



# Decontaminating Groundwater Sampling Devices

Louise V. Parker and Thomas A. Ranney

October 1997

**Abstract:** These studies are the second part of a two-year project that examines decontaminating groundwater sampling devices. In the first year, the efficiency of various decontamination protocols was tested using small test pieces of materials that are commonly used in groundwater sampling devices. Those tests showed that a hot detergent wash and rinse followed by hot air drying (105°C) was the most effective decontamina-

tion protocol. In these studies, two groundwater sampling devices, a bailer and a bladder pump, were used to sample groundwater that was contaminated with either trichloroethylene (TCE), munitions, or pesticides. These studies showed that a hot detergent wash and hot water rinse followed by hot air drying is an effective method for decontaminating these sampling devices.

**How to get copies of CRREL technical publications:**

Department of Defense personnel and contractors may order reports through the Defense Technical Information Center:

DTIC-BR SUITE 0944  
8725 JOHN J KINGMAN RD  
FT BELVOIR VA 22060-6218  
Telephone 1 800 225 3842  
E-mail help@dtic.mil  
msorders@dtic.mil  
WWW <http://www.dtic.dla.mil/>

All others may order reports through the National Technical Information Service:

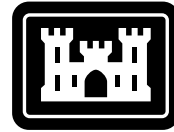
NTIS  
5285 PORT ROYAL RD  
SPRINGFIELD VA 22161  
Telephone 1 703 487 4650  
1 703 487 4639 (TDD for the hearing-impaired)  
E-mail orders@ntis.fedworld.gov  
WWW <http://www.fedworld.gov/ntis/ntishome.html>

A complete list of all CRREL technical publications is available from

USACRREL (CECRL-LP)  
72 LYME RD  
HANOVER NH 03755-1290  
Telephone 1 603 646 4338  
E-mail techpubs@crrel.usace.army.mil

**For information on all aspects of the Cold Regions Research and Engineering Laboratory, visit our World Wide Web site:**  
<http://www.crrel.usace.army.mil>

# Special Report 97-25



**US Army Corps  
of Engineers®**  
Cold Regions Research &  
Engineering Laboratory

## Decontaminating Groundwater Sampling Devices

Louise V. Parker and Thomas A. Ranney

October 1997

Prepared for  
U.S. ARMY ENVIRONMENTAL CENTER  
SFIM-AEC-ET-CR-97021

Approved for public release; distribution is unlimited.

## **PREFACE**

This report was prepared by Louise V. Parker, Research Physical Scientist, Applied Research Division, Research and Engineering Directorate, U.S. Army Cold Regions Research and Engineering Laboratory (CRREL), and Thomas A. Ranney, Staff Scientist, Science and Technology Corporation, Hanover, New Hampshire. Funding for this work was provided by the U.S. Army Environmental Center (USAEC), Aberdeen Proving Ground, Maryland, Martin H. Stutz, Project Monitor.

The authors thank Martin Stutz and the U.S. Army Environmental Center for their support of this work. They also thank Daniel Harrelson and Kenneth Stroud, U.S. Army Waterways Experiment Station, Vicksburg, Mississippi, for providing the munitions-contaminated water; Zachary Parker, CRREL, and George Lemieux, formerly of CRREL, for their assistance with the operation of the sampling pumps and “steam cleaner”; and Franceska Wilde, Groundwater Quality Hydrologist, U.S. Geological Survey, Water Resources Division, Office of Water Quality, Reston, Virginia, and Dr. Clarence Grant, Professor Emeritus, Department of Chemistry, University of New Hampshire, Durham, New Hampshire, for their technical reviews of this manuscript.

This publication reflects the personal views of the author and does not suggest or reflect the policy, practices, programs, or doctrine of the U.S. Army or Government of the United States. The contents of this report are not to be used for advertising or promotional purposes. Citation of brand names does not constitute an official endorsement or approval of the use of such commercial products.

## CONTENTS

	Page
Preface .....	ii
Introduction .....	1
Factors affecting decontamination efficiency .....	2
Studies that demonstrate the factors that affect decontamination efficiency .....	3
Findings from our initial studies .....	3
Purpose of this study .....	4
Materials and methods .....	4
General information .....	4
TCE studies .....	6
Pesticide study .....	7
Munitions study .....	8
Results and discussion .....	9
TCE studies .....	9
Pesticide study .....	10
Munitions study .....	11
Conclusions .....	11
Future applications .....	12
Literature cited .....	13
Appendix A. Raw data from decontamination studies .....	15
Abstract .....	21

## TABLES

Table	
1. Summary of TCE studies using a bailer .....	9
2. Summary of TCE studies using a bladder pump .....	10
3. Summary of pesticide study .....	11
4. Summary of munitions study .....	11

# Decontaminating Groundwater Sampling Devices

LOUISE V. PARKER AND THOMAS A. RANNEY

## INTRODUCTION

Decontamination methods are used primarily to reduce cross contamination, especially when groundwater sampling devices are not dedicated and are moved from well to well. In 1989, Mickam et al. surveyed the various decontamination procedures required by state and other regulatory agencies and in 1995 Parker conducted a literature review on decontamination methods. They found that 1) there are a number of published decontamination protocols, 2) there is a lot of disparity between these protocols, and 3) there has been almost no systematic study on the effectiveness of the various procedures.

Although decontamination procedures vary considerably in their methodology, most utilize some type of aqueous cleaning method, and often use solvent cleaning as a final or additional rinse. A typical protocol for decontaminating groundwater sampling devices that have been used to sample organic solutes is as follows: wash with detergent, rinse with tap water, rinse with (high quality) organic solvents, rinse with some type of high-quality water (e.g., distilled, deionized, organic-free reagent water), and air dry (Mickam et al. 1989). In addition, steam cleaners or high-pressure washing systems are sometimes recommended for decontaminating sampling devices, especially to remove gross contamination such as dirt and oils.

Aqueous cleaning is used to first remove gross contamination and particles. Water acts as a solvent medium for contaminants that are soluble in water, and as a dispersal medium for substances that do not dissolve in water but can be carried in suspension. A surface active agent (or surfactant), such as detergent, is commonly added to improve the wetting ability of the cleaning solution and aid cleaning by separating the contaminant from the solid surface and then keeping the contaminants in suspension, thus preventing redeposition.

With steam cleaning, pressure developed in the steam boiler imparts a high velocity to a mixture of water droplets and steam, which is directed from a nozzle onto the target surface. Detergent and heat from the steam weaken the bonds between the dirt and surface while the high velocity of the water droplets has sufficient power to remove debris from the surface (Summers 1982). Depending upon the contaminant, steam can also facilitate volatilization and hydrolysis, and may aid in the removal of subsurface contaminants. Problems associated with steam cleaning include workers being burned, corrosion of metal surfaces, warping of some polymers, and liberation of toxic vapors. However, from what we have been able to determine, most "steam cleaners" used for decontaminating groundwater sampling devices are actually high-temperature, high-pressure washing systems.

With pressurized water washing systems, high-pressure pumps produce a stream of water rather than the small droplets produced by steam cleaning. The advantages of this type of cleaning over steam cleaning are that there is increased force available, the energy requirements are lower because water does not have to be converted to steam, polymeric materials are less likely to be degraded, and there is less likelihood of being burned.

Organic solvent rinses are used to remove any residual contaminants by dissolving them. Generally like dissolves like; i.e., polar solvents dissolve polar contaminants and nonpolar solvents dissolve nonpolar contaminants. Because water is a very polar solvent, nonpolar solvents are typically used to remove nonpolar organic contaminants (e.g., oils, tars) that have not been removed previously by aqueous cleaning.

Recommended organic solvents vary with the particular protocol but typically include acetone, hexane, or methanol (Parker 1995). In most protocols, these solvents are recommended without any

regard to the type of contaminants, and it should be noted that among the three solvents mentioned only hexane is relatively nonpolar. Obviously any organic solvent that is used as a rinsing agent should not be one of the target analytes or interfere with chemical analyses.

There are a number of problems associated with using organic solvents. These can include flammability, toxicity, disposal (although recycling can reduce this problem), and spillage, which can cause additional contamination problems on site. Also, many polymers (e.g., thermoplastics) are degraded by various organic solvents. Information on incompatibilities between polymers and organic solvents can be found in chemical resistance tables published by the Plastics Design Library (1994a, b) and in some of the scientific supply catalogs (e.g., Nalgene Co. and Cole-Parmer Co.). In addition, all polymers sorb some organic chemicals and these contaminants may be subsequently desorbed, thereby contaminating a water sample.

