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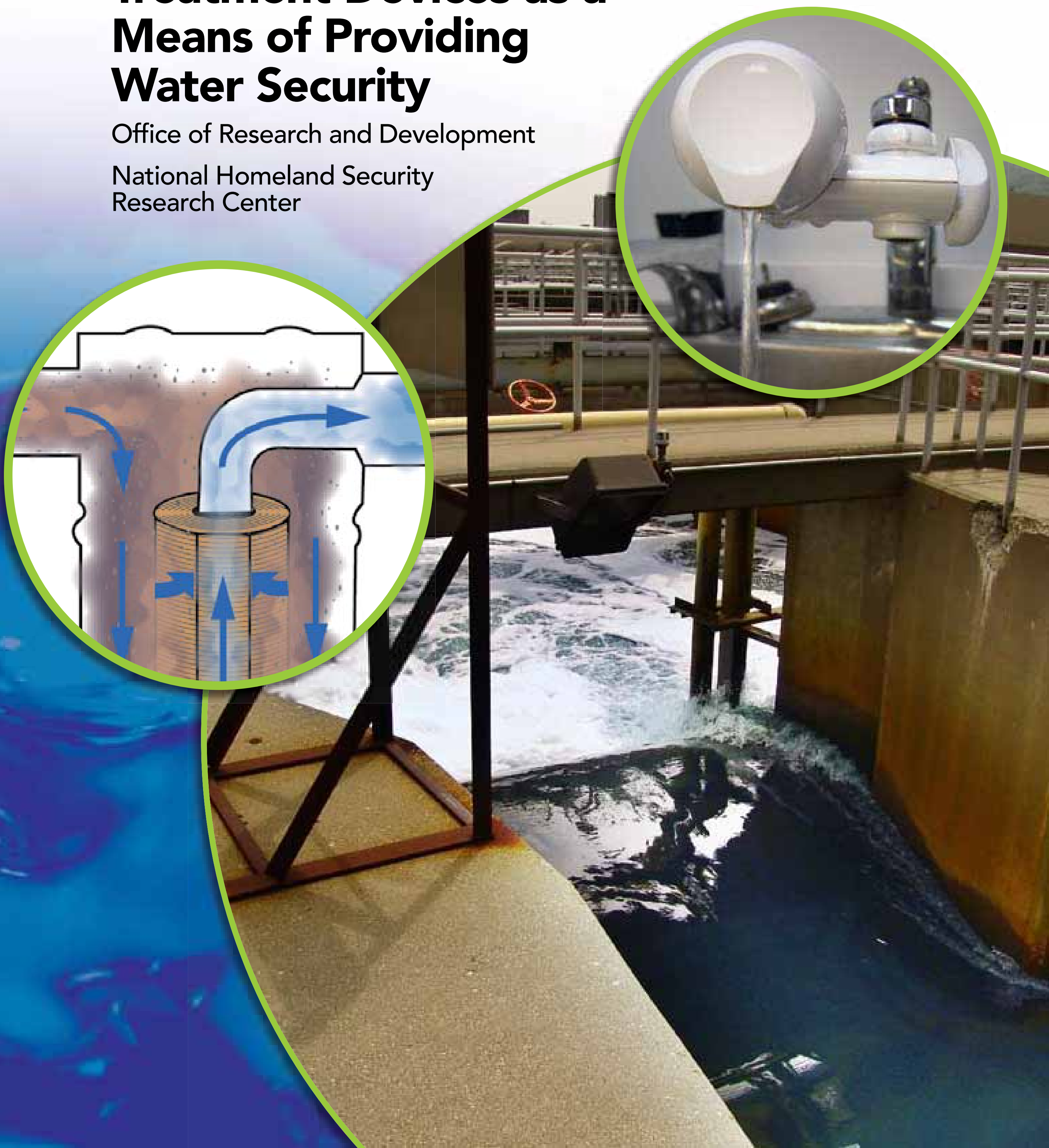
RESEARCH REPORT ON

Investigation of the Capability of Point-of-Use/Point-of-Entry Treatment Devices as a Means of Providing Water Security

Office of Research and Development

National Homeland Security Research Center



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U.S. Environmental Protection Agency
Office of Research and Development
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Mention of trade names, products, or services does not convey, and should not be interpreted as conveying, official EPA approval, endorsement, or recommendation.

Acronyms and Abbreviations

ANSI	American National Standards Institute
AWWA	American Water Works Association
AwwaRF	American Water Works Association Research Foundation
AX	Anion Exchange
CAM	Cellulose Acetate Membrane
CX	Cation Exchange
DBP	Disinfection Byproduct
EPA	U.S. Environmental Protection Agency
ETV	Environmental Technology Verification Program
GAC	granular activated carbon
gpd	gallons per day
gph	gallons per hour
gpm	gallons per minute
HPC	Heterotrophic Plate Count
HSPD	Homeland Security Presidential Directive
IE	Ion Exchange
MCL	Maximum Contaminant Level
MF	Microfiltration
mJ	millijoules
MGD	million gallons per day
NHSRC	National Homeland Security Research Center
NPDWR	National Primary Drinking Water Regulations
NRC	National Research Council
NSF	National Sanitary Foundation
ORD	Office of Research and Development
OW	Office of Water
POE	Point-of-Entry
POU	Point-of-Use
QC	Quality Control
PCB	Polychlorinated Biphenyl
psi	pounds per square inch
RCRA	Resource Conservation and Recovery Act
RO	Reverse Osmosis
ROWPU	Reverse Osmosis Water Purification Unit
SBAC	Solid Block Activated Carbon
SSCT	Small System Compliance Technology
SDWA	Safe Drinking Water Act
SOC	Synthetic Organic Compound
TDS	Total Dissolved Solid
TFM	Thin Film Membrane
TOC	Total Organic Carbon
TSWG	Technical Support Working Group
TWPS	Tactical Water Purification System
UF	Ultrafiltration
UV	Ultraviolet
VOC	Volatile Organic Compound
WIPD	Water Infrastructure Protection Division
WSD	Water Security Division
WQA	Water Quality Association

Executive Summary

Point-of-use (POU) and point-of-entry (POE) water treatment devices are cited in the United States Environmental Protection Agency (EPA) Water Security Research and Technical Support Action Plan as a topic requiring further research. POU devices are designed to purify only that portion of incoming water that is being used for drinking and cooking purposes, while POE devices treat all the water coming into a house or facility. What are the capabilities of these devices for treating or capturing the most likely contaminants? How should such devices be disposed of if they become contaminated? This paper investigates the use of these devices as a potential strategy for addressing water security concerns.

Study Objectives

The first objective of this study was to conduct a literature review regarding the types of devices and technologies currently available for removing contaminants at the point of use and/or at the point of entry. The most promising technologies and combinations of technologies (e.g., treatment trains) were investigated with regard to their principle of operation; effectiveness for removing radiological, biological, or chemical contaminants; and limitations. Of particular interest was a determination of a device's efficacy in preventing exposure to biological agents.

The second objective was to examine the potential water security role of POU/POE treatment devices. To fulfill this objective, different implementation strategies and their ramifications were discussed; issues associated with disposal and residuals management were addressed; and costs, benefits, and limitations from a water security perspective were described.

Drawing on the results of the first two objectives, the third objective was to offer a set of recommendations for consideration regarding POU/POE treatment and water security. The results of this effort were to help identify the best preventive measures, treatment alternatives, and post-treatment disposal options regarding the intentional contamination of drinking water.

Available Technologies

This review produced a comparative study showing the types of devices that are currently available, the principles of operation, the types of contaminants that can effectively be removed and those that cannot, removal efficiencies, and the anticipated service life. The two most widely used POU devices are a faucet-mounted device and a pitcher-style filter. The former is composed of activated carbon in solid block configuration with 1-micrometer pore space plus an activated agent to remove lead; the latter uses a sieve filter, granular activated carbon (GAC), and ion exchange resin in sequence. POU and POE treatment devices can be used to meet drinking water standards, but this use is constrained by EPA guidance, third-party certification by the National Sanitary Foundation (NSF) International, standards developed by the American National Standards Institute, and federal regulations.

Optimal Design Features

Because the type of contaminant threat can be so variable and unpredictable, a combination of treatment technologies could be most successful. Desirable characteristics of these devices include:

- having greater than 99 percent removal efficiency for chemicals and greater than 3 logs for microbial agents
- remaining mechanically sound and maintaining a consistent performance level over time, despite variations in intake water characteristics
- exhibiting a high level of quality assurance/quality control by the manufacturer to ensure confidence by many users
- signaling either by sounding an alarm or by shutting down when the device no longer can achieve desirable removal efficiencies
- being easy to install and maintain to encourage continued use
- having the ability to obtain performance certification
- being readily available and relatively inexpensive
- demonstrating an acceptable level of performance under real-agent exposure conditions

Table E-1 Most Promising Technologies

Technology	Removes				Notes
	Viruses	Bacteria	Cysts	Organic Compounds	
Solid Block Activated Carbon (SBAC)	no	some	yes	most	Limited removal capability for some pesticides; can remove methyl tert-butyl ether and selected disinfection byproducts; also removes chlorine and can be formulated to remove metals
Granular Activated Carbon (GAC)	no	no	no	most	Limited removal capability for atrazine, aldicarb, and alachor; shows promise for removal of biotoxins; removes chlorine; and is moderately effective at removing some metals
Reverse Osmosis (RO)	yes	yes	yes	most	Not effective at removing low molecular weight organic compounds; removes many metals and radionuclides
Ultraviolet (UV) Light	most	yes	yes	no	Requires prefiltration; used alone or in combination with other technologies
Microfiltration (MF)	no	yes	yes	no	Used as prefilters in combination with RO
Ultrafiltration (UF)	some	yes	yes	some	Cannot remove low-weight (less than 100,000 daltons) organic compounds
Nanofiltration	yes	yes	yes	some	Can be configured to remove arsenic

The final characteristic can be accomplished via extensive testing, using actual contaminants of concern.

Table E-1 lists the most promising technologies, their effectiveness, and their limitations.

Costs

This paper presents comparative costs for different POU/POE units that could be used in response to a contamination event. Approximate purchase and installation costs are summarized in Table E-2, with the caveat that they do not take into account the uncertainty regarding the markup in price that could occur during an emergency.

Approximate amortized costs (7 percent over a 10-year life expectancy) for households that would use these units in a proactive (i.e., preventive) manner are summarized in Table E-3.

A comparison of approximate capital and annual operating and maintenance (O&M) costs for four different POE treatment technologies used at large facilities and institutions is shown in Table E-4. While two combinations, microfiltration/ultrafiltration (MF/UF) and reverse osmosis/ultraviolet light/granular activated carbon (RO/UV/GAC) offer the greatest protection against the largest variety of potential contaminants, all four treatment systems have limitations against certain contaminants. Therefore, cost must be weighed against the desired level of protection.

