4 from the Long Island and New Jersey Coastal Drainages, the Mississippi Embayment, and the Upper Tennessee River Basin Study Units—Continued

[Bold type indicates detected compounds and concentrations. IUPAC, International Union of Pure and Applied Chemistry; E, estimated; <, less than; NA, not analyzed]

| VOC (IUPAC compound name) | Concentrations, in micrograms per liter | | | | | |
|---|---|---|---|---|---|---|
| | Well A | | | Well B | | |
| | Sample 1 | Sample 3 | Sample 4 | Sample 1 | Sample 3 | Sample 4 |
| **Upper Tennessee River Basin Study Unit (fig. 1)—Continued** | | | | | | |
| **Other Analytes—Continued** | | | | | | |
| 2,2-Dichloropropane | <0.078 | <0.078 | <0.078 | <0.078 | <0.078 | <0.078 |
| 1,1-Dichloropropene | <.026 | <.026 | <.026 | <.026 | <.026 | <.026 |
| (1,1-Dimethylethyl)benzene | <.096 | <.096 | <.096 | <.096 | <.096 | <.096 |
| 1,4-Epoxybutane | <8.79 | <8.79 | <8.79 | <8.79 | <8.79 | <8.79 |
| 1-Ethyl-2-methylbenzene | <.100 | <.100 | <.100 | <.100 | <.100 | <.100 |
| Ethyl 2-methyl-2-propenoate | <.278 | <.278 | <.278 | <.278 | <.278 | <.278 |
| 2-Hexanone | <.746 | <.746 | <.746 | <.746 | <.746 | <.746 |
| Iodomethane | <.208 | <.208 | <.208 | <.208 | <.208 | <.208 |
| 1-Isopropyl-4-methylbenzene | <.110 | <.110 | <.110 | <.110 | <.110 | <.110 |
| Methyl 2-methyl-2-propenoate | <.350 | <.350 | <.350 | <.350 | <.350 | <.350 |
| 4-Methyl-2-pentanone | <.374 | <.374 | <.374 | <.374 | <.374 | <.374 |
| 2-Methyl-2-propenenitrile | <.570 | <.570 | <.570 | <.570 | <.570 | <.570 |
| Methyl-2-propenoate | <1.36 | <1.36 | <1.36 | <1.36 | <1.36 | <1.36 |
| (1-Methylpropyl)benzene | <.048 | <.048 | <.048 | <.048 | <.048 | <.048 |
| 1,1'-Oxybisethane | <.170 | <.170 | <.170 | <.170 | <.170 | <.170 |
| 2-Propanone | <4.90 | <4.90 | <4.90 | <4.90 | <4.90 | <4.90 |
| 1,1,1,2-Tetrachloroethane | <.044 | <.044 | <.044 | <.044 | <.044 | <.044 |
| 1,1,2,2-Tetrachloroethane | <.132 | <.132 | <.132 | <.132 | <.132 | <.132 |
| 1,2,3,4-Tetramethylbenzene | <.230 | <.230 | <.230 | <.230 | <.230 | <.230 |
| 1,2,3,5-Tetramethylbenzene | <.240 | <.240 | <.240 | <.240 | <.240 | <.240 |
| 1,2,3-Trimethylbenzene | <.124 | <.124 | <.124 | <.124 | <.124 | <.124 |
| 1,3,5-Trimethylbenzene | <.044 | <.044 | <.044 | <.044 | <.044 | <.044 |