#### **Factors affecting decontamination efficiency**

Parker (1995) listed several factors that affect how readily a sampling device can be decontaminated. These include the type of sampling device (e.g., pump vs. bailer), the materials to be decontaminated, and physical characteristics of the organic contaminant, such as its aqueous solubility, volatility, and propensity to adsorb on or absorb into materials used in the sampling device. Contact time and the degree of initial contamination on the surface are also critical factors. Cleaning a surface that has been exposed to trace-level organic contaminants is much different from cleaning a surface exposed to neat (pure product) hydrocarbons or organic solvents. Other types of contaminants such as grease and oil may also affect removal.

Several studies (Gillham and O'Hannesin 1990, Parker et al. 1990, Reynolds et al. 1990) have shown that nonpermeable surfaces, such as glass and stainless steel, do not tend to sorb more hydrophilic organic solutes (with log octanol-water partition coefficient [ $K_{ow}$ ] values less than 4). However, there are reports that these surfaces sorb more hydrophobic contaminants, such as polychlorinated biphenyls (PCBs), chlorinated pesticides, and polyaromatic hydrocarbons (PAHs) (Champion and Olsen 1971, Ogan et al. 1978, Sharom and Solomon 1981, Strachan and Hess 1982, and Jones and Miller 1988). Most likely these

losses are due to adsorption rather than absorption. Sharom and Solomon (1981) concluded that pesticides with solubilities in the  $\mu\text{g}/\text{L}$  range have a tendency to be adsorbed by glass while more soluble compounds do not.

There has been relatively little study of desorption of hydrophobic organic contaminants from nonpermeable surfaces. Sharom and Solomon (1981) noted that the pesticide permethrin was much more readily desorbed from glass than from polyvinyl chloride (PVC), polyethylene (PE), or fluoropolymer (Teflon) surfaces. They were able to recover 94% of the lost permethrin by shaking with water for one minute. Parker (1995) proposed that decontamination of nonpermeable surfaces such as metals and glass should involve removing only surface contaminants, such as any residual film (either wet or dry) that is left on the surface when the sampling device is removed from the well, and any highly hydrophobic contaminants that may have adsorbed to the surface.

In contrast, several studies (Barcelona et al. 1985, Reynolds and Gillham 1985, Gillham and O'Hannesin 1990, Parker et al. 1990, Reynolds et al. 1990, Parker and Ranney 1996, 1997a) have shown that polymeric materials, such as well casings and the tubings used in groundwater sampling pumps, sorb substantial quantities of some organic contaminants from aqueous solutions. Most of these studies agree that these organic compounds have diffused into the polymer matrix, i.e., absorption has occurred. The rate and extent of sorption varies among analytes for a given material, and varies considerably among polymers for a given analyte. Generally, flexible materials tend to be much more sorptive (Barcelona et al. 1985, Gillham and O'Hannesin 1990, Reynolds et al. 1990, Parker and Ranney 1996). As an example, Gillham and O'Hannesin (1990) found that after only 10 minutes, sorption of low-ppm levels of benzene by flexible PVC was approximately 35%, while losses were less than 1% for solutions exposed to rigid PVC.

For polymers exposed to low concentrations of organic solutes, diffusion of the organic molecule in the polymer is considered to be concentration independent, and at slightly higher concentrations (activities) diffusion is considered to be concentration dependent (Berens 1985, Jenkins et al. 1986, Holsen 1988). However, when glassy amorphous polymers (e.g., rigid PVC) are subjected to neat (undiluted) chemicals or very high concentrations (i.e., approaching the compound's aqueous solubility) and the chemical is a solvent or

swelling agent of the polymer, then diffusion increases several orders of magnitude and becomes first anomalous and then Case II (i.e., has a swelling front) (Berens 1985, Jenkins et al. 1986, Holsen 1988). In instances where Case II diffusion has occurred, the polymer will be seriously degraded (swollen, softened, dissolved) and the sampling device will no longer be useful.

Parker (1995) proposed that decontaminating permeable materials should involve more than removing surface contaminants if desorption of absorbed contaminants is significant. Unfortunately, there have been only a few studies (Miller 1982, Barcelona et al. 1985, Parker et al. 1990) that have examined desorption of organic contaminants from polymeric materials. Barcelona et al. (1985) followed the kinetics of desorption of chloroform from five tubing materials (polypropylene, polyethylene, PVC, silicone rubber, and polytetrafluoroethylene [PTFE]) that had been previously exposed to a 100-ppb solution of chloroform for one hour. They found that 80–90% of the desorption they observed occurred within the first 5–10 minutes and that the amount desorbed after one hour constituted less than 10% of the total chloroform sorbed. Those results indicate that contaminants at or near the surface desorb rapidly and that release of the remainder of the absorbed contaminants is slower, most likely because it is controlled by diffusion. All three studies found that the compounds that were present in the greatest concentrations following desorption were not the same compounds that had been sorbed the most rapidly or to the greatest extent. Parker et al. (1990) also noted that the smaller molecules were more readily desorbed and attributed this to the fact that diffusion is more rapid for smaller molecules (Berens and Hopfenberg 1982, Reynolds et al. 1990).

#### **Studies that demonstrate the factors that affect decontamination efficiency**

Although not many studies have examined the efficiency of the various decontamination protocols, Parker (1995) found three studies demonstrating the impact that the type of contaminants, the level of contamination, or the materials being decontaminated can have on decontamination effectiveness. These studies are summarized below.

Devlin (1987) found that polyethylene tubing was harder to decontaminate than Teflon tubing (the actual type was not specified). These tubings had been exposed to ppb levels of a suite of volatile organic compounds (VOCs) and were decon-

taminated by pumping deionized water through them.

Schuh et al. (1993) compared the effectiveness of distilled water rinses for removing seven pesticides from a PVC bailer. They selected a brief contact time (one minute) to represent the time required to take a bailed sample in a shallow well or gravelly aquifer. With one exception (dimethoate), they found a reasonably good correlation between the effectiveness of this procedure and the analyte's solubility in water or its  $K_{ow}$  value. They found that the most hydrophilic contaminants (i.e., with a solubility greater than 500 mg/L or  $\log K_{ow}$  less than 2.3) were removed from the bailer with no residual carryover with just one rinse, while the most hydrophobic analytes (i.e., with a solubility of less than 3 mg/L or  $\log K_{ow}$  ~4.6–4.7) had residual carryover after six rinses.

Fink and Boyajian (1989) decontaminated a stainless steel bladder pump (with a PTFE bladder and PTFE-lined sample tubing) after it had been used to sample VOCs. The pump was cleaned by steam cleaning the outside of the pump and tubing, and then circulating hot (120°F, 49°C) aqueous detergent (1%) solution through the system followed by ambient temperature rinse water. In each test, the pump was contaminated by pumping at least five sampling pump/tubing assembly volumes of contaminated water. Detectable levels of trichloroethylene (TCE) (1–2 µg/L) were found in the final rinse water when the pump was used to sample the two wells with the highest TCE concentrations (1600 µg/L and 2215 µg/L, respectively) but not when the pump was used to sample wells with lower concentrations.

Because both Mickam et al. (1989) and Parker (1995) concluded that there have been almost no systematic scientific studies on decontamination of groundwater sampling devices, we initiated these studies to determine the effectiveness of various decontamination protocols. These studies were designed to consider the type of contaminants, concentration of contaminants, materials being decontaminated, and contact times.

#### **Findings from our initial studies**

In the first phase of our studies, we (Parker and Ranney 1997b) exposed three materials commonly used in sampling devices (rigid PVC, PTFE, and stainless steel) to a test solution containing either VOCs or pesticides and then tested various decontamination protocols. These chemicals were selected because they ranged from being relatively hydrophilic to relatively hydrophobic. In



the VOC studies, the test solution initially contained ~2 mg/L each of *m*-nitrotoluene (MNT), TCE, *p*-dichlorobenzene (PDCB), and tetrachloroethylene (perchloroethylene or PCE). In the pesticides studies, three additional polymeric tubing materials were also tested: low-density polyethylene (LDPE), polyvinylidene fluoride (PVDF), and a copolymer of vinylidene fluoride and hexafluoropropylene [P(VDF-HFP)]. Initial concentrations of the pesticides ranged from 576-5605 µg/L for lindane, from 0 to 96 µg/L for heptachlor, from 160 to 625 µg/L for aldrin, and from 191 to 393 µg/L for dieldrin. Generally exposure times for sorption and desorption were 10 minutes/10 minutes, 24 hours/10 minutes, and 24 hours/24 hours.

We found that all the organic contaminants tested could be readily removed from the nonpermeable stainless steel surfaces with a hot detergent wash and hot water rinse. However, as expected, the permeable polymeric materials were much less readily decontaminated. Ease of decontamination was a function of the analyte, the rigidity or sorptive nature of the polymer, and the contact time.