Table E-2 Comparative POU/POE Treatment Costs — Reactive Scenario

Treatment Technology	Cost
RO POU without UV disinfection	$400 – 700
RO POU with UV disinfection	$600 – 900
RO/GAC - faucet mount	$50
RO/GAC - under the sink	$300
RO POE	$5,000 – 20,000
UV POE	$1,000
Specialty media POU - arsenic removal	$300 – 650
Cation exchange (CX) POE	$3,300
GAC POU without UV - faucet mount	$10 – 30
GAC POU without UV - under the sink	$500
GAC POU with UV - under the sink	$750
GAC POE with UV	$3,000
Rented RO POU without UV	$20 per month

Table E-3 Comparative POU/POE Treatment Costs at Households — Proactive Scenario

Treatment Technology	Amortized Cost
RO POU	$200 – 400
Rented RO POU	$200 – 300
Specialty media POU	$150 – 250
Pitcher filters	$75
GAC - under the sink	$100 – 150
CX POE	$600 – 650
Rented GAC POU without UV	$250 – 300
Rented GAC POU with UV	$350 – 400

Table E-4 Comparative POE Treatment Costs at Large Facilities/Institutions

Average flow (in gallons per day)	RO	GAC/UV	MF/UV	RO/UV/GAC
	Capital/O&M	Capital/O&M	Capital/O&M	Capital/O&M
50,000	$350,000/$40,000	$250,000/$20,000	$600,000/$40,000	$550,000/$40,000
100,000	$500,000/$50,000	$350,000/$25,000	$750,000/$50,000	$800,000/$50,000
250,000	$900,000/$85,000	$600,000/$40,000	$1,200,000/$80,000	$1,400,000/$75,000
500,000	$1,500,000/$125,000	$1,000,000/$60,000	$2,000,000/$100,000	$2,000,000/$100,000

Benefits and Limitations Associated With the Implementation of POU/POE Treatment Water Security

POU/POE treatment devices can contribute to increased water security, subject to the circumstances of the water security concern and the limitations described below. The type of contaminant a terrorist might use cannot be known ahead of time, but the use of POU/POE treatment can serve in a protective role. When one of these technologies is used for other reasons (e.g., aesthetics or to address a specific problem with the finished water), there could be an added, serendipitous security benefit if the device happens to be effective against the contaminant that was introduced into the distribution system. In addition, consumers may feel that by using these units, they are taking an action to increase their security against an intentional act. This sense of empowerment can also be a motivating force for installing these devices in the first place.

Benefits, applicability, and limitations of POU/POE from a water security perspective are summarized below. In addition to the water security benefits, POU/POE treatment may have some collateral beneficial effects on public health that are not necessarily related to protecting against intentional contamination of the distribution system.

Benefits/Applicability of POU/POE Treatment

The benefits/applicability of POU/POE treatment can be summarized as follows:

- For certain contaminants, POU/POE treatment devices can play a proactive role and perhaps be protective of human health.
- In an emergency situation, POU devices can reduce human exposure associated with chronic/subchronic effects caused by contaminants, even though these devices would not offer total protection from acute contaminants and all exposure pathways, particularly those other than ingestion.
- POE devices using RO plus GAC plus UV represent a promising technology combination for a large number, albeit not all, contaminants of concern.
- POE devices may be desirable as a means of protecting vulnerable or potential target facilities both proactively and also in reaction to a water contamination emergency involving these facilities.
- POU devices could serve as an interim measure until a water treatment system has been decontaminated or an alternative supply has been put into service.
- POU devices could serve as a polishing step during the final stages of water treatment system decontamination.

- For long-term distribution system leaching scenarios involving a contaminant that can cause chronic toxicological and/or aesthetic ill effects, POU/POE devices may be appropriate.
- POU devices placed by utilities at critical points in the distribution system might play monitoring and forensics roles in either detecting a contaminant or in confirming a contaminant after the fact.

Limitations of POU/POE Treatment

The limitations of POU/POE can be summarized as follows:

- POU is not recommended for use in a post-contamination mode for infectious agents as these devices may over time leach trapped, absorbed, or adsorbed contaminants. This effect is of particular concern for immunosuppressed individuals and other sensitive subpopulations.
- Nonpathogenic bacteria tend to accumulate in carbon POU devices and can adversely affect children and other susceptible individuals, especially when these devices are not well maintained.
- If POU rather than POE is used, the potential risk exists of using an untreated tap, especially for an interval of time during which a contaminant has been introduced but has not yet been detected.
- During a contamination incident, users of POU devices must be reminded that only the faucet in their homes that is fitted with the POU device is safe to use.
- Many POU/POE treatment devices are not effective against all possible contaminants. Choosing the appropriate device must be done carefully and would be assisted by accurate knowledge of the contaminant identity.
- There is limited historical information available on the performance of POU/POE treatment devices using chemical or biological agents or their simulants or surrogates.
- Except in small communities, distributing POU or POE devices that require several hours to install in a post-contamination mode may take too long.
- POE treatment trains can be expensive ($5,000 to $20,000); POU devices generally cost $500 to $1,000 per unit, as discussed above.
- Widespread installation as a response action would likely not be done until flushing, hyperchlorination, and the use of bottled water were deemed impractical or inadequate.
- Bottled water may offer a higher confidence alternative to consumers during an emergency incident but would not address other uses for water.
- Additional technicians and installers may be needed for possible widespread installation scenarios.

Conclusions and Recommendations

POU/POE treatment devices can provide some water security benefits, especially if selectively deployed. For example, POE treatment devices could be employed at certain high-risk or sensitive facilities such as hospitals, military bases, police stations, and fire stations. While widespread proactive use of POU treatment devices is not recommended, they could have a water security application under circumstances in which a limited population has been affected, the type of contamination is well understood, and the POU treatment technology has demonstrated effectiveness against that type of contamination. Prefiltration, RO, carbon adsorption, and UV disinfection represent the most promising combination of technologies that would likely be effective against the vast majority of potential contaminants, especially during an acute incident.

The following short-term considerations should be taken into account when weighing the risks and benefits for the particular situation:

- Consider the installation of POE devices that use SBAC, RO, and UV for all facilities that would be of critical value during an attack (e.g., hospitals, fire departments, police stations) and all high-risk targets (e.g., government buildings, military bases).
- Continue testing POU/POE treatment devices against actual contaminants of concern. This testing will help inform the Agency and the general public regarding which devices are effective in either a proactive or reactive manner.
- Compile and periodically update an informational database, reflecting the test results on the efficacy of each type of device against various contaminants. This information would provide

guidance regarding the use of devices with the highest likelihood of success.

- Compile and periodically update an inventory database of manufacturers and distributors of various POU and POE treatment devices, including production capacity, number of devices and replacement cartridges in stock, delivery time estimates, and, if available, testing and certification status for contaminants or classes of contaminants of concern.
- Include a distribution plan as part of local emergency response preparation for POU treatment devices to provide short-term protection in the event an incident occurs in the community. This distribution plan would be dependent upon the informational database developed as part of the previous recommendation.

The following strategies should be considered, but further analysis is required to determine whether implementation of the strategy is to be recommended:

- Investigate whether POU devices may have some value being readily attachable to a faucet and being available for engagement by the homeowner once a warning has been issued about a potential or confirmed emergency. To prevent use of the device in non-emergency situations that would raise maintenance costs and concerns, there could be a carefully considered lockout feature.
- Consider the potential benefits of a proactive and random distribution of POU treatment devices from a post-contamination forensics perspective. If technology permits, there is the potential for these devices to provide sensing points for collection and transmission of water quality data in the distribution system as part of a more extensive contamination warning system.
- Develop a consumer kit that could provide a bridge response action during an emergency. This kit would contain different modular units, employing various treatment technologies. For example, there would be a prefiltration module, an SBAC module, an RO module, and possibly a UV module as well. The kit would also include adaptors so that the modules could be properly attached to a faucet. The parts of the kit would not be used until the responsible authority specified what module or combination of modules should be used in the short term. Consumer use of the modules on a routine basis could be a drawback to this strategy.
- Consider the implications of decontamination and disposal of treatment devices once they have served their purpose. Issues to consider include routine versus incident-specific use, the type of contaminant captured or retained, and the most effective methods for decontamination and disposal of the device and its contents.

Introduction

Terrorist acts are not directed solely toward individuals but also toward a country's key resources and critical infrastructure, such as the nation's drinking water and wastewater systems. Government institutions, water utilities, state and local water agencies, public health organizations, emergency responders, technical assistance providers, academia, and the private sector across the country can all be affected. The Public Health Security and Bioterrorism Preparedness and Response Act (Bioterrorism Act) of 2002[1] placed the responsibility for protecting the country's drinking water supply under the purview of the U.S. Environmental Protection Agency (EPA). This mandate was reinforced by Homeland Security Presidential Directive (HSPD)7[2], "Critical Infrastructure Identification, Prioritization, and Protection, " which reinforced the role of the Agency as the sector-specific lead for water infrastructure security. To meet these responsibilities, the Agency's Office of Research and Development (ORD) officially established the National Homeland Security Research Center (NHSRC) in February 2003. In addition, the Agency's Office of Water (OW) established the Water Protection Task Force, which was formally organized as the Water Security Division (WSD) in August 2003. ORD and OW collaborate to provide research and technical support to the drinking water and wastewater sectors.

NHSRC's Water Infrastructure Protection Division (WIPD), formerly the Water Security Team, conducts applied research to obtain reliable and credible documentation of data for use by a variety of individuals and organizations. WIPD is responsible for developing analytical tools and procedures, technology evaluations, models and methodologies, decontamination techniques, technical resource guides and protocols, and risk assessment methods for carrying out EPA's mission. All of this applied research is done in close cooperation with the OW's WSD and the responsible water representatives in each of the Agency's ten regional offices.

To meet the charge of the Bioterrorism Act and HSPD 7, ORD and OW developed the Water Security Research and Technical Support Action Plan in March 2004 to "identify critical research and technical support projects in the areas of physical and cyber infrastructure protection; contaminant identification; monitoring and analysis; treatment, decontamination, and disposal; contingency planning; infrastructure interdependencies; and risk assessment and communication."[3] While the primary objective of the Action Plan is to protect the infrastructure of source water, drinking water, and wastewater from terrorist threats, once a distribution system has been compromised, a better understanding of response options to a contamination incident is required. Accordingly, Chapter 3, Section 3.4.1(c)(6) of the Action Plan cites the need for further research regarding the capabilities of point-of-use (POU) and/or point-of-entry (POE) devices "for treating or capturing the most likely contaminants and disposal procedures for such devices should they become contaminated." POU treatment devices are designed to purify only that portion of incoming water that is being used for drinking and cooking purposes. POE treatment devices are designed to purify all the water coming into a house or facility via its placement within the water supply line.

The Action Plan was reviewed by the National Research Council (NRC), and NRC supplied comments with regard to POU/POE technology as a means of providing water security.[4] While acknowledging that this technology could play a role during a persistent distribution system contamination incident, NRC concluded that its widespread application throughout communities would be daunting with regard to logistics, installation, and expense. NRC also expressed reservations that without a rigorous testing program against potential terrorist agents, it is unknown how such devices would perform during a distribution system contamination incident. Furthermore, some types of units could eventually release trapped contaminants back into the water and produce a delayed impact on the user. However, NRC did see some merit in considering the application of this technology to protect critical, vulnerable, and potentially targeted facilities such as hospitals, military bases, and police and fire stations.

Overall, the NRC comments point to the need to study the role of POU/POE devices in more detail. Another report pointing toward such an investigation was prepared by the General Accounting Office (GAO) in 2003[5] on how future federal spending could best be spent to improve security. This report cited improved treatment technologies as one of the nine priorities warranting federal funding and support. Some of the experts who provided input to the GAO report recognized the need for more research and development of POU/POE treatment devices, which would provide additional security against contamination. Specifically cited were treatment technologies using ultraviolet (UV) systems and improved reverse osmosis (RO) techniques. The Government Accountability Office reinforced concerns regarding contaminant introduction into the distribution system in its testimony on September 30, 2004, before the House Subcommittee on Environment and Hazardous Materials, Committee on Energy and Commerce.[6]

Study Objectives

The implementation of POU/POE treatment requires further investigation for consideration as a water security strategy with regard to drinking water infrastructure contamination. This study has three objectives, each designed to elucidate different aspects of the potential water security role of these treatment devices.