Detergent washing and rinsing with cold water was not effective for removing VOCs from the more sorptive PTFE test pieces, or from the rigid PVC test pieces that had been exposed to the test solution for the longer sorption/desorption regime. However, VOCs were readily removed from the PVC test pieces by washing with a hot detergent solution and rinsing with hot water. For the more sorptive PTFE, additional oven drying (105°C) was necessary for effective decontamination. Apparently oven drying speeds diffusion of the VOCs out of the polymer.

Pesticides were readily removed from most of the polymeric materials by using a hot detergent wash and hot water rinse. (A cold detergent wash procedure was not tested.) LDPE was the exception to this, and could not be adequately cleaned using this method if the exposure times were longer (24 hr/24 hr). Detergent washing followed by oven drying substantially improved removal of these contaminants (by a factor of 10), with only low-µg/L concentrations of one pesticide still detected. LDPE tubing was the most sorptive of the tubing materials tested and absorption within the polymer matrix appears to be quite significant. Again it appears that oven drying speeds diffusion of the sorbed organic chemicals out of the polymer.

This study also showed that solvent rinsing

did not aid in the removal of the VOCs from the more sorptive PTFE surfaces. While solvent rinsing did slightly improve removal of the pesticides from LDPE tubing, oven drying was much more effective. We (Parker and Ranney 1997b) concluded that a considerably cumbersome, expensive, and hazardous step (i.e., solvent rinsing) serves no useful purpose and thus could be eliminated from all decontamination protocols.

## PURPOSE OF THIS STUDY

The purpose of this phase of this study was to test various decontamination procedures on groundwater sampling devices that have been exposed to a variety of organic contaminants. Protocols that used hot detergent washes and hot air drying were used in these studies because of our previous findings. Presumably, sampling devices will be harder to decontaminate than the small test pieces of the various materials that were used in the previous study. This is because sampling devices are larger and more complex in structure and, in some instances, may be fabricated with several types of materials.

## MATERIALS AND METHODS

### General information

Two groundwater sampling devices were used in this study: a dual-check valve bailer and a bladder pump. These devices were used to sample water that contained either TCE, a mixture of various munitions, or a mixture of pesticides. TCE-contaminated groundwater was obtained by sampling two monitoring wells that are located on our laboratory grounds. Water contaminated with pesticides and munitions was sampled by filling a large standpipe with one of these solutions.

The bailer was contaminated by lowering it into the well or standpipe and then recovering a sample. For samples taken from the standpipe, the bailer was allowed to sit in the standpipe for two minutes before the sample was retrieved. This was done to simulate the time it took to sample our deeper well. To contaminate the bladder pump, it was lowered into the well or standpipe, and ten system (pump and tubing) volumes were pumped through the system. In the case of the standpipe, the test solution was recirculated by pumping it back into the standpipe. After pumping the ten pump volumes through the system, a

sample was collected to determine the initial concentrations of the analytes in the well or standpipe. The system was then left for 24 hours, and then another ten volumes were pumped through the system. Another sample was taken at this point to determine analyte concentrations in the well, or standpipe, at the time the system was decontaminated. The pump was then removed from the well, drained, and decontaminated (described later in the text).

After decontamination, the devices were used to sample distilled (DI) water. For the bailer, this was done by lowering the bailer (without the sampling line) into a 1-L, glass graduated cylinder filled with DI water and allowing it to sit for two minutes. Again, a two-minute contact time was used to simulate the time it took us to retrieve a bailer from our deeper well. For the bladder pump, the DI water sample was taken by lowering the pump into a clean standpipe containing DI water and then pumping the DI water out of the standpipe.

The decontamination efficiency was determined by measuring the amount that was desorbed from the decontaminated sampling devices back into the distilled water during the (DI water) sampling event. The decontamination treatment was considered effective if we were unable to detect any residual contaminant in the distilled water sample.

### *Materials*

*TCE-contaminated monitoring wells.* Four-in.-diameter PVC casing and screen were used in the two monitoring wells. One well was ~139 ft deep with a static water level of 130 ft. This well had consistently high TCE concentrations (~150 mg/L). The other well was ~100 ft deep with a static water level of 87 ft, and it had consistently low concentrations (~0.02 mg/L) of TCE. Both wells contained bladder pumps that had been left in the well for one year. Thus, the contaminants had had time to permeate the polymeric materials in the bladder and lines.

*Standpipes.* The standpipes used to hold the contaminated well water and the distilled water consisted of 8-in.-diameter, schedule 40 PVC pipe, approximately 8 ft long. A PVC end cap was pounded on one end of the pipe; no organic solvent was used to join the end cap and casing.

Another small standpipe was used in some experiments for washing the pump. It consisted of a 3-in.-diameter, schedule 40 PVC pipe approximately 4 ft long. The PVC end cap was installed as described previously.

*Sampling devices.* The wall of the dual-check valve bailer was made of fluorinated ethylene propylene (FEP), and the top and bottom check assemblies were made of PTFE. The bailer had a 350-mL capacity, was 12 in. in length, and had an outside diameter of 1.88 in. It was raised and lowered on a nylon line.

The bladder pump consisted of a stainless steel (type 316) body with a PTFE bladder. The pump was 1.5 in. in diameter and approximately 41 in. in length. The pump was attached to either 96 ft or 135 ft of twin-line bonded tubing. The compressed air supply line was polyethylene (0.25-in. o.d.) and the sample discharge line was FEP-lined polyethylene (0.50-in. o.d., with the FEP lining 0.0165 in. thick and the PE layer 0.042 in. thick). Air was supplied to the bladder pump with an oilless gasoline-driven compressor capable of delivering 2.1 standard cubic feet per minute (SCFM) at 165 psig providing lifts to 320 ft. Regulation of air pressure, fill and discharge cycle times, and hence sample flow rates were accomplished with a portable pneumatic control unit. The tubing length in the deeper well was 135 ft and 96 ft in the shallower well.

*Virgin sampling tubing.* In our third TCE study, a 6-ft piece of virgin FEP tubing was used to pump DI water. This was done to separate the relative contaminant contributions of the "cleaned" bladder pump and tubing. Prior to the study, the virgin tubing was cleaned by running DI water through it for several minutes. A blank sample was then taken and no TCE was found.

*Pressure washer.* A tap outside of our laboratory building supplied ambient temperature tap water to a high-temperature (~99°C) pressure (1000 psi) washer. The pressure washer supplied the hot detergent solution and the hot water rinse water.

*Detergent solution.* A 1% Liqui-Nox detergent solution was used. Liqui-Nox is a phosphate-free liquid detergent with a pH of 8.0–8.5, is biodegradable, and is recommended by the manufacturer for cleaning equipment that is used for environmental sampling and testing.

*DI water.* DI water was provided by running a virgin LDPE line out the window of our chemistry laboratory to either our washing station or to the DI-water standpipe (both directly outside of the laboratory). The tubing was cleaned by running several volumes of DI water through the line and then collecting a blank sample. No TCE, pesticides, or munitions were found in any of the blank samples.

## TCE studies

### *Experimental methods*

*First TCE study—Effect of hot detergent wash on bailer.* After sampling the well, the bailer was taken to the laboratory and washed as follows:

- 1) Remove nylon line and disassemble the bailer.
- 2) Place the bailer parts in 4 L of hot (~50°C) detergent solution and scrub with a brush (the nylon line was not decontaminated).
- 3) Soak for five minutes.
- 4) Rinse bailer parts and wash tub with tap water to remove the suds from the detergent.
- 5) Soak in 4 L of hot (~50°C) tap water for five minutes.
- 6) Rinse with ambient temperature tap water.
- 7) Reassemble the bailer (without the sampling line).
- 8) Rinse by submerging the bailer in DI water contained in a 1-L, glass graduated cylinder. Remove the bailer and pour the water out of the bailer and graduated cylinder. Repeat this process two more times.

*Second TCE study—Effect of hot detergent wash and hot air drying on bailer.* In this study, the bailer was washed and rinsed as described in the previous study and then placed in an oven at 105°C for 24 hours.

*Third TCE study—Effect of detergent wash on a pump exposed to high concentrations.* After removing the pump from the well, the following wash procedure was used:

- 1) Rinse the outside of the tubing and pump as it is withdrawn from the well using the pressure washer. Place the rinsed equipment on a clean, large plastic sheet.
- 2) Connect the pump and tubing to the DI water line and flush three system volumes of DI water through the system.
- 3) Attach the pressure washer to the pump/tubing.
- 4) Pump 10 system volumes (10 gal.) of hot detergent solution through the system.
- 5) Pump 75 system volumes of hot tap water. (This large volume of rinse water was required to remove all the suds from the system.)
- 6) Disconnect the pressure washer.
- 7) Connect the system to a DI water line and flush system with three system volumes of DI water.
- 8) Disconnect DI water line from system.