The first objective of this study was to conduct a literature review regarding the types of devices and technologies currently available for removing distribution system contaminants at the point of use and/or point of entry. The most promising technologies and combinations of technologies (e.g., treatment trains) were investigated with regard to their principle of operation; effectiveness for removing radiological, biological, and chemical contaminants; and limitations. Of particular interest was a determination of a device's efficacy in preventing exposure to biological agents.

The second objective was to examine the potential water security role of POU/POE treatment devices. To fulfill this objective, different implementation strategies and their ramifications were discussed; issues associated with disposal and residuals management were addressed; and costs, benefits, and limitations from a water security perspective were described.

Drawing on the results of the first two objectives, the third objective was to offer a set of recommendations for consideration regarding POU/POE treatment and water security. The recommedations are intended to help identify the best preventive measures, treatment alternatives, and post-treatment disposal options regarding the intentional contamination of drinking water.

Literature Review on the State of the Art

1

A literature review of currently available POU/POE treatment devices was conducted. The results of this review are organized into several topic areas relevant to POU/POE operation:

- comparison of POU and POE treatment devices
- extent of POU/POE use and commercialization
- use of POU/POE treatment devices to meet drinking water standards
- state-of-the-art technologies and designs

This review produced a comparative study showing the types of devices that are currently available, the principles of operation, the types of contaminants that can and cannot effectively be removed, removal efficiencies, and maintenance considerations.

Comparison of POU and POE Treatment Devices

POU treatment devices are designed to purify only that portion of incoming water used for drinking and cooking purposes. These devices can be configured in a flow-through mode so that they are, for instance, attached to a faucet, placed on top of a counter, or installed within the plumbing beneath the kitchen sink. POU treatment can also be free-standing, whereby water is placed into and treated by the device on a batch basis. Batch POU treatment could also include adding treatment chemicals to a volume of water and then filtering it prior to use. POE treatment devices, on the other hand, are designed to purify all the water coming into a house or facility.

The major differences between POU and POE units with regard to their applications are as follows:

- Many households use POU treatement devices on only one tap, as opposed to using a POE device to treat all incoming water, so occupants are more vulnerable to water contamination, whether accidental or intentional, because other unprotected taps may be used.
- POE units are inherently more expensive and require more maintenance because they are treating all the water entering the household; however, if multiple tap POU devices were used instead of one POE unit, sampling and analysis costs associated with drinking water regulations would be higher.
- Regarding disposal, there may be some economy of scale in disposing of a few larger units (POEs) versus many smaller units (POUs).
- Consumer behavior is a consideration regarding maintenance because a device that is in the basement and out of sight (POE) might be less well maintained than a unit that is visible in the kitchen (POU).

A discussion of the major differences between POU and POE units as they relate to drinking water regulations begins on page 6.

Extent of POU/POE Use and Commercialization

Information gathered by the AWWA Research Foundation (AwwaRF)[7] and from a survey conducted in February 2004 by the Water Quality Association (WQA)[8] of approximately 2,000 adults living in private households provides some insight regarding the current sales and use of POU and POE treatment devices in the United States. Such sales were estimated at more than a billion dollars by a January 2003 survey report prepared by the market research firm of Frost and Sullivan.[9] These sources indicated that the two most widely used POU devices are a faucet-mounted device and a pitcher-style filter. The former is comprised of activated carbon in solid block configuration with 1-micrometer (µm) pore space plus an activated agent to remove lead; the latter uses a sieve filter, granular activated carbon (GAC), and ion exchange (IE) resin in sequence. Detailed descriptions of these technologies begin on page 10. Additionally, the WQA survey results indicated:

- Faucet-mounted POU filters are thought by consumers to be of the same quality as bottled water and refrigerator filters (a type of in-line device integral to the refrigerator that uses treatment technologies similar to faucet-mounted POU devices).

- Many consumers are unaware of the differences between the various POU devices and the relative effectiveness of the technologies used.
- Taste is the predominant driving factor for consumer use of filtered or bottled water.
- Sixty-eight percent of the respondents purchase bottled water, and twenty-eight percent use POU devices (mostly faucet-mounted and pitcher-style products).
- Faucet-mounted devices are the most popular.

A phone survey of four commercial vendors indicated that POE technologies are currently in use at all types of facilities described earlier as vulnerable or potentially targeted, e.g., hospitals, military bases, and police and fire stations. POE technologies were not installed in all such facilities, and it is uncertain whether the decision to install these technologies was made for water security purposes.[10] Types of POE treatment trains include primarily RO and GAC for commercial and residential buildings, with UV and micro-, ultra-, and nano-filtration mainly in use at residences. RO systems can be used at potential target facilities for flow rates from 15,000 gallons per day (gpd) to greater than 1 million gallons per day (MGD). UV systems are limited because of the need for significant pretreatment of the water and because flow rates generally do not exceed 10 to 30 gallons per minute (gpm) unless a number of units are used in a parallel configuration.

Use of POU/POE Treatment Devices to Meet Drinking Water Standards

The use of POU and POE treatment devices to meet drinking water standards is constrained by EPA guidance and regulations, third-party certification by the National Sanitary Foundation (NSF) International, standards developed by the American National Standards Institute (ANSI), and federal laws and state involvement. Furthermore, the use of POU treatment on only one tap raises regulatory concerns regarding nonresidential taps and associated health risks. A discussion of these constraints is presented below.

EPA Guidance

In 1986, EPA established the "Guide Standard and Protocol for Testing Microbiological Water Purifiers." This document provides a protocol for testing treatment systems that claim microbial purification of drinking water, specifically with regard to removing, killing, or deactivating bacteria, viruses, and protozoan cysts. For a device to be federally registered as a "purifier," data must be gathered in accordance with specific protocols. The guide provides technology-specific test protocols for halogenated resins, UV treatment systems, and ceramic candles. In addition, the guide presents a general framework for developing specific testing protocols for other technologies. For example, the framework specifies the makeup of the challenge water so that it is representative of worst-case source water. Such characteristics include pH extremes, varying temperatures, and elevated amounts of turbidity, total dissolved solids (TDSs), and total organic carbon (TOC), depending on the technology to be tested.[11]

The guide requires that a minimum percent reduction of bacteria, viruses, and cysts be achieved. For bacteria, the challenge organism is *Klebsiella terrigena* and the influent concentration to be used is 10 million organisms per 100 milliliters. A minimum reduction of 99.9999 percent (6 logs) is required. For viruses, the combined challenge organisms are polio and rotavirus and the influent concentration is 10 million per liter of each virus. A minimum reduction of 99.99 percent (4 logs) is required. Alternatively, MS2 bacteriophage may be used with an influent concentration of 20 million per milliliter, and a minimum reduction of 4 logs is required. In the case of protozoans, either *Giardia* or *Cryptosporidium* at an influent concentration of 1 million cysts per liter, or 3-µm microspheres at an influent concentration of 10 million per liter is used. A reduction of 99.9 percent (3 logs) is required; however, if NSF/ANSI Standard 53 (see below) is used, a 99.95 percent reduction is required.

NSF/ANSI Standards

NSF International (***http://www.nsf.org***) is an independent testing organization for many products related to public health. Certification is accredited by ANSI and indicates that a product has met specific criteria related to materials, design, construction, and performance. NSF International standards are developed with the active participation of public health and other regulatory officials, users, and industry. See below for a description of NSF/ANSI Standards 53, 55, 58, and 62.

NSF International developed a certification for microbiological water purifiers known as NSF Protocol P231 by combining the EPA "Guide Standard and Protocol for Testing Microbiological Water Purifiers" with several NSF/ANSI standards for evaluating materials, structural integrity, and requirements for product literature. A new comprehensive NSF/ANSI standard for microbial contaminants is currently in development. Cyst reduction is covered by Standard 53, while Standards 55 and 62 address other microbial issues. Standard 55 was recently updated, using MS2 bacteriophage as a surrogate for validation of UV units. In addition, *Bacillus subtilis* is used as a surrogate to validate the capability of the distiller in Standard 62.[11] Testing, evaluation, and performance standards relevant to POU/POE treatment are summarized below.

NSF/ANSI Standard 44 - Residential Cation Exchange Water Softeners

This standard applies to the use of cation exchange resins to remove calcium and magnesium ions, which are responsible for hardness in water. These cations are replaced with sodium and potassium ions during the exchange process. Although water softeners are primarily designed to remove calcium and magnesium, other divalent ions are exchanged, some of which (lead, beryllium, cadmium, and radium) are regulated under the Safe Drinking Water Act (SDWA). According to data presented at a February 2003 NSF International conference, there were 3 companies making a total of 43 POE products that met this standard.[12]

NSF/ANSI Standard 53 - Drinking Water Treatment Units - Health Effects

This standard applies to both POU and POE units. The substances covered by this standard include asbestos, cysts (based on the use of microspheres or *Cryptosporidium parvum* oocysts), barium, cadmium, hexavalent and trivalent chromium, copper, fluoride, lead, mercury, nitrate, nitrite, selenium, radon, turbidity, and total trihalomethanes. A number of volatile organic compounds (VOCs), such as synthetic organic compounds (SOCs), chlordane, toxaphene, and polychlorinated biphenyls (PCBs), are also covered. Typically, the testing done by NSF International requires that to be certified, the device must reduce the influent challenge concentrations to below the maximum permissible concentration of a contaminant in drinking water as established by a recognized regulatory agency, such as the EPA or Health Canada. A given product may be certified under this standard for removal of some of the challenge substances. For example, activated carbon filters covered by this standard are not intended to be used with water that is microbiologically unsafe or of unknown quality unless there is adequate disinfection before and after the carbon treatment component. Products that use activated carbon adsorption would be certified in a way that indicates it has achieved acceptable reduction regarding a partial list of the substances cited above. In other words, a product may be certified under this standard to remove lead and asbestos, but not VOCs.

Although the current universe of certified devices is ever-changing, data presented at the February 2003 NSF International conference[12] on public drinking water compliance using POU and POE treatment devices indicated that there were about 80 companies making a total of about 800 products that meet this standard for all or some of the contaminants of concern. With regard to specific contaminants, 12 companies make 61 media filter products that were certified to remove asbestos, 23 companies make 101 media filter products that were certified to remove lead, and 10 companies make 37 media filter products that were certified to remove mercury. Also, 16 companies make 58 products certified to achieve SOC reduction by VOC surrogate test, and 2 companies make 20 products certified to achieve acceptable chlordane, PCBs, and toxaphene reduction. Currently, there is at least one POU adsorptive media unit that has been certified under this standard for arsenic removal (in addition to other contaminants) and there are numerous GAC-containing POU units that are certified for removal of SOCs (in addition to other contaminants). No POE units have been tested and certified by any of the testing agencies for SOC, VOC, or radon reduction.

NSF/ANSI Standard 55 - UV Microbiological Water Treatment Systems

This standard is applicable when the treatment train uses UV light energy to disinfect water in a Class A system (designed to disinfect microbiologically contaminated water that is nonturbid, without any interfering turbidity, to meet all public health standards) or reduce the heterotrophic plate count (HPC) bacteria in water in a Class B system (designed to reduce normally occurring nonpathogenic or nuisance organisms only). Units certified for Class B are offered only for aesthetic improvement, not disinfection. According to data presented at the February 2003 NSF International conference, 6 companies make a total of 32 products that meet this standard. Of these products, all treat water at the point of entry.[12]

NSF/ANSI Standard 58 - RO Drinking Water Systems

The certification associated with this standard would apply to a list of substances (all or some) as follows: arsenic (V) [arsenate], barium, cadmium, copper, chromium (III) and chromium (VI), fluoride, lead, nitrate, nitrite, radium 226/228, selenium, TDS, and cysts. According to data presented at the February 2003 NSF International conference, about 70 companies make a total of about 560 products that meet this standard. Most inorganic compounds of health concern are removed by certified RO devices. In particular, 23 companies make 86 products that were certified to remove most of these inorganic compounds.[12]

NSF/ANSI Standard 62 - Drinking Water Distillation Systems

The certification associated with this standard would apply to a list of substances such as arsenic, barium, cadmium, chromium, copper, lead, nitrite, and selenium, which are tested by chemical reduction with TDS as a surrogate. Mercury and fluoride must be tested separately to make the reduction claim. Typically, VOCs are not removed by this process as they are carried with the water vapor and show up in the condensate. Certified distillers adequately remove all inorganics, with the exception of asbestos and radium, which are not covered by this standard. According to data presented at the February 2003 NSF International conference, 3 companies make a total of 31 products that meet this standard.[12]

Federal Regulations

After the establishment of EPA in 1970, concerns about waterborne diseases and chemical contamination led to the passage of the Safe Drinking Water Act (SDWA) in 1974. This act authorized the Agency to promulgate regulations to protect the public health. The first set of these regulations, known as the National Interim Primary Drinking Water Regulations, was passed in 1975. These regulations became effective in 1977 and established maximum contaminant levels (MCLs) for 10 inorganic contaminants, 6 organic contaminants, turbidity, coliforms, radionuclides, and radioactivity. The states are responsible for establishing and enforcing state drinking water standards that are at least as stringent as the federal standards. The states' role also includes identifying and resolving significant violations that are detected, keeping the EPA informed about compliance assurance and enforcement activities, and requesting assistance when necessary from EPA to achieve timely and effective enforcement.

A series of amendments and rules were added to the SDWA between 1986 and 2002. The 1986 SDWA amendments required EPA to apply future National Primary Drinking Water Regulations (NPDWR) to community and nontransient noncommunity water systems. Challenges facing small water systems, defined as serving 10,000 or fewer people, were a major focus of the 1996 SDWA amendments. At that time, the U.S. Congress directed EPA to explicitly allow the use of POU/POE devices to achieve compliance with some of the MCLs established by the NPDWR. As a result of the 1996 amendments, SDWA regulates the design, management, and operation of POU and POE treatment devices used to achieve such compliance. One important aspect of this change is that certain POU/POE devices are specifically listed as small-system compliance technologies (SSCTs). For example, both activated alumina POU and RO POU devices are listed as SSCTs for compliance with the revised arsenic standard of 0.01 milligrams per liter (mg/L); ion exchange POU and RO POU devices are listed as SSCTs for radionuclides. A technology may have met NSF/ANSI certification requirements but may not be acceptable with regard to the SDWA as an SSCT (e.g., a distillation product may be certified to remove arsenic but this technology is not currently listed as an SSCT or in a rule for arsenic).[13] Similarly, there are technologies that are recognized as effective for removal of certain contaminants, but they have not yet gone through a formal NSF/ANSI certification process and therefore could not be considered an SSCT.[12, 13]

Using POU/POE devices to meet MCLs also adds administrative burden and cost and raises a number of concerns, including sabotage, disposal of wastes associated with spent materials, and vandalism. These concerns can be pronounced when transient populations are involved because of a reduced sense of ownership and empowerment.

Additional concerns include a lack of utility personnel with expertise to manage and coordinate sampling and maintenance, and the presence of unprotected taps if a household has only one POU unit. Furthermore, the following restrictions apply regarding the use of POE/POU devices in meeting MCLs:[13]

- Only POE treatment devices can be used to achieve compliance regarding microbial contaminants or indicators of microbial contaminants.
- POU and POE treatment devices must be owned, controlled, and maintained by the public water utility or by a contractor hired by the utility to ensure their proper operation and maintenance and compliance with the MCLs. The utility must retain oversight of device installation, maintenance, and sampling, and is responsible for the quality and quantity of water provided to the community.
- POU and POE treatment units must be equipped with a warning device (e.g., an alarm, a light) to alert the consumer that it is no longer functioning properly. Alternatively, there must be an automatic shutoff feature.
- Only units that have met NSF/ANSI standards may be used. If they are covered by these standards, they must be independently certified according to these standards by an accredited laboratory.

The SDWA does not specify the technologies and/or designs (see "State-of-the-Art Technologies and Designs," beginning on page 10) to be used in POU/POE devices, except for the following:

- Only the arsenic rule and the radionuclides rule list POU devices as acceptable SSTCs.
- A proposed radon rule lists GAC POE treatment as the only SSCT.
- Ion exchange POU units (radium, uranium, and beta and photon activity only) and RO POU units are acceptable SSCTs regarding radionuclides.
- POU devices cannot be used to treat water for radon or VOCs.

Role of the States

When the use of POU/POE devices is regulations driven, the water utility bears the responsibility to properly install, maintain, and monitor the device, subject to state approval. For example, the state must approve a monitoring plan prepared by the water utility when a POE device is installed for regulatory compliance. It can be challenging to obtain a statistically valid sample because deployment of the units will be decentralized and limited in number. This is not typically a problem for monitoring of municipal water supplies. EPA guidance allows the annual collection of samples at 1/9 of homes that employ these devices or a statistically valid sample with regard to meeting regulatory monitoring requirements. The state must also require adequate certification of performance and field-testing for POE devices. In addition, a state may require a feasibility study to justify a water utility's selection of a POU or POE technology instead of an alternative means of meeting an MCL. Furthermore, the state may want a detailed engineering study that verifies how a POU or POE device will perform regarding MCL compliance. Finally, plumbing and electrical codes must be considered to ensure the proper installation of these devices.

Despite the amendments to the SDWA that allow implementing POU/POE treatment as a means of meeting the NPDWR, some states prohibit or restrict a utility from doing so. Pennsylvania is one of the states that does not allow POU treatment devices to be used to meet compliance requirements. Some states allow POU/POE treatment devices for a restricted list of contaminants.[14] Of the 24 states that responded to an AwwaRF survey,[24] only Delaware, Kansas, Missouri, and Washington had systems currently using POUs for SDWA compliance, and only New York, Pennsylvania, and Wisconsin had systems using POEs for compliance to address microbial and VOC contaminants. Only nine states (Arizona, California, Florida, Idaho, Massachusetts, New York, Pennsylvania, Vermont, and Washington) indicated that POUs/POEs could be used to meet arsenic compliance regulations. Eight states (Alaska, Arizona, Illinois, Massachusetts, New York, Virginia, Washington, and Wisconsin) plan to conduct further study regarding SDWA compliance using POUs/POEs. A recent report by the Arizona Department of Environmental Quality indicated that for small water systems with a dispersed population of users, POU treatment devices may be an appropriate means to meet the new arsenic standard.[15]

State-of-the-Art Technologies and Designs

POU/POE devices on the market today rely on various types of basic technology. Each of these basic treatment technologies is discussed in more detail below. Although these technologies are first discussed separately, often they are used in combination. A discussion of some of the designs of POU/POE systems begins on page 16. Performance of current POU/POE treatment products, mobile treatment technologies, and costs are discussed in subsequent sections.

Technologies

Solid Block Activated Carbon (SBAC) Filters

All types of carbon filters effect the removal of organic substances by adsorption onto the carbon surface as shown in Figure 1. The filter in this device consists of extremely small particles of activated carbon that are fused together into a solid block with uniform pore size. If the carbon block configuration is properly constructed, the pore size may be uniformly 0.5 micrometer (μm), which would be effective at removing asbestos fibers, protozoan cysts (e.g., *Cryptosporidia*, *Giardia*), and some bacteria (e.g., *Escherichia coli*, *Bacillus anthracis*). SBAC filters are less prone than GAC filters to channeling and can also be effective at removing organic contaminants such as some insecticides and pesticides and chlorinated solvents. In addition, some SBAC devices are certified by NSF International for removal of methyl tert-butyl ether and selected disinfection byproducts (DBPs) such as total trihalogenated methanes. Furthermore, they can remove chlorine and can be formulated to remove metals such as mercury and lead.[12, 16]

With regard to limitations, SBAC filters typically will not remove most heavy metals, viruses, small bacteria, arsenic, fluoride, iron, or nitrates. These filters also tend to harbor bacteria that grow on trapped organic matter, and the bacteria can migrate from the filter to the water at a later time. Most manufacturers recommend that the filters be replaced about every six months, even though the adsorptive capacity may not yet be totally exhausted. However, replacement may be required sooner depending on the quality of the incoming water and the amount of usage. Replacement filters generally cost $30 to $50.[17]

Figure 1 Carbon Adsorption Process

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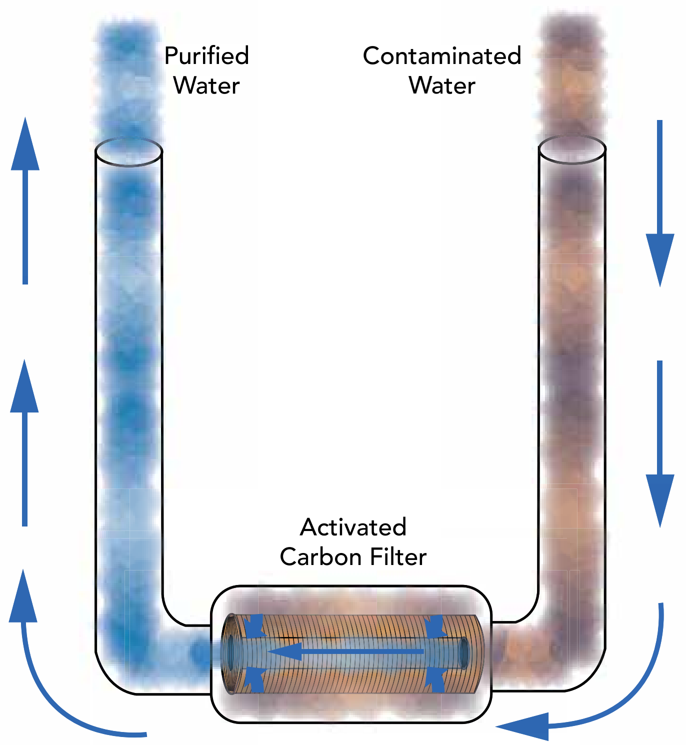

Granular Activated Carbon (GAC) Filters

GAC is extremely porous and can have a surface area of about 1,000 square meters per gram (equivalent to 125 acres per pound). Many organic compounds, such as chlorinated and nonchlorinated solvents, select SOCs, naturally occurring organic matter, some gasoline components, and trihalomethanes, can be adsorbed onto the GAC surface. For some pesticides, such as atrazine and alachlor, GAC has a very low adsorptive ability. This material is also effective for removal of chlorine and moderately effective for removal of some heavy metals and metals that are bound to organic molecules. In addition, activated carbon processes show promise for removal of biotoxins and other potential organic contaminants of concern.[13]

Typically, GAC is a viable treatment technology for those compounds with a Freundlich K value greater than 200 ug/g (L/ug)1/n. The Freundlich K is defined as a constant generated during adsorption isotherm studies in which the mass of material adsorbed is plotted against an equilibrium concentration; for a log-log plot, log K represents the Y-intercept. While this rule of thumb may be helpful, the adsorption of some compounds is difficult to predict when the Freundlich K value is near that threshold. However, many SOCs have Freundlich K values in the thousands, enabling their ready adsorption. When a Freundlich K value is not known, it can be predicted typically within an order of magnitude from the molecular weight, density, and solubility values.[18] The error in this prediction becomes important for weakly adsorbing compounds.