- 9) Place bladder pump and tubing in standpipe containing DI water.

A sample was collected after step 2 was completed prior to detergent washing the system. This sample was collected to determine if contamination would occur in a system that had been only briefly rinsed. Samples were also collected after the system was washed and rinsed and three, six, and nine system volumes of DI water had been pumped through the system.

After we completed our sampling, the pump and tubing were disconnected from each other, drained, and placed in an unused laboratory. After allowing the equipment to air dry for one week, 6 ft of virgin FEP tubing was attached to the pump, the pump was placed in the standpipe containing DI water, 58 pump volumes (5 gal.) of DI water was pumped through the system, and then a water sample was taken. The bladder pump was then removed from the standpipe, the virgin FEP tubing was removed, and the (original) sampling tubing was reattached to the pump. The system was then placed in the standpipe containing fresh DI water, five system volumes (5 gal.) were pumped through the system, and another sample was taken. This was done so that we could separate the amount of contamination from the bladder pump vs. the tubing.

*Fourth TCE study—Effect of a wash procedure on pump exposed to low concentrations.* The pump used in this study had been in a well for over one year. Concentrations of TCE were consistently low. The pump was decontaminated using the same wash procedure as the previous study with the following exception. We were able to substantially reduce the volume of rinse water required to remove all the suds (10 system volumes vs. 75 used in the previous study) by running tap water through the pressure washer prior to hooking it up to the sampling pump system. Samples were collected after three system volumes of DI water were pumped through the system.

*Fifth TCE study—Effect of EPA wash protocol on pump exposed to high concentrations.* Following the first study, the pump used in that experiment was placed back in the well, 10 system volumes of well water were pumped through it, and it was allowed to sit for one week prior to the start of this study. In this experiment, a different detergent wash procedure, Procedure 2 given by the US EPA Region I (1996), was used. This protocol was as follows, with our modifications noted in parentheses:

- 1) Place the pump inside the wash standpipe.

Direct hot water from a steam cleaner jet inside the standpipe to clean the pump exterior, filling the standpipe. (We used a pressure washer rather than a steam cleaner.)

- 2) Using the bladder pump, pump the hot water in the standpipe through the pump system. Remove the pump, discard the remaining water, and replace the pump in standpipe.
- 3) Add the detergent solution to the standpipe using the pressure washer. Using the bladder pump, pump the wash solution (5 gal. or ~5 system volumes) through the pump system. (No mention is made as to temperature; we used hot detergent solution.)
- 4) Remove pump from standpipe, drain remaining detergent solution, rinse the standpipe with water from the pressure washer, and fill standpipe with water. (No mention is made as to temperature; we used hot water.)
- 5) Pump (5 gal.) ambient temperature tap water through the pump.
- 6) Remove pump from standpipe and drain remaining water from system.
- 7) Place the pump in a large standpipe filled with DI water, and pump DI water through the system.

Samples were collected after one, three, and six system volumes of DI water were pumped through the system.

*Sixth TCE study—Effect of a wash and oven drying on pump exposed to high concentrations.* The EPA protocol used in the previous study was also followed in this study. In addition, a hot air drying step was added. After the rinse water was drained from the system, the pump was disconnected from the tubing and any remaining water was drained. For 24 hours, hot air was passed through the pump and tubing, each separately. The entry temperature was 70°C. The temperature of the exit air was approximately 45°C from the pump and 25°C from the tubing (135 ft). DI water was run through the bladder pump (without any tubing) and samples were taken after 1, 3, 6, and 9 gal. of water were flushed through the pump. A gallon of water represents 11.5 pump volumes. The tubing was connected to the laboratory DI water and samples were taken after 1, 3, 6, and 9 gal. were flushed through the tubing. A gallon of water represents 1.3 tubing volumes.

### *Sample handling and analysis*

Samples were collected in glass vials (care was taken to eliminate any bubbles or headspace) and sealed with Teflon-lined plastic caps. For each sample that was taken, there were three replicate vials. These vials were stored in a refrigerator until it was time to analyze the samples. At that time, an aliquot was transferred to a glass, 1.8-mL autosampler vial using a glass Pasteur pipet.

Analytical determinations were performed using reversed-phase high-performance liquid chromatography (RP-HPLC). A modular system was employed consisting of a Spectra Physics SP8875 autosampler with a 100- $\mu$ L injection loop, a Spectra Physics SP8810 isocratic pump, a Spectra Physics SP8490 variable-wavelength UV detector set at 215 nm, and a Hewlett Packard 3396 series II digital integrator. Separations were obtained on a 25-cm  $\times$  0.46-cm (5  $\mu$ m) LC-18 column (Supelco) and eluted with 2.0 mL/minute of 65/35 (V/V) methanol/water. The detector response was obtained from the digital integrator operating in the peak height mode.

A primary TCE standard was made by weighing neat TCE into methanol in a 100-mL glass volumetric flask, giving a final concentration of 3000 mg/L. This standard was kept in the freezer. Each sampling day, the primary standard was diluted in methanol to give a working standard (30 mg/L). A series of water standards was made from the working standard by serial dilution using glass pipets and glass volumetric flasks. These standards ranged in concentration from 3.0 to 0.006 mg/L. The method detection limit (MDL) was obtained according to the EPA protocol described in the Federal Register (1984).

### **Pesticide study**

#### *Experimental methods*

The pesticide solution contained four analytes: lindane, heptachlor, aldrin, and dieldrin. These compounds were selected because they varied in their hydrophobicity. The pesticide solution was made by adding the pesticides directly to deionized water in four 5-gal. glass bottles and stirring for two weeks on a magnetic stirrer. When the solutions were poured into the standpipe, the solution was filtered through a polymeric fabric to remove any undissolved particles of analyte.

*Bailer study.* The bailer was washed as described in the first TCE study.

*Pump study.* After removing the pump from the standpipe, the exterior of the pump and the 5 ft of tubing that contact the test solution were sprayed with hot water from the pressure washer, scrubbed with a brush using a hot detergent solution, and rinsed with hot water. The pump was then washed using the EPA protocol outlined in the TCE studies. Samples were taken at one, three, six, and nine volumes.

#### *Sample handling and analysis*

Samples were collected in 40-mL glass vials with Teflon-lined plastic caps. For each sample collected there were five replicate vials. Ten mL was removed from the vials and discarded. The pesticides in the remaining 30 mL were extracted according to modified EPA Method #505 (US EPA 1991) as follows: nine grams of reagent sodium chloride was added to the vials, which were then shaken to dissolve the salt. Three mL of pesticide-grade hexane was added, the vials were recapped and placed horizontally on a shaking table, and shaken for three hours. The vials were allowed to stand vertically for approximately 10 minutes to allow separation of the two phases. Enough hexane was carefully drawn off with a Pasteur pipet to fill a 1.8-mL amber glass, autosampler vial. The autosampler vials were stored in a refrigerator (4°C) until analyzed.

Analyses were performed on a Hewlett-Packard (HP) 5890 series II gas chromatograph (GC) with an electron capture detector (ECD) equipped with an HP 6890 series autosampler-injector, all under the control of HP-Chemstation software. The GC was operated in splitless mode with 1- $\mu$ L injections. Nitrogen was used as carrier and makeup gas. The instrument was set with the following operating parameters: an injector temperature of 250°C; initial oven temperature of 150°C and hold time of two minutes, ramp at 10°/minute to 250°C and hold eight minutes; detector temperature of 300°C; purge time 1.0 minute. The column was a J&W DB-5.625, 30-m  $\times$  0.25-mm-i.d., 0.50- $\mu$ m film. Gas flows were as follows: 1.0 mL/minute for the column, 2.5 mL/minute for the purge gas, and 60 mL/minute for the makeup gas.

Primary certified pesticide standards were purchased from Ultra Scientific (100  $\mu$ g/mL in hexane) and each was diluted with pesticide-grade hexane to yield 10  $\mu$ g/mL. A combined standard was made by pipeting 1 mL of each of the diluted pesticide standards into a 10-mL volumetric flask and filling to volume with hexane (1  $\mu$ g/mL). All these standards were kept in the dark in a freezer.

Working standards were made each sampling day by serially diluting the combined standard in hexane (600, 400, 200, 100, 20, and 4 ng/mL). The MDL was obtained according to the EPA protocol as described in the Federal Register (1984).

## **Munitions study**

#### *Experimental methods*

A barrel containing water contaminated with munitions was obtained from Louisiana Army Ammunition Plant. A barrel pump was used to fill the standpipe with this solution.

*Bailer study.* The procedure for contaminating and decontaminating the bailer was the same as that used in the pesticide study.

*Pump study.* The procedure for this study was the same as that used to contaminate and decontaminate the pump in the pesticide study.

#### *Sample handling and analysis*

Samples were collected in 500-mL glass jars with Teflon-lined plastic screw caps. There were three replicates (jars) for each sample taken.

Analysis of the munitions-contaminated water was made by using a modified HPLC method (Thorne and Leggett in press) using a modular system consisting of a Waters 717 autosampler, 616 pump, 600S controller, 996 photodiode array detector, and Millennium workstation. A Phenomenex (Torrance, California, USA) Ultracarb 5 ODS (20) (4.6 mm  $\times$  250 mm, 5  $\mu$ m) reverse-phase column with an Alltech C-18 guard cartridge was used for the analytical separations. The aqueous/methanol (V%/V%) gradient elution time steps were as follows: start at 85/15, ramp to 65/35 at eight minutes, ramp to 42/58 at 10 minutes and hold for 13 minutes, ramp to 0/100 at 28 minutes and hold for seven minutes, ramp down to 85/15 at 40 minutes and hold for 10 minutes before the next injection. The flow rate was 0.8 mL/minute. Quantification was performed at 254 nm. Peak identities were determined by comparing sample and standard peak spectra and retention times.

In order to work at lower detection levels in the analyses of the munitions desorbed into the DI water, the munitions were extracted by passing 500 mL of water through Sep-Pak Vac, Poropak Rdx cartridges and eluting with 4 mL acetonitrile. The extract was stored in a freezer until analyzed by GC/ECD according to a method being developed by Walsh and Ranney (in prep.). A modular system consisting of a Hewlett-Packard (HP) 5890 series II GC with an ECD and equipped with an

HP 6890 series autosampler-injector, all under the control of HP-Chemstation software, was used. The GC was operated in direct injection mode with 1- $\mu$ L injections. Hydrogen was used as the carrier gas (151 cm/sec) and nitrogen as the makeup gas (60 mL/minute). The instrument was set with the following operating parameters: an injector temperature of 270°C; and a detector temperature of 300°C. The oven was programmed with an initial temperature of 150°C and a hold time of one minute, then ramp at 20°C/minute to 250°C and hold five minutes. The column was a Restek Rtx-200, 6-m  $\times$  0.53-mm i.d., 1.50- $\mu$ m film. The estimated detection limits were determined according to the EPA protocol described in the Federal Register (1984).

## RESULTS AND DISCUSSION

### TCE studies

The experimental data showing the results for all the replicates in the TCE studies can be found in Tables A1–A6.

#### Bailer studies

*First TCE study—Effect of a hot detergent wash on bailer exposed to high concentrations.* In this study, the bailer was washed with hot detergent and rinsed with hot water after it was used to sample a well with relatively high concentrations of TCE. Table 1 shows that this treatment still leaves residual contamination on the bailer; the contamination is then desorbed back into the DI water at detectable levels when a sample is taken.

*Second TCE study—Effect of an additional hot air drying step on bailer exposed to high concentrations.* Because the previous study showed that washing alone was not sufficient to completely remove the contamination, the bailer was dried in an oven at 105°C for 24 hours after using the same wash procedure on the bailer as in the previous study. The hot air treatment appears to have been effective as we were unable to detect any TCE when the bailer was used to sample fresh DI water (Table 1).

However, there was one problem with this decontamination protocol: the bailer was warped by the oven drying step. We are at a loss to explain this because information supplied by the manufacturer of FEP and PTFE tubing (the same materials used in the bailer) claimed that this tempera-

**Table 1. Summary of TCE studies using a bailer.**

TCE study	Mean initial conc. (mg/L)* (S.D.)	Treatment	Mean desorbed conc. (mg/L)† (S.D.)
First	119 (0.6)	wash	0.0032 (0.0001)
Second	132 (0.0)	wash wash + oven dry	0.0044 (0.0005) LD

\* Concentration of the well water

† Concentration found in DI water from the “decontaminated” device

LD = Less than method detection limit (0.0024 mg/L)

S.D. = Standard deviation

ture was well below the materials’ reported degradation temperature. Clearly, if this method is to be used, the hottest temperature the materials in the device can withstand needs to be determined.

#### Pump studies

*Third TCE study—Effect of a wash procedure on a pump exposed to high concentrations.* We see that when the pump and tubing received no cleaning treatment other than pumping three system volumes of DI water through the system, substantial concentrations of TCE were released into the DI water as it was pumped through the system (Table 2).

Following a hot detergent wash and rinse, there were still detectable concentrations of TCE in the DI water when it was pumped through the system. However, these concentrations were more than an order of magnitude lower than before the wash treatment. We observed that the desorbed concentration actually increased after more water was pumped through the system. We believe this is because outer portions of the sampling tubing and the compressed-air tubing were made of polyethylene. Polyethylene tubing has been shown to be more sorptive of TCE than the rigid fluoropolymers (FEP, PTFE, etc.) (Parker and Ranney 1996, 1997a) and also desorbs higher concentrations of TCE back into solution (Parker and Ranney 1997a). Thus, we believe that TCE sorbed by the outer PE tubing was desorbed into the DI water in the upper portions of the standpipe (above the pump) and was then drawn down into the pump with additional pumping.

Following this treatment, the tubing and bladder pump were left to air dry for one week. This was done to allow for slow desorption of the sorbed TCE. However, even after one week, significant levels of TCE were released into the DI water by both the bladder pump and the tubing. Thus, air drying at room temperature for one

**Table 2. Summary of TCE studies using a bladder pump.**

TCE study	Mean initial conc. (mg/L)* (S.D.)	Treatment	Volumes of DI rinse	Whole system	Bladder pump only	Tubing only
				(pump + tubing)	Bladder pump only	Tubing only
				Mean desorbed conc. (mg/L)† (S.D.)	Mean desorbed conc. (mg/L)† (S.D.)	Mean desorbed conc. (mg/L)† (S.D.)
Third	136 (1)	none wash	3	0.524 (0.003)		
			3	0.010 (0.001)		
			6	0.010 (0.002)		
			9	0.026 (0.002)		
			wash + one week storage		0.053 (0.002)	0.011 (0.005)
Fourth	0.0156 (0.0008)	none	3	0.0039 (0.001)		
		wash	3	LD		
Fifth	152 (3)	EPA wash	1	0.034 (0.002)		
			3	0.015 (0.002)		
			6	0.026 (0.001)		
Sixth	130 (1)	hot air drying	1		0.183 (0.040)	0.0043 (0.0013)
			3		LD	0.0046 (0.0010)
			6		LD	0.0057 (0.0006)
			9		LD	0.005 (0.001)

\* Concentration of the well water

† Concentration found in DI water from the “decontaminated” device

LD = Less than method detection limit (0.0024 mg/L)

S.D. = Standard deviation

week was not sufficient to remove this contamination.

*Fourth TCE study—Effect of wash procedure on pump exposed to low concentrations.* When the same wash procedure was used to clean a different pump system that had been exposed to relatively low concentrations of TCE, decontamination was effective (Table 2). We anticipated that desorbed TCE concentrations would be below the detection limit given the very low initial concentration of TCE in the well, and that the previous study showed that this washing procedure yielded 3- and 4-log reductions in desorbed TCE concentrations.

*Fifth TCE study—Effect of EPA washing protocol on pump exposed to high concentrations.* Because the previous wash procedure was not effective in removing all the contamination from the sampling pump that had been exposed to high concentrations of TCE, we tested a second washing procedure outlined by the US EPA Region I (1996). The pump was exposed to high concentrations of TCE for one week. However, again we see that there was detectable residual contamination in the DI water that was pumped through the decontaminated system (Table 2).

The results from this study and the third study are not unexpected given that our findings in

phase I of these studies (Parker and Ranney 1997b) have shown that permeable polymeric materials, such as PTFE, that had sorbed VOCs required hot air drying (105°C) in addition to a hot detergent wash and a hot water rinse.

*Sixth TCE study—Effect of a wash and oven drying on a pump exposed to high concentrations.* In this study, we used the same wash procedure as the previous experiment and then pumped hot air (70°C) through the pump and sampling tubing line, each individually. We selected a lower temperature, 70°C, for this study because of problems we had experienced with the bailer warping at the higher temperature (105°C). By running DI water through the pump and tubing separately, we see that we were able to completely decontaminate the pump itself but not the tubing (Table A6). Desorbed concentrations from the tubing were approximately the same as the EPA’s maximum contamination level (MCL) of 0.005 mg/L and well above the EPA’s maximum contaminant level goal (MCLG) of zero (US EPA 1994).