From a regulatory perspective, GAC POU units, as well as SBAC POU units, have been identified as small-system compliance technologies for SOCs (except as noted above), and GAC and SBAC POE units are under investigation as small-system compliance technologies for SOCs. GAC is a recognized technology for removal of many VOCs, and GAC POE treatment has been identified as a small-system technology in the proposed radon rule. Regardless of the design, GAC filters are subject to clogging and, like all types of activated carbon filters, provide an environment for bacterial growth. When obtaining a variance under SDWA to allow the use of this technology at the point of use or point of entry to meet the National Primary Drinking Water Regulations, post-device disinfection (e.g., UV, discussed below) to address HPC bacteria must be considered.[13] The variance consideration applies despite the April 2002 opinion by the World Health Organization that the presence of HPC growth in POU/POE treatment devices does not indicate a health risk, provided the entry water is biologically safe.[19] Backwashing can improve long-term effectiveness for removal of organic compounds and provide some control of bacterial growth, but it does not improve radon removal efficiency.

GAC is not effective at removing fluoride, chloride, nitrate, hardness (calcium and magnesium), or most metal ions and is not recommended at the point of use for removal of radon or VOCs. GAC is also not as effective as SBAC, especially with regard to removal of chlorine, taste-causing substances, or halogenated organic compounds. Maintenance considerations include replacement of spent cartridges and particulate prefilters, if used, and periodic backwashing when GAC is employed at the point of entry.

Reverse Osmosis (RO)

This type of POU/POE treatment relies on water pressure to force only "clean" water to migrate through the pores of a semipermeable membrane (see Figure 2). The effect of the applied pressure is to reverse the tendency of dissolved materials in water from moving naturally via osmosis from a solution of lower concentration to one of higher concentration. The membrane or filter typically will have a pore size between 0.00025 and 0.001 µm, which will allow water and molecules less than 200 daltons in size to pass. The liquid on the other side of the membrane that contains the retained contaminants is conveyed away as waste. For POU/POE treatment, typical clean water production rates are 10 to 30 gpd, while the wastes, usually 70 to 75 percent of the influent water, are discarded.

The two most common RO membrane types are thin film membranes (TFMs) made of polyamide polymers and cellulose acetate membranes (CAMs). CAMs are hydrophilic and are less prone to fouling than TFMs. One inherent weakness of a CAM is that it is subject to being degraded by microorganisms. While CAMs are more chlorine-resistant, TFMs are more widely used because they are more durable and can tolerate a higher range of pH. Also, their performance is better, especially in low-pressure water systems. Both these types of membranes have pores small enough to remove high molecular weight organic compounds, as well as many

Figure 2 RO Process

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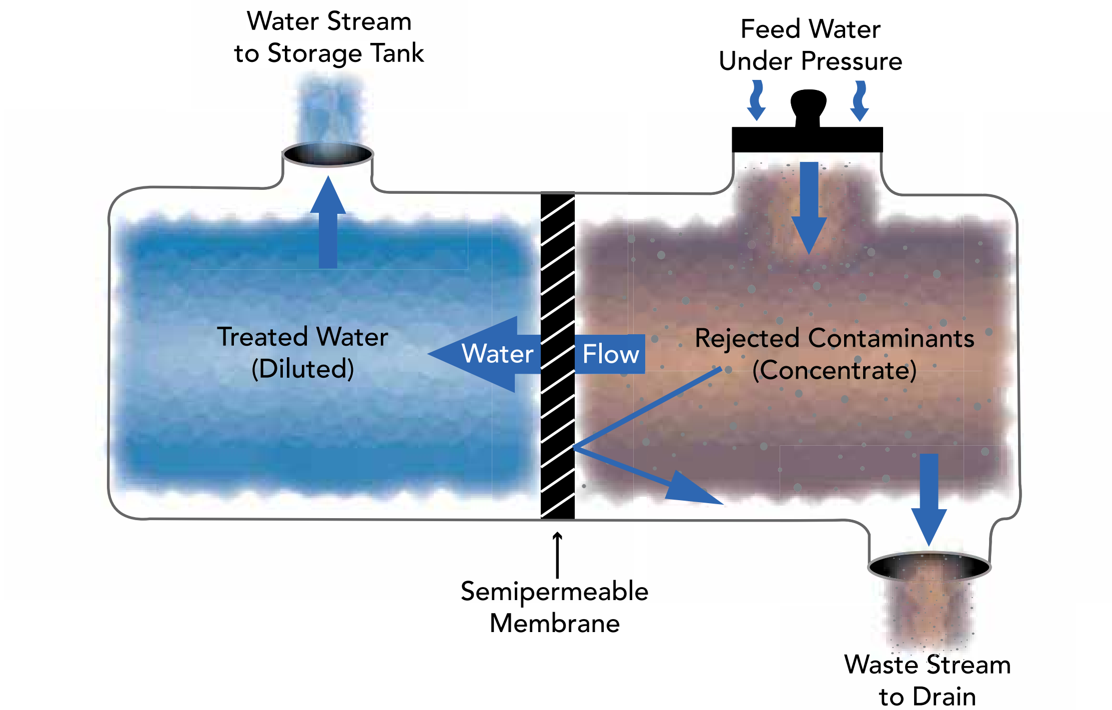

low molecular weight anionic species by electrostatic repulsion because the membrane acquires a slight negative charge at drinking water pHs. Typical inorganic contaminants removed include a number of metals, chlorides, fluoride, and sulfates. RO is not effective for removal of low molecular weight (less than 100 daltons) organic compounds such as trichloroethylene, trihalomethanes, and some pesticides, although removal is dependent on both molecular weight and geometry.[20]

While these filters will effectively remove viruses, membranes are subject to tearing, which could allow viruses and other microbes to pass through. Leakage can occur around seals of the assembled device, which can allow contaminants to short-circuit the membrane barrier. In addition, RO membranes are subject to biological fouling, and strong oxidants, such as chlorine, can damage the membranes. The presence of salts in the influent can lead to membrane scaling problems, and exposure to air can lead to the precipitation of elemental sulfur or metallic sulfides on the membrane. The waste stream from POE RO units may have special disposal requirements and may require pH adjustment to prevent corrosive wear on piping. Furthermore, the introduction of waste liquid into the wastewater collection system could disrupt processes at the wastewater treatment plant.

RO membrane filtration requires more maintenance than SBAC filters and many other POU/POE technologies. Maintenance considerations include cleaning of the storage vessel and replacement of spent or worn membranes, particulate prefilters, and post-treatment GAC polishing filters. RO filtration is more costly than SBAC filtration and produces less water (only a few gallons of treated water per day in POU applications). Also, since POE filters rely on high pressures—a minimum of 40 pounds per square inch (psi)—they will not function in an emergency involving a power outage, unless there are standby generators. Offsetting these disadvantages is the fact that RO may be able to remove many more types of contaminants. From a regulatory perspective, RO POU is an acceptable SSCT for antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, fluoride, radium, selenium, thallium, and uranium. An RO POE unit is not an SSCT, but it is recognized as a removal technology for arsenic, copper, lead, fluoride, nitrate, SOCs, radium, uranium, and microbials.

Figure 3 Microfiltration Process

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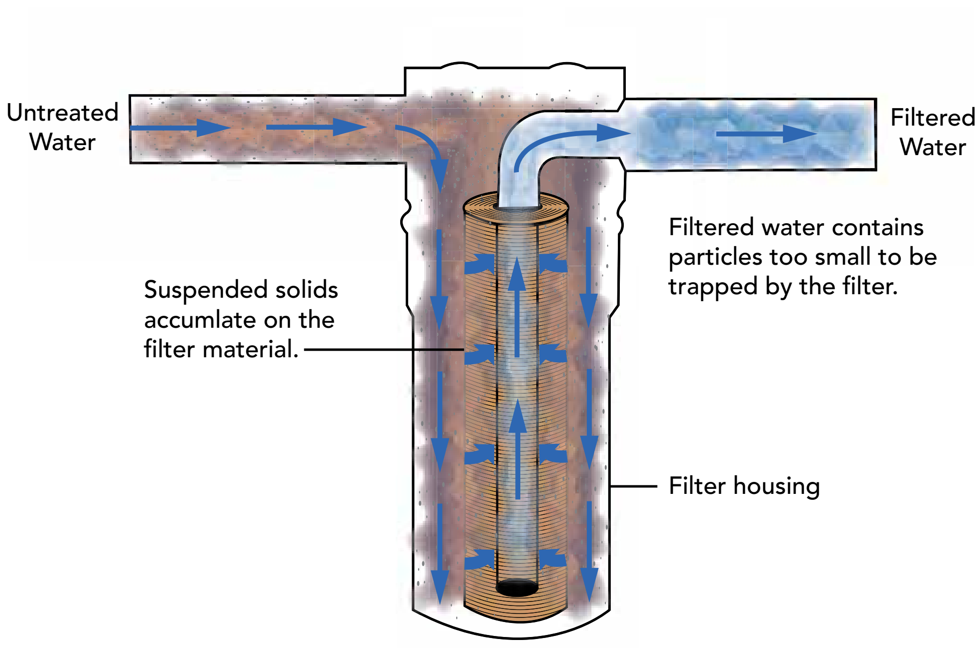


Microfine Filters

Microfiltration (MF) membranes have pore sizes that typically range from about 0.1 to 0.2 µm. These filters are capable of removing bacteria and cysts and typically can retain particles down to 0.1 µm in size. For example, *Cryptosporidium* oocysts range from 4 to 7 µm in size. Ceramic and SBAC are commonly used to provide MF. The former has an advantage over the latter because it can be cleaned and reused a number of times before requiring replacement. Microfilters also can be configured as flat-sheet, spiral-wound elements; hollow-fiber modules; or tubular modules. An example of a hollow-fiber arrangement in which the untreated water passes through the filter in a cross-flow manner is shown in Figure 3. In addition, microfilters are used as prefilters in combination with RO treatment devices.[20]

Ultrafilters

The implementation of ultrafiltration (UF) membranes for POU treatment is similar to that of MF membranes. However, UF membranes have pore sizes that range from about 0.01 to 0.04 µm and are capable of preventing the passage of particles greater than 100,000 daltons, including proteins and suspended solids. Smaller particles, such as mono- and di-saccharides, salts, amino acids, low-weight organic compounds, inorganic acids, and sodium hydroxide, are not removed. UF membranes can, however, remove viruses, bacteria, and cysts. These filters can also be configured in flat-sheet, hollow-fiber, or tubular arrangements.[13, 21]

Specialty Media

Specialty chemical adsorbents, in a configuration similar to GAC POU treatments described earlier, are being used to remove one type of contaminant or group of contaminants at the point of use and the point of entry. Removal of inorganic contaminants such as arsenic and fluoride can be accomplished by using activated alumina (e.g., hydrated aluminum oxide), granular ferric hydroxide, and other specialty iron-based media; these typically consist of ferric oxide or ferric hydroxide granules, activated alumina coated with iron, or natural materials substantially impregnated with ferric hydroxide. These media will require periodic replacement when spent, and periodic backwashing and occasional cleaning of a storage tank will be necessary when used at the point of entry.

Iron Media and Activated Alumina Various designs and materials have been investigated to improve the removal efficiency for specific contaminants. With regard to arsenic removal, the iron-based media perform longer than activated alumina before media replacement is required. While activated alumina primarily removes fluoride and arsenic (V) [arsenate] and does perform better at a lower pH (best between 5.6 and 6), iron-based media generally are more effective at removing both arsenic (III) [arsenite] and arsenic (V) [arsenate], although oxidation of arsenite to arsenate prior to filtration can increase its removal efficiency, depending on pH. In addition, activated alumina is more likely to experience interference affecting arsenic removal from competing ions such as silica, fluoride, phosphate, and sulfate than iron-based media. Although it is feasible to regenerate both types of media, albeit less practical for POU/POE applications, granular ferric hydroxide and ferric oxide cannot be regenerated. When used to meet arsenic removal requirements in a POU unit, activated alumina cannot be regenerated and must be taken off-site for disposal. Furthermore, both types of media also remove selenium and chromium. From a regulatory perspective, specialty media using activated alumina is a recognized POE technology only for removal of arsenic, fluoride, and uranium, and is considered an SSCT for the final arsenic rule in a POU mode. However, activated alumina is undergoing further investigation in a POU mode for fluoride and selenium.[12]

Nanofilters Nanofilters can remove particles in the 0.001 to 0.005 µm range, which include some dissolved organic compounds, as well as viruses, bacteria, and cysts. Nanofilters are also capable of arsenic removal. Two types of nanofilters are described below.

One manufacturer has produced a nano alumina electropositive filter consisting of heavily aggregated fibers that are primarily boehmite (AlOOH). These fibers are 2 nanometers (nm) in diameter, tens to hundreds of nm long, and are distributed over a microglass fiber (0.6 µm) matrix. The manufacturer has reported that this filter is capable of retaining viruses, bacteria, and other pathogens. For example, the manufacturer reported that a greater than 6-log reduction was achieved for bacteriophage MS2, greater than 6-log for the enterobacteria *Klebsiella terrigena*, greater than 5-log for *Cryptosporidium*, as well as greater than 99.5 percent for DNA and greater than 99.96 percent for endotoxins. No other test results were reported regarding removal efficiencies for other potential biological contaminants.[22]

In an EPA Phase I research project that investigated arsenic removal capabiltity to meet the 0.01 mg/L drinking water standard, the manufacturer [23, 24] first evaluated a nonwoven fibrous nano alumina fiber filter previously used in pathogen challenge testing and then a filter comprised of granular forms of nano alumina/iron hydroxide composites (primarily FeOOH and AlOOH, with small amounts of MnOOH). Based on experimental data evaluating this hydroxide composite sorbent bed as a function of challenge concentration and flow, it was projected that a conventional POU cartridge 2.75 inches in diameter and 12 inches in length can contain sorbent in excess of what is necessary to meet a 2,000-gallon test conducted under EPA's Environmental Technology Verification Program (***http://www.epa.gov/etv***). Accordingly, there is sufficient volume in the cartridge to add components such as a biological (including virus) filter or activated carbon for chlorine removal. For example, one option is to use the nano alumina fiber electropositive filter in combination with the granular hydroxide composite to achieve acceptable microbial and arsenic removal efficiencies. The nanofibers can also absorb trace heavy metals, as initial data showed that they absorb low ppb levels of arsenate and chromium (III). Another variation on these filters showed some promise regarding removal rates for chromium (VI). An additional option is to mix GAC directly with the granular hydroxide composite to remove chlorine and halogenated methanes (e.g., DBPs).

Ultraviolet (UV) Light

This technology uses UV radiation to inactivate microbes. The UV spectrum is divided into four regions, defined by wavelength expressed in nm: UV (100 to 200 nm), UV-C (200 to 280 nm), UV-B (280 to 315 nm), and UV-A (315 to 400 nm). For application in POU/POE devices, an effective and practical germicidal wavelength range is 200 to 300 nm. UV light deactivates microbes by causing dimers (i.e., a molecule composed of two identical subunits, such as thymine, which is one of the DNA base units) to form within the organism's DNA, thereby making it difficult for survival unless the organism is able to repair this damage.[25] The effective UV dosage as a function of irradiance in milliwatts per area multiplied by time in seconds is expressed as an energy flux. An energy dosage of 15 to 30 millijoules per square centimeter (mJ/cm^2) is effective for killing bacteria, 8 to 20 mJ/cm^2 for *Cryptosporidium*, 40 mJ/cm^2 for *Giardia*, while it takes 60 mJ/cm^2 to achieve a 4-log reduction in most viruses. In the case of adenoviruses, however, a dosage of 60 mJ/cm^2 will achieve only a 0.5-log reduction and it takes 120 mJ/cm^2 to achieve a 4-log reduction. The reason for the high dosage required for adenoviruses is that they have the ability to repair the dimers caused by the radiation. Adenoviruses are on the EPA Contaminant Candidate List (***http://www.epa.gov/safewater/ccl/ccl2.html***), the list from which future regulated drinking water contaminants may be selected. The actual design for UV devices may include a safety factor of three to four, which is not reflected in the values above, to ensure enough energy per area reaches the target organisms.[26]

A benefit to using UV treatment is that it has not been shown to produce regulated DBPs at levels of concern. With regard to limitations, this type of treatment is energy intensive, does not address organic or inorganic contaminants, and typically requires the use of 1- to 5-µm prefilters to remove particulate matter that would interfere with the effectiveness of the process. There are other types of media filters that can remove color-causing substances, such as tannins, that can also interfere with UV performance. Periodic maintenance (e.g., UV bulb replacement and the cleaning of the bulb housing) is important to prevent UV lamps from becoming fouled from substances occurring naturally in the source water. Fouling results in an increase in the required energy dosage [26] and may make it impossible to achieve the desired level of disinfection.

Ozone

Ozone is generated at its point of use by passing air or oxygen gas between two electrodes separated by a dielectric material and a discharge gap. When voltage is applied to the electrodes, oxygen molecules are dissociated, leading to the formation of ozone molecules. Ozone is a strong oxidizing agent that can break down many inorganic and organic compounds found in water. It also acts as a disinfectant by breaking apart the cell wall of a microorganism and then destroys enzymes, proteins, and nucleic acids, causing the organism to die. The contact time necessary to achieve the disinfecting effect is relatively brief in comparison with chlorine, and no chlorinated DBPs will result. However, if the bromide ion is present in the source water, its reaction with ozone can form brominated DBPs. Ozone can also react with organic matter in water to form aldehydes, ketones, and acids.[27]

Ozone is recognized as a treatment technology for destroying microbial contaminants but is not considered as an SSCT at the point of entry. A typical system involves an ozone injection/contact step followed by mechanical filtration to remove solids that may precipitate. In some cases, it is used as part of a more elaborate POE treatment train involving other technologies such as GAC and RO. While it is an effective disinfecting technology, the results are mixed with regard to the destruction of organic contaminants because harmful byproducts (e.g., formaldehyde and bromate) may result.[27, 28]

Ion Exchange (IE)

IE resins are used primarily to address the presence of inorganic contaminants by removing contaminant ions in water and replacing them with relatively harmless ions. Ion exchange can involve anion exchange (AX) or cation exchange (CX), typically with the ionic exchanger immobilized on a synthetic polymer backbone. From a regulatory perspective (POU units only), AX is an SSCT for antimony, chromium, fluoride, selenium, and uranium, while CX is an SSCT for barium, beryllium, cadmium, copper, lead, radium, and thallium. AX and CX are also used in POE treatment units for removal of arsenic, fluoride, nitrate, and uranium (AX) and copper, lead, and radium (CX) but are not SSCTs for those contaminants in the POE mode.

CX resins can be either the strong acid or weak acid type, and devices with CX resins are sometimes referred to as water softeners. Strong acid resins are more common because they are regenerated with sodium chloride rather than with hazardous chemicals. This type of water softener can also remove hazardous metals such as barium, cadmium, chromium III, copper, lead, mercury, radium, and zinc, but is not very effective against organic or biological contaminants. Some limitations of these devices include susceptibility to fouling, channeling that allows the short-circuiting of untreated water, the introduction of waste brine to the wastewater system or septic tank during regeneration, and the introduction of additional sodium into the drinking water supply to a household, thereby affecting those members on strict low-sodium diets. No CX POU units have been certified by NSF/ANSI, but a CX POE unit has been certified for radium removal (Standard 44).

When IE is used at the point of use, periodic replacement of spent resin cartridges and particulate prefilters is required. When used at the point of entry, periodic backwashing is required as an additional system component. Also, the salt used for resin regeneration needs to be replaced, and if a storage tank is used, it should be periodically cleaned.

Distillation

This principle of operation involves applying a heat source to evaporate the water to be treated and condensing the vapors into a receiving vessel or trap. However, a VOC trap is needed to remove VOCs that evaporate off with the water as a secondary step. Inorganic contaminants will be left behind during the evaporation process. In principle, heating the water to boiling temperature should kill biological contaminants; however, it is important to verify that there is a sufficient combination of temperature and boiling time so that spores such as *Bacillus anthracis* are also killed. These devices typically produce 1 gallon of water per 3 kilowatt-hours of electricity.[29] Their design is typically configured to contain aerosols produced during evaporation. The aerosols can contain harmful substances.

With regard to limitations, distillation effectiveness for organic contaminants is dependent upon the performance of the VOC trap. The traps are highly energy dependent and will not work if there is a power outage and no backup power available. Those powered by solar energy can operate intermittently. The cost is about $0.35 of electrical energy per gallon of production (typically taking 5 hours to produce a gallon of water), which is twice the RO cost and four times the SBAC cost. Although distillation is capable of removing arsenic, copper, lead, SOCs, radium, and uranium, it is not listed as an SSCT in either the Federal Register or in any rule.[30]

Batch Treatment

One manufacturer has produced a POU approach for treating contaminated water in a batch mode. The motivation for developing this technology is to address unsafe drinking water conditions caused primarily by the presence of pathogens and arsenic in third world countries. In particular, the goal was to overcome the difficulty in achieving sufficient disinfection, either by solar or chemical means, because of the presence of turbidity. Toward this end, a combination of flocculation and disinfection was employed. The POU consists of a coagulant (ferrous sulfate), an alkaline agent, an oxidizing agent (potassium permanganate), a coagulation aid (bentonite), a flocculation aid (i.e., a polymer), and a chlorine-based disinfectant (calcium hypochlorite). These constituents are combined in a packet to be added to 10 liters of water. After the packet contents are mixed with the water and floc particles have developed, a final filtration step using any type of cotton cloth or dish towel takes place.

Tests were conducted under laboratory and field conditions, with varying amounts of time allowed for floc development and contact time between the disinfectant and the water to be treated. The laboratory results indicated that POU treatment of test waters seeded with microbes achieved greater than 7-log reduction and no bacteria (less than one per liter) were detected in the treated waters. Both poliovirus and rotavirus results showed a greater than 4-log reduction. These results meet the EPA requirements for water purification, which specify that polio and rotaviruses should achieve a 4-log reduction. Furthermore, a reduction of greater than 3 logs was achieved for *Cryptosporidium* oocysts, which is consistent with the EPA performance standard for water purification. None of the field samples treated with the product had detectable levels of coliforms or *Escherichia coli*. Pretreatment arsenic levels were reduced by greater than 99.5 percent.[31]

POU/POE Product Design

Diagrams are provided showing some typical configurations of the treatment technologies discussed in the previous section. As discussed above, there is a vast array of devices manufactured today, so not all configurations or treatment combinations are shown.