### Pesticide study

Initial concentrations of two of the pesticides, heptachlor and aldrin, were significantly lower in samples taken with the bladder pump than those taken with the bailer (Table A7). We believe this

**Table 3. Summary of pesticide study.**

Analyte	Bailer		Bladder pump system			MDL ( $\mu\text{g/L}$ )
	Mean initial conc. ( $\mu\text{g/L}$ )* (S.D.)	Mean desorbed conc. ( $\mu\text{g/L}$ ) <sup>†</sup> (S.D.)	Mean initial conc. ( $\mu\text{g/L}$ )* (S.D.)	Mean conc. after 24 hr ( $\mu\text{g/L}$ )* (S.D.)	Mean desorbed conc. ( $\mu\text{g/L}$ ) <sup>†</sup> (S.D.)	
Lindane	525 (47)	LD	484 (32)	503 (31)	LD	0.74
Heptachlor	17.5 (3.4)	LD	13.0 (1.4)	6.83 (0.95)	LD	0.84
Aldrin	46.3 (5.7)	LD	37.9 (7.5)	20.5 (1.9)	LD	0.55
Dieldrin	58.0 (5.3)	LD	53.8 (3.9)	35.1 (2.0)	LD	0.85

\* Concentration of the well water

<sup>†</sup> Concentration found in DI water from the “decontaminated” device

LD = Less than method detection limit

MDL= Method detection limit

S.D. = Standard deviation

means that the materials used in the bladder pump sorbed these analytes as the sample was pumped through the system. The hot water wash procedure was effective in removing these contaminants from both the bailer and bladder pump system (Table 3).

### Munitions study

In this study, we see that washing was relatively effective for removing most of the munitions (Table 4, Table A8). Ultra-low concentrations (ppt) of two munitions were detected in samples taken with the decontaminated bailer and the pump. However, these concentrations were well below the EPA’s lifetime health advisory limits of 2  $\mu\text{g/L}$  for TNT and 0.1  $\mu\text{g/L}$  for 2,4-DNT (Gordon and Hartley 1989, Brower et al. 1992). Because these concentrations were well below the health advisory limits, we did not test the efficiency of using an additional hot air treatment with these contaminants.

### CONCLUSIONS

This research clearly shows that if groundwater sampling devices are not decontaminated, residual contamination will be carried over into the next sample. A simple detergent cleaning procedure (consisting of a hot tap water detergent wash, hot tap water rinse, and DI water rinse) was effective in reducing residual pesticide concentrations in DI water that was sampled with the decontaminated bailer and bladder pump. Concentrations of munitions in DI water sampled with devices decontaminated with this procedure were also reduced to either nondetectable or low-ppt levels. TCE, a volatile organic, proved to be the most recalcitrant contaminant. VOCs have been shown to be readily absorbed by polymeric materials. We found that a hot detergent wash and hot water rinse followed by hot air drying (~70°C initial temperature) was effective in removing TCE from both the bailer and bladder pump but not

**Table 4. Summary of munitions study.**

Analyte	Bailer		Bladder pump system	EDL ( $\mu\text{g/L}$ )
	Mean initial conc. ( $\mu\text{g/L}$ )* (S.D.)	Mean desorbed conc. ( $\mu\text{g/L}$ ) <sup>†</sup> (S.D.)	Mean desorbed conc. ( $\mu\text{g/L}$ ) <sup>†</sup> (S.D.)	
HMX	168 (18)	LD	LD	0.0041
TNB	100 (21)	LD	LD	0.0066
DNB	108 (4)	<0.0057	LD	0.0036
TNT	2425 (7)	0.037 (0.004)	0.034 (0.006)	0.014
2,4-DNT	100 (14)	0.041 (0.013)	0.032 (0.006)	0.0092

\* Concentration of the well water

<sup>†</sup> Concentration found in DI water from the “decontaminated” device

LD = Less than estimated detection limit

EDL = Estimated detection limit by method being developed by Walsh and Ranney (in prep.)

S.D. = Standard deviation



from the tubing used with the bladder pump. Based on the results of our previous study (Parker and Ranney 1997b), which showed that heating at 105°C was sufficient to reduce residual contamination of several VOCs from the most sorptive polymer tested (PTFE), we believe that the residual contamination could be removed from this tubing also. There are several ways this might be accomplished: using a higher temperature than 70°C, blowing hot air through *both the air line and sampling portions* of this tubing, or heating *both the exterior and interior of the tubing* by placing the tubing in an oven or some type of heated compartment. The results from the third TCE study indicate that there should be more focus on cleaning the outside of all the tubing exposed to the contaminants.

Based on the results of these two studies, we feel that the most effective way to decontaminate groundwater sampling devices exposed to trace levels of organic contaminants is to use a hot detergent wash, hot water rinse, and DI water rinse, followed by hot air drying (~105°C) for 24 hours. The exact drying protocol would be based upon information supplied by the manufacturer on the ability of the materials in the device to withstand this treatment.

It should be noted that we did not decontaminate devices that had been exposed either to neat organic solvents or to very high concentrations of those chemicals (approaching their aqueous solubility). At some point this issue should also be addressed. This would be especially important for devices that are made of fluoropolymers, which would not be destroyed by this environment but could sorb large quantities of these chemicals. Also, we did not address decontamination of the nylon line used with the bailer or decontamination of groundwater sampling devices with respect to inorganic contaminants.

## FUTURE APPLICATIONS

The results from our previous studies (Parker and Ranney 1997b) have shown the critical importance of hot air drying for removing organic contaminants from permeable polymeric materials, especially VOCs. Those studies also showed that rinsing with organic solvents was not effective for removing organic contaminants. The results from the third TCE study also showed that air drying a bladder pump for a week at room temperature was not sufficient to remove TCE

contamination. Given that a hot air drying step is critical to adequately decontaminate a groundwater sampling device, then how practical is this approach?

Clearly this method is feasible for decontaminating smaller devices such as a bailer. However, because this method requires 24 hours drying time and a distilled water rinse, decontamination most likely would not be conducted in the field but rather at a support station (motel room, mobile laboratory, etc.). Because of the time required to oven dry a sampling device, additional sampling equipment would have to be purchased so that some was being decontaminated while the rest was in use.

Our initial studies (Parker and Ranney 1997b) indicated that, for VOCs, heat (~105°C) alone without any detergent washing was sufficient for removing VOCs from the most sorptive polymer tested, PTFE. Although we did not test this, these data suggest that perhaps this decontamination method could be further streamlined as follows:

- Wash with ambient temperature detergent solution (using tap water).
- Rinse with tap water.
- Hot air dry (~105°C) for ~24 hours.

This procedure eliminates having to provide hot water for washing and rinsing and DI water rinses and thus is logistically less demanding. Presumably, any residual organic contaminants would be removed during the hot air drying procedure. Small portable drying ovens could be powered by an electric generator or gas driven. This streamlined procedure appears feasible but requires additional testing.

However, there are more issues to work out with respect to decontaminating groundwater sampling pumps. Some pumps have shut-off switches for when water temperatures exceed a certain limit. To circumvent this problem, it might be possible to pump ambient temperature rinse water (as described in the streamlined method) through the device and then gently heat the device. Ideally, some type of device that heats the inside and outside of the pump and tubing and is vented to allow air exchange would be best. This could be a drying oven or some type of "heated suitcase" that could be produced by the pump's manufacturer. These devices would provide a constant temperature for the entire length of the tubing and for all components of the sample tubing, including the compressed air tubing. However, the size of some pumps limits the practicality of this solution. In addition, it is difficult to coil the

rigid fluoropolymer tubing that is typically used to a small enough size for drying.

Results from one of our recent studies (Parker and Ranney 1997a) indicate that more flexible fluoropolymer tubing might be a suitable replacement for the rigid fluoropolymers with respect to sorption and desorption of organic solutes. This tubing could be coiled up to a much smaller size, thereby reducing the size of drying oven required. However, we suspect that these tubings are not strong enough for this purpose.

Another possibility is to develop protocols where the pump (or entire system) is decontaminated but the tubing is dedicated to one well. This solution would be less costly than dedicating the whole system, but still costly because of the expense of the fluoropolymer tubing typically used. However, some in the groundwater sampling community argue that the pumps and tubing of even dedicated devices should be decontaminated prior to each sampling event so that decreases in organic contaminant concentrations can be more readily determined.

Given that dedicating sampling pumps and tubing are expensive and that heating is essential to remove organic contaminants (especially VOCs) from any device with polymeric materials, and the logistical problems associated with hot air drying a pump, perhaps our whole approach to groundwater sampling needs to be reexamined. Perhaps we need to seriously consider some of the quicker, easier, less costly, small grab devices and passive systems that are currently being developed.