Prefiltration

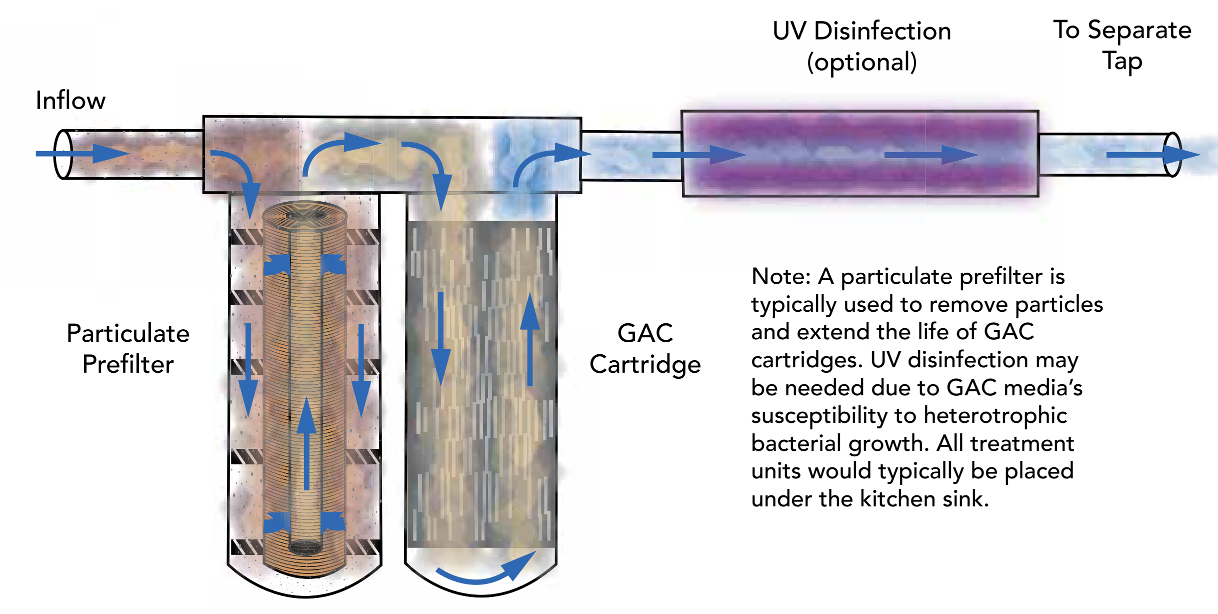
Many of the POU/POE treatment technologies require prefiltration to remove coarser materials and to prevent clogging and impairment of treatment efficiency. For POU treatment, a prefilter made of foam or cotton can mitigate the development of clogging in general and inhibit bacterial growth in GAC devices. With regard to POE treatment, a prefiltration technology developed by one manufacturer uses a 5-part segmented device that can remove particles down to a size of 5 µm. Each filtration segment is prevented from interacting or mixing with other segments so that backwashing can be done on a segment-by-segment basis and without loss of filtration media. This technology has had application as a prefiltration device for wastewater treatment but may also have applicability in water treatment as a means of protecting RO membranes.[32]

GAC Treatement Devices

Regardless of the type of prefiltration used, the GAC filters will eventually need to be replaced as the adsorption sites become filled. From that point on, contaminants will pass through untreated. A manufacturer's prediction for when a cartridge should be changed reflects crude estimates because factors that are characteristic to a specific water source, such as pollutant concentration, are not taken into consideration. The detection of contaminants at this breakthrough condition is usually indicated by a reduction in water pressure, change in taste, or the presence of sediment in the water. When these conditions are observed, the cartridge should be replaced. Greater acidity and lower water temperatures tend to improve the performance of GAC filters. With regard to operation and maintenance, tests show that under-the-sink models generally have more carbon, superior performance, and greater convenience than faucet or countertop models.

An illustration of a GAC POU unit treatment train is shown in Figure 4.

Figure 4 GAC POU Unit[29]

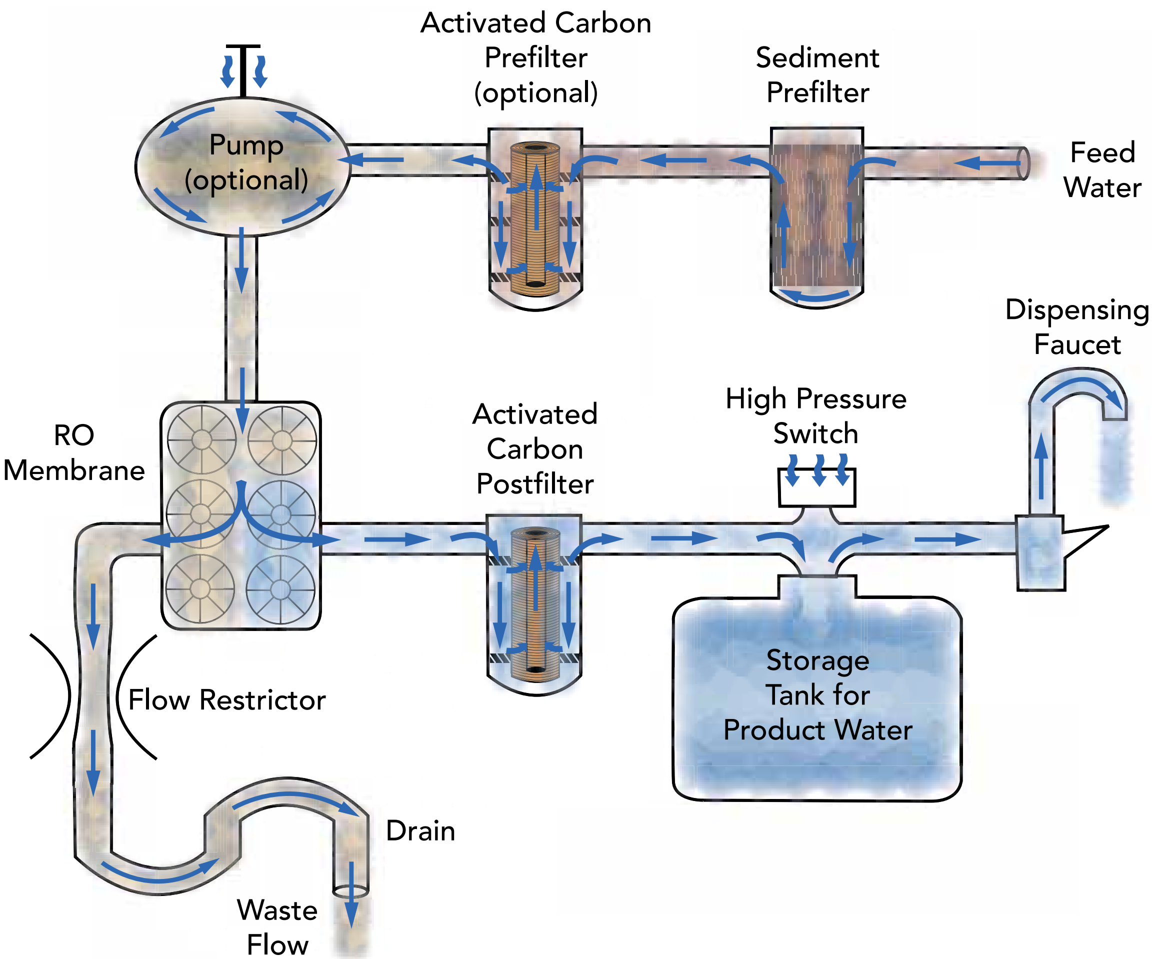


RO Treatment

Figure 5 depicts an RO POU treatment unit. As indicated in the diagram, membrane-damaging chlorine is removed by the GAC prefilter and the GAC post-filter removes low molecular weight organic compounds and taste- and odor-causing compounds. When used to comply with the SDWA requirements, the units must have a mechanical warning device with an indicator light that may be actuated on the basis of volume usage registered by a water meter or due to an unacceptable change in the TDS concentration indicated by a conductivity meter. An optional disinfection step using a UV light source (not shown) could be added to address microbial colonization of the GAC filters.

Figure 5 RO POU Unit

Image was reproduced with permission from Home Water Treatment (NRAES-48), 1995, Natural Resources, Agriculture, and Engineering Service, Cooperative Extension, Ithaca, N.Y., ***http://www.nraes.org***



Specialty Media

Figure 6 illustrates an SBAC POU device with specialty media that is certified for removal of arsenic by Standard 53 of NSF/ANSI. The cartridge removes contaminants in a way analogous to the schematic shown in Figure 4.

Ion Exchange

A typical POE unit, as depicted in Figure 7, typically has a life expectancy of 10 years and produces treated water at a rate of 5 to 10 gpm.

Figure 6 Specialty Media for POU Arsenic Removal

Image was reproduced with permission from Home Water Treatment (NRAES-48), 1995, Natural Resources, Agriculture, and Engineering Service, Cooperative Extension, Ithaca, N.Y., ***http://www.nraes.org***

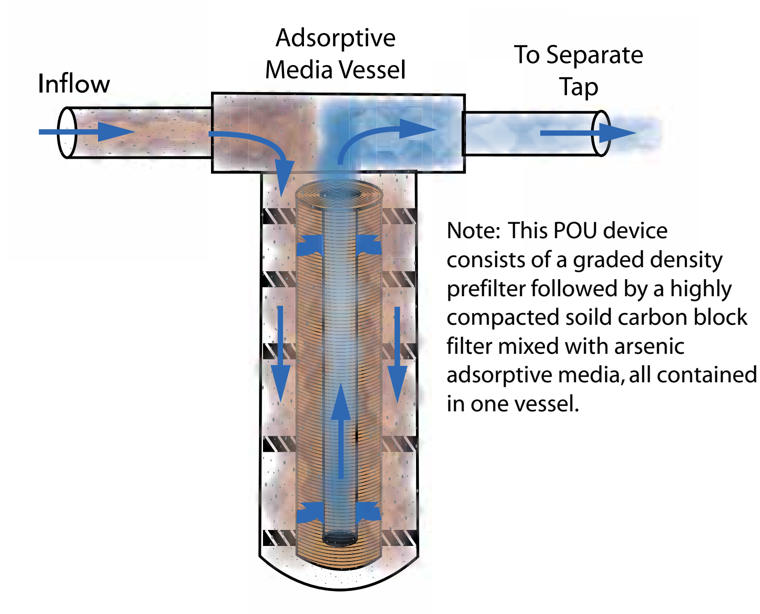
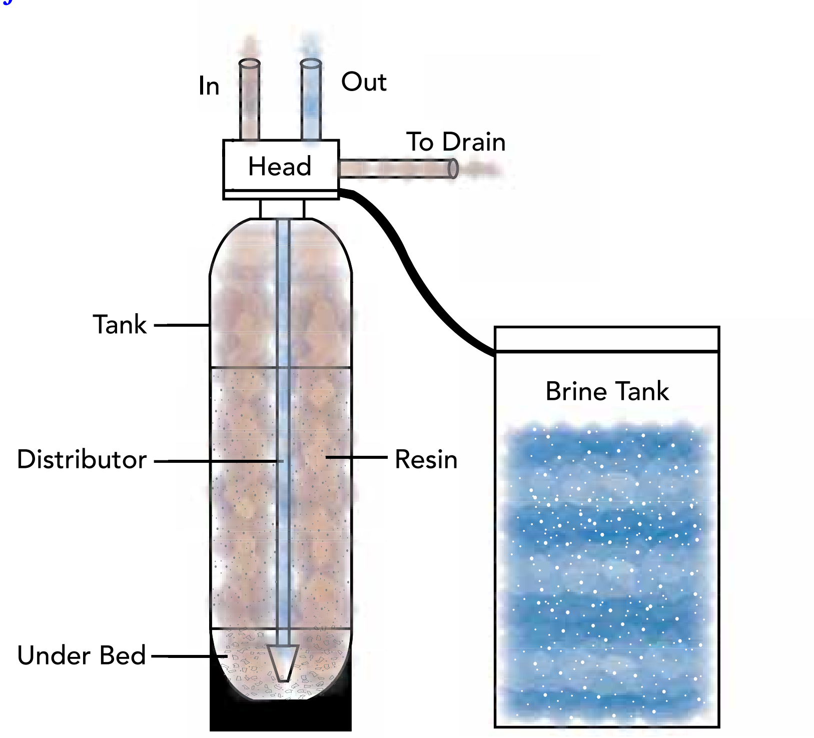


Figure 7 Typical POE IE Installation

Image was reproduced with permission from Mr. Jeffrey Twitchell, Vice President, Air and Water Quality Inc., ***http://www.awqinc.com/softener.html***



Portable Purifiers

In a pitcher-type purifier, untreated water is placed into a pitcher that contains a sieve, GAC, and an ion exchange resin. The water passes through the three-part filter and is purified by carbon adsorption and ion exchange. In other designs, water is manually pumped through units that incorporate silver-impregnated ceramic filters to retain and kill microorganisms. There are also some hand-held pump purifiers that use GAC in combination with ceramic filtration. However, most of the commercial products employing these designs are not certified to be effective against microbial contaminants.