## LITERATURE CITED

**Barcelona, M.J., J.A. Helfrich, and E.E. Garske** (1985) Sampling tubing effects on ground water samples. *Analytical Chemistry*, **57**: 460–464.

**Berens, A.R.** (1985) Prediction of organic chemical permeation through PVC pipe. *Journal of the American Water Works Association*, p. 57–65.

**Berens, A.R., and H.B. Hopfenberg** (1982) Diffusion of organic vapors at low concentrations in glassy PVC, polystyrene, and PMMA. *Journal of the Membrane Sciences*, **10**: 283.

**Brower, M.E., W.C. Roberts, and W.R. Hartley** (1992) Health advisory for 2,4- and 2,6-dinitrotoluene (DNT). U.S. Environmental Protection Agency, Office of Science and Technology, Office of Water, Washington, D.C.

**Champion, D.F., and S.R. Olsen** (1971) Adsorp-

tion of DDT on solid particles. *Soil Science Society of America Proceedings*, **35**: 887–891.

**Devlin, J.F.** (1987) Recommendations concerning materials and pumping systems used in the sampling of groundwater contaminated with volatile organics. *Water Pollution Research Journal of Canada*, **22**(1): 65–72.

**Federal Register** (1984) Definition and procedure for the determination of the method detection limit. Code of Federal Regulations, Part 136, Appendix B, October 26.

**Fink, M.J., and R.T. Boyajian** (1989) Decontamination procedure for ground water sampling equipment. In *Proceedings of the Third National Outdoor Action Conference on Aquifer Restoration, Ground Water Monitoring and Geophysical Methods*, National Water Well Association, Dublin, Ohio, p. 305–311.

**Gillham, R.W., and S.F. O'Hannesin** (1990) Sorption of aromatic hydrocarbons by materials used in construction of ground water sampling wells. In *Ground Water and Vadose Zone Monitoring*, ASTM STP 1053, American Society for Testing and Materials, Philadelphia, p. 108–122.

**Gordon, L., and W.R. Hartley** (1989) Health advisory on 2,4,6-trinitrotoluene. U.S. Environmental Protection Agency, Office of Drinking Water, Washington, D.C.

**Holsen, T.M.** (1988) The effect of soils on the permeation of plastic pipes by organic chemicals. Ph.D. Thesis, University of California-Berkeley. University Microfilms International Dissertation Service order number 8902122.

**Jenkins, D., R.E. Selleck, L. Bontoux, and D. Soong** (1986) Permeation of plastic pipes: Literature review and research needs. Sanitary Engineering and Environmental Health Research Laboratory, College of Engineering, School of Public Health, University of California, Berkeley, SEEHRL Report 86-12.

**Jones, J.N., and G.D. Miller** (1988) Adsorption of selected organic contaminants onto possible well casing materials. In *Groundwater Contamination: Field Methods*, ASTM STP 963 (A.G. Collins and A.I. Johnson, Ed.), American Society for Testing and Materials, Philadelphia, p. 185–198.

**Mickam, J.T., R. Bellandi, and E.C. Tiff, Jr.** (1989) Equipment decontamination procedures for ground water and vadose zone monitoring programs: Status and prospects. *Ground Water Monitoring Review*, **9**(2): 100–121.

**Miller, G.D.** (1982) Uptake and release of lead, chromium, and trace level volatile organics exposed to synthetic well casings. In *Proceedings of*

the Second National Symposium on Aquifer Restoration and Ground Water Monitoring, National Water Well Association, U.S. Environmental Protection Agency, and National Center for Ground Water Research, p. 236–245.

**Ogan, K., E. Katz, and W. Slavin** (1978) Concentration and determination of trace amounts of several polycyclic aromatic hydrocarbons in aqueous samples. *Journal of Chromatographic Science*, **16**: 517–522.

**Parker, L.V.** (1995) Decontamination of organic contaminants from groundwater sampling devices: A literature review. USA Cold Regions Research and Engineering Laboratory, Special Report 95-14.

**Parker, L.V., and T.A. Ranney** (1996) Sampling trace-level organics with polymeric tubings. USA Cold Regions Research and Engineering Laboratory, Special Report 96-3.

**Parker, L.V., and T.A. Ranney** (1997a) Sampling trace-level organics with polymeric tubings: Dynamic studies. USA Cold Regions Research and Engineering Laboratory, Special Report 97-2.

**Parker, L.V., and T.A. Ranney** (1997b) Decontaminating materials used in groundwater sampling devices. USA Cold Regions Research and Engineering Laboratory, Special Report 97-24.

**Parker, L.V., A.D. Hewitt, and T.F. Jenkins** (1990) Influence of casing materials on trace-level chemicals in well water. *Ground Water Monitoring Review*, **10**(2): 146–156.

**Plastics Design Library** (1994a) *Chemical Resistance. Volume I—Thermoplastics*. Morris, New York: Plastics Design Library.

**Plastics Design Library** (1994b) *Chemical Resistance. Volume II—Thermoplastic Elastomers, Thermosets, and Rubbers*. Morris, New York: Plastics Design Library.

**Reynolds, G.W., and R.W. Gillham** (1985) Absorption of halogenated organic compounds by polymer materials commonly used in ground water monitors. In *Proceedings of Second Canadian/American Conference on Hydrology: Hazardous Wastes in Ground Water: A Soluble Dilemma* (B. Hitchon and M.R. Trudell, Ed.), National Water Well Association, Dublin, Ohio, p. 125–132.

**Reynolds, G.W., J.T. Hoff, and R.W. Gillham** (1990) Sampling bias caused by materials used to monitor halocarbons in groundwater. *Environmental Science and Technology*, **24**(1): 135–142.

**Schuh, W.M., R.L. Cline, M.J. Kosse, and D.W. Sletton** (1993) Review and experimental evaluation of effects of short-term PVC contact and distilled water wash procedures on measured pesticide concentrations in field samples. Water Resource Investigation No. 24, North Dakota State Water Commission.

**Sharom, M.S., and K.R. Solomon** (1981) Adsorption and desorption of permethrin and other pesticides on glass and plastic materials used in bioassay procedures. *Canadian Journal of Fisheries and Aquatic Sciences*, **38**: 199–204.

**Strachan, S.D., and F.D. Hess** (1982) Dinitroaniline herbicides adsorb to glass. *Journal of Agricultural Food Chemistry*, **30**: 389–391.

**Summers, D.A.** (1982) Decontamination nozzle optimization study. U.S. Army Chemical Systems Laboratory, Aberdeen Proving Ground, Aberdeen, Maryland. NTIS Number AD B063655.

**Thorne, P.G., and D.C. Leggett** (in press) Hydrolytic release of bound residue from compacted TNT-contaminated soil. *Environmental Toxicology and Chemistry*.

**U.S. Environmental Protection Agency** (1991) *Methods for the Determination of Organic Compounds in Drinking Water*. U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C.

**U.S. Environmental Protection Agency** (1994) *National Primary Drinking Water Standards*. U.S. Environmental Protection Agency, EPA 810-F-94-001A, Office of Water, Washington, D.C.

**U.S. Environmental Protection Agency Region I** (1996) *Low Stress (Low Flow) Purging and Sampling Procedure for the Collection of Ground Water Samples from Monitoring Wells, Revision 2*. U.S. Environmental Protection Agency Region I, SOP # GW 0001, Boston, Massachusetts.

**Walsh, M.E., and T.A. Ranney** (in prep.) Determination of nitroaromatic, nitramine, and nitrate ester explosives in water using solid phase extraction and GC-ECD. USA Cold Regions Research and Engineering Laboratory, Special Report.

**APPENDIX A: RAW DATA FROM DECONTAMINATION STUDIES**

**Table A1. First TCE study—Effect of a hot detergent wash on bailer.**

Initial TCE concentration (mg/L) in well water	
A	119
B	120
C	119
$\bar{X}$	119
Desorbed TCE concentration (mg/L) in DI water after wash treatment	
A	0.0033
B	0.0033
C	0.0031
$\bar{X}$	0.0032

**Table A2. Second TCE study—Effect of a detergent wash and hot air drying on bailer.**

Initial TCE concentration (mg/L) in well water	
A	132
B	132
C	132
$\bar{X}$	132
Desorbed TCE concentration (mg/L) in DI water after wash treatment	
A	0.0049
B	0.0044
C	0.0040
$\bar{X}$	0.0044
Desorbed TCE concentration (mg/L) in DI water after wash treatment and oven drying	
A	LD
B	LD
C	LD
$\bar{X}$	LD

LD = Less than detection limit  
 MDL = 0.0024 mg/L

**Table A3. Third TCE study—Effect of detergent wash on pump exposed to high levels of TCE.**

	Initial TCE concentration (mg/L) in well water
A	136
B	135
C	137
$\bar{X}$	136
	Desorbed TCE concentration (mg/L) in DI rinse (3 vol.) before wash treatment
A	0.527
B	0.524
C	0.521
$\bar{X}$	0.524
System volumes of DI water pumped	Desorbed TCE concentration (mg/L) after initial wash treatment
3	0.010
3	0.011
3	0.009
$\bar{X}$	0.010 <sup>a*</sup>
6	0.010
6	0.008
6	0.011
$\bar{X}$	0.010 <sup>a</sup>
9	0.024
9	0.027
9	0.027
$\bar{X}$	0.026 <sup>b</sup>
	Desorbed TCE concentration (mg/L) in DI water following one week storage
	Bladder pump alone
A	0.016
B	0.010
C	0.006
$\bar{X}$	0.011
	Bladder pump and tubing
A	0.055
B	0.052
C	0.053
$\bar{X}$	0.053

MDL = 0.0024 mg/L

\* = For each analyte, values with the same letter are not significantly different at the 95% confidence level using Fisher's Least Significant Difference Test.

**Table A4. Fourth TCE study—Effectiveness of wash procedure on pump exposed to low levels of TCE.**

Initial TCE concentration (mg/L) in well water	
A	0.0160
B	0.0147
C	0.0162
$\bar{X}$	0.0156
Desorbed TCE concentration (mg/L) in DI rinse before wash treatment	
System volumes of DI water pumped	
3	0.0028
3	0.0050
3	0.0038
$\bar{X}$	0.0039
Desorbed TCE concentration (mg/L) in DI water after wash treatment	
3	LD
3	LD
3	LD
$\bar{X}$	LD

LD = Less than detection limit  
MDL = 0.0024 mg/L

**Table A5. Fifth TCE study—Effect of EPA washing protocol on pump exposed to high levels of TCE.**

Initial TCE concentration (mg/L) in well water	
A	155
B	151
C	149
$\bar{X}$	152
Desorbed TCE concentration (mg/L) in DI water after EPA wash procedure	
System volumes of DI water pumped	
1	0.032
1	0.035
1	0.035
$\bar{X}$	0.034
3	0.013
3	0.014
3	0.017
$\bar{X}$	0.015
6	0.025
6	0.026
6	0.027
$\bar{X}$	0.026

**Table A6. Sixth TCE study—Effect of a wash and oven drying on a pump exposed to high levels of TCE.**

Initial TCE concentration (mg/L) in well water		
A	131	
B	129	
C	129	
$\bar{X}$	130	
Desorbed TCE concentration (mg/L) in DI water after wash and hot air drying		
DI water (gal.)	Pump*	Tubing**
1	0.195	0.0056
1	0.215	0.0041
1	0.138	0.0031
$\bar{X}$	0.183	0.0043
3	LD	0.0046
3	LD	0.0045
3	LD	0.0047
$\bar{X}$	LD	0.0046
6	LD	0.0054
6	LD	0.0053
6	LD	0.0064
$\bar{X}$	LD	0.0057
9	LD	0.0054
9	LD	0.0037
9	LD	0.0060
$\bar{X}$	LD	0.0050

LD = Less than detection level

MDL = 0.0024 mg/L

\* One gallon equals eight pump volumes pumped through pump.

\*\* One gallon equals 1.3 tubing volumes flushed through tubing.

**Table A7. Pesticide study.**

	<i>Analytes</i>			
	<i>Lindane</i>	<i>Heptachlor</i>	<i>Aldrin</i>	<i>Dieldrin</i>
Initial concentrations (µg/L) in test solution				
Bailer	469	16.1	42.0	49.2
	572	21.6	54.7	61.6
	530	20.4	41.7	62.7
	569	13.4	49.5	58.4
	485	15.8	43.4	57.9
	$\bar{X}$	525 <sup>a*</sup>	17.5 <sup>a</sup>	46.3 <sup>a</sup>
% RSD	8.99	19.7	12.3	9.2
Pump	512	12.1	36.0	55.1
	477	12.8	33.0	58.4
	449	14.5	33.1	50.0
	523	14.5	50.9	55.8
	461	11.3	36.3	49.5
	$\bar{X}$	484 <sup>a</sup>	13.0 <sup>b</sup>	37.9 <sup>b</sup>
% RSD	6.61	11.0	19.7	7.16
Concentration (µg/L) in test solution after 24 hours				
Pump	540	7.11	23.2	37.3
	529	8.34	19.7	36.5
	473	6.31	20.5	33.0
	475	5.90	21.1	33.0
	500	6.49	18.1	35.9
	$\bar{X}$	503 <sup>a</sup>	6.83 <sup>c</sup>	20.5 <sup>c</sup>
% RSD	6.12	13.91	9.23	5.79
Desorbed concentration (µg/L) in DI water after wash procedure				
Bailer	LD	LD	LD	LD
	LD	LD	LD	LD
	LD	LD	LD	LD
	LD	LD	LD	LD
	LD	LD	LD	LD
	$\bar{X}$	LD	LD	LD
Pump	LD	LD	LD	LD
	LD	LD	LD	LD
	LD	LD	LD	LD
	LD	LD	LD	LD
	LD	LD	LD	LD
	$\bar{X}$	LD	LD	LD

LD = Less than detection limit  
 MDL (µg/L) = 0.74                      0.84                      0.55                      0.85  
 \*For each analyte, values with the same letter are not significantly different at the 95% confidence level using Fisher's Least Significant Difference Test.



**Table A8. Munitions study.**

	<i>Analyte</i>				
	<i>HMX</i>	<i>TNB</i>	<i>DNB</i>	<i>TNT</i>	<i>2,4-DNT</i>
Initial concentration (µg/L) in test solution					
A	180	115	110	2430	110
B	155	85	105	2420	90
$\bar{X}$	168	100	108	2425	100
Desorption concentrations (µg/L) after wash procedure					
Bailer	LD	LD	LD	0.034	0.026
	LD	LD	0.010	0.041	0.051
	LD	LD	LD	0.037	0.045
$\bar{X}$	LD	LD	<0.0057	0.037	0.041
Pump	LD	LD	LD	0.030	0.026
	LD	LD	LD	0.031	0.037
	LD	LD	LD	0.040	0.032
$\bar{X}$	LD	LD	LD	0.034	0.032

LD = Less than detection limit

DL (µg/L)\* = 0.0041      0.0066      0.0036      0.014      0.0092

\*Estimated detection limit by GC/ECD method being developed by Walsh and Ranney (in prep.).

# REPORT DOCUMENTATION PAGE

Form Approved  
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestion for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE October 1997	3. REPORT TYPE AND DATES COVERED	
4. TITLE AND SUBTITLE  Decontaminating Groundwater Sampling Devices			5. FUNDING NUMBERS	
6. AUTHORS  Louise V. Parker and Thomas A. Ranney				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)  U.S. Army Cold Regions Research and Engineering Laboratory 72 Lyme Road Hanover, New Hampshire 03755-1290			8. PERFORMING ORGANIZATION REPORT NUMBER  Special Report 97-25	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)  U.S. Army Environmental Center Aberdeen Proving Ground, Maryland 21010-5401			10. SPONSORING/MONITORING AGENCY REPORT NUMBER  SFIM-AEC-ET-CR-97021	
11. SUPPLEMENTARY NOTES For conversion of SI units to non-SI units of measurement, consult ASTM Standard E380-93, <i>Standard Practice for Use of the International System of Units</i> , published by the American Society for Testing and Materials, 1916 Race St., Philadelphia, Pa. 19103.				
12a. DISTRIBUTION/AVAILABILITY STATEMENT  Approved for public release; distribution is unlimited.  Available from NTIS, Springfield, Virginia 22161			12b. DISTRIBUTION CODE	
13. ABSTRACT ( <i>Maximum 200 words</i> )  These studies are the second part of a two-year project that examines decontaminating groundwater sampling devices. In the first year, the efficiency of various decontamination protocols was tested using small test pieces of materials that are commonly used in groundwater sampling devices. Those tests showed that a hot detergent wash and rinse followed by hot air drying (105°C) was the most effective decontamination protocol. In these studies, two groundwater sampling devices, a bailer and a bladder pump, were used to sample groundwater that was contaminated with either trichloroethylene (TCE), munitions, or pesticides. These studies showed that a hot detergent wash and hot water rinse followed by hot air drying is an effective method for decontaminating these sampling devices.				
14. SUBJECT TERMS  Bailers Cleaning Decontamination Groundwater sampling devices Groundwater-sampling pumps			15. NUMBER OF PAGES 28	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT UL	