Performance of Current POU/POE Products

Certified POU/POE treatment devices will remove specified inorganic chemicals, SOCs, radium, and other radionuclides that present a health concern. Only POE treatment devices are certified for the removal of microbials and VOCs that pose a health concern. The following subsections describe how commercially available products perform with respect to arsenic, radium, and microbial contaminants.

Arsenic

Both organic arsenic (V) [arsenate] and inorganic (arsenite) forms of arsenic can be removed sufficiently by distillation systems to meet NSF/ANSI Standard 62. However, RO devices are certified under NSF/ANSI Standard 58 only for arsenate. Any POU/POE treatment device used to remove arsenate would not be regenerated, and therefore, disposal would eventually be required.

Radium

About 30 companies that make about 150 POU products using RO have been certified by NSF for radium reduction. However, there is no current protocol in Standard 53 for radium and no protocols in any of the standards for other radionuclides at this time. As stated earlier, the CX POE unit is NSF/ANSI certified for removal of radium.[11]

Microbial Issues

Several studies have been performed recently to investigate POU/POE devices for various purposes, including homeland security. The following is a synopsis of several studies conducted under EPA's Environmental Technology Verification program (***http://www.epa.gov/etv)*** with regard to the response of commercially available products to microbial and chemical challenges.[33]

Microbial challenge testing was completed[33] at the NSF facility in Ann Arbor, Michigan, in the latter part of 2004 for three POU products currently on the market. Each manufacturer submitted ten units for testing. These were split into two groups of five. One group received 25 days of conditioning prior to challenge testing, while the second group was tested immediately. The two groups were identically challenged. The challenge organisms were the bacteriophage viruses fr, MS2, and Phi X 174 (ranging in size from 19 to 25 nm), and the bacteria *Brevundimonas diminuta* and *Hydrogenophaga pseudoflava* (0.1 to 0.2 µm). The test units were challenged at two different inlet pressures, 40 and 80 psi, gauge (psig). The virus challenges were conducted at three different pH settings (6, 7.5, and 9) to assess whether pH influences the performance of the test units. The bacteria challenges were conducted only at pH 7.5. The objective of the testing was to determine whether a 6-log reduction in viruses and a 5-log reduction in bacteria could be achieved. All the units were challenged without sediment or carbon filters in place to eliminate the possibility that these filters could temporarily trap a portion of the challenge organisms, causing a positive bias in system performance.

All the units performed better when tested after 25 days as opposed to being tested under virgin conditions. The best-performing unit consists of 5 stages (prefilter, RO membrane, a virus filter, an SBAC filter, and a microfilter), with a storage tank between the virus filter and the SBAC filter. Another product consists of a GAC prefilter, RO membrane, a storage tank, and a GAC final filter. The third product consists of five stages: a sediment filter, two SBAC filters, an RO membrane, and a final SBAC filter. (After the water passes through the RO membrane, it is sent to a product storage tank before the final filtration step.)

Preliminary conclusions regarding the testing of these units with microbial agents were:

- POU devices that rely on RO can offer significant protection against biological agents.
- Variation in performance was observed among the units of the same manufacturer and when the units of each manufacturer were cross-compared.
- Conditioning improves and/or stabilizes RO membrane performance.

- Filtration of viruses and bacteria may be more effective at higher pressures.
- Additional research and testing are needed.

Chemical Contaminants

The same three products that were microbially challenged are currently being subjected to testing of 14 chemicals that include heavy metals (cadmium, cesium, mercury, and strontium), pesticides (aldicarb, carbofuran, dicrotophos, dichlorvos, fenamiphos, mevinphos, oxamyl, and strychnine), and other organic substances (benzene and chloroform). The testing protocol is to first condition each unit for 7 days with water that does not contain the 14 chemicals. Next, each unit is tested for all four metals at once and then one organic chemical at a time at an inlet pressure of 50 psig, using only the RO component of the device (prefilter, post-filter, and GAC are all removed). Next, the carbon filter of each unit is challenged for only those chemicals that were not removed by the RO membrane within one order of magnitude of the EPA MCL, if one exists (if not, professional judgment was used to determine whether carbon challenging would occur). The challenge test period was 15 hours. Completion of testing is anticipated by the third quarter of 2005.[33]

Preliminary conclusions regarding the testing of these units with chemical agents were:

- Variation in performance was observed among the units of the same manufacturer and when the units of each manufacturer were cross-compared.
- RO membranes maintained rejection of chemicals over an 8-hour rest period.
- POU devices using RO membranes and high-quality post-membrane carbon filters can offer significant protection against chemical contaminants.

More long-term testing of these units is planned, including the testing of a membrane-impregnated GAC device. In addition, testing of POE devices that are not characterized as "off-the shelf" products was planned to begin at the NSF facility in the spring of 2005 and is expected to last three months. This shorter test period is expected because test plans are already in place and because of the experience of testing the POU units. The POE systems will consist of prefiltration, RO, and carbon filtration. They will be challenged first with microbials and then chemicals. The POE testing may involve some variation in that additional chemicals may be used in the challenge.

Mobile Treatment Technologies

Most of the mobile treatment units described below have not been purposefully demonstrated to remove chemical, biological, or radiological contaminants of water security concern. However, they have demonstrated success for purifying water under natural emergency conditions and for use in military applications. For example, the Federal Emergency Management Agency can deploy mobile units called Reverse Osmosis Water Purification Units (ROWPUs) to provide potable water at a rate of about 300 to 480 gallons per hour (gph). The Department of Defense (DoD) has ROWPUs that can produce potable water at an average rate of 600 gph. (The actual rate of potable water production is dependent on the temperature and salinity of the feed water.) These units include a 3,000-gallon capacity tanker to haul non-potable feed water, a generator, and a pump to overcome elevation changes. While the 600-gph ROWPU units are the ones most commonly used in DoD's inventory, there are also some other ROWPUs that produce 3,000 gph and still larger ROWPUs that have a maximum capacity of 150,000 gph. A review of national programs for mobile treatment units is among the objectives of a current EPA and Army Corps of Engineers study regarding alternative water supplies for consideration by utilities in an emergency.[34]

Next Generation ROWPU-Type Units

The next generation DoD ROWPUs are called Tactical Water Purification Systems (TWPS). TWPS also produce 600 gph and are still being field-tested. The Office of Naval Research's (ONR's) Expeditionary Unit Water Purification (EUWP) system has already manufactured a mobile treatment unit based on ultrafiltration and RO technology and is developing an improved version that is expected to have a higher production rate and can be used to treat seawater and brackish water.[34]

Technical Support Working Group (TSWG) Project

A mobile POE treatment device has been developed as a Technical Support Working Group (TSWG, ***http://www.tswg.gov***) project by an engineering firm (***http://www.RAScoEngineers.com***), which is also the vendor. This project has progressed from concept to bench-scale to prototype and is now ready for deployment. The unit uses commercial off-the-shelf technology and has a treatment train that consists of carbon filtration, RO using multi-element modular vertical membranes, ozonation, carbon polishing, and chlorination. It has a control system that monitors for TDS, oxidation-reduction potential, pH, and chlorine, and the control system has the ability to interface with other supervisory control and data acquisition systems. These units are also scalable in terms of the physical size of the unit and finished water output and can be readily configured for either built-in, skid-mounted, or trailer-portable applications. It was also reported as scalable from about 20 gpm to 2 mgd and can be leased from the manufacturer.[28]

The manufacturer claims that this technology is capable of removing very high concentrations of diverse chemical and biological agents as well as levels of certain types of dissolved radionuclides and suspended radioactive particulates. This unit successfully met a very rigorous TSWG test protocol and has reportedly been tested with actual contaminants of concern that include military grade weapons agents (e.g., VX), industrial (e.g., cyanide) and agricultural chemicals, hallucinogenic drugs, and viruses. While there are data reports showing how water quality monitor fluctuations served as indicators of contamination, EPA has not yet reviewed these data. Disposal of wastewater that may be contaminated was recognized as an issue. One means of addressing this potential issue is to have a holding tank to which the contaminated wastewater can be conveyed until it is confirmed that the contamination event has ended.

Potential Water Security Role of POU/POE Devices

2

If the public is asked not to drink or use the water, a water utility should consider provisions for an alternate drinking water supply. A discussion of issues surrounding the provision of alternative water supplies, either through direct or indirect means, is provided in EPA's Response Protocol Toolbox, downloadable at ***http://www.epa.gov/safewater/watersecurity/pubs*** and summarized in Magnuson, et al.[35] In terms of providing water directly to consumers, options for consideration include bottled water, packaged treatment plants (i.e., POE treatment), and POU/POE treatment devices.

The following section specifically discusses topics that include administrative planning and optimal design associated with POU/POE usage in water security applications. It then describes the potential roles of these devices in both a proactive mode, i.e., being placed before a contamination incident, and in a reactive mode, i.e., in response to a contamination incident. In the latter, their use could occur during an incident and also during remediation and recovery. The costs associated with the use of these devices in both modes are presented, along with considerations surrounding POU/POE devices after a water contamination incident. Finally, benefits and limitations of these devices from a water security perspective are summarized.

It is not the purpose of this section to exhaustively compare and contrast all means of providing alternative water supplies; however, it is worth mentioning that although bottled water can play a role in response to an incident, POE treatment is a more comprehensive response action. Unlike bottled water, it can continually meet other water-related needs over time such as cooking and bathing. Also, POE treatment would enable the continued operation of hot water heating systems and the potential use of water pumps to operate standby electrical generators. Furthermore, while bottled water is regulated by the U.S. Food and Drug Administration, which has established allowable levels for its microbiological (e.g., allowable coliform levels), chemical (more than 70 substances), radiological (e.g., radium-226 and radium-228 radioactivity), and physical (e.g., turbidity and color) quality,[36] this product is seldom tested for parasites such as *Cryptosporidium*.[37]

Administrative Planning for Possible POU/POE Usage

To maximize the effectiveness of POU/POE usage during a water security response, there are several administrative challenges and issues. Some of these are listed below, although others may exist, depending on the situation.

- Identifying manufacturers and types of devices, as well as their locations and delivery time
- Evaluating the ability of manufacturers to ramp up production of devices if needed
- Factoring in user plumbing configurations and climate conditions
- Determining unit costs for delivery and installation
- Catagorizing devices with respect to effectiveness against a given contaminant or class of contaminants
- Indicating the performance capability with regard to utility water characteristics, where feasible
- Defining the skill level needed to install and maintain devices if implemented
- Determining installation time (typically, about 1 hour for POU units and 3 to 24 hours for POE units)
- Comparing time requirements for POU/POE implementation with respect to other strategies

Optimal Design Features of POU/POE Devices for Water Security Applications

Because the type of contaminant threat can be so variable and unpredictable, a combination of treatment technologies would be most successful. There are limitations against some types of contaminants when using RO, GAC, UV light, or distillation alone. However, combining RO with GAC, for example, can offer a more effective approach. In some cases, if the contaminant or contaminant group (e.g., VOC or biological) is well identified, a single technology might be sufficient. Some desirable characteristics for these units identified by AwwaRF include:

- having greater than 99 percent removal efficiency for chemicals and greater than 3-log reduction for microbial agents
- remaining sound mechanically and maintaining a consistent performance level over time, despite variations in intake water characteristics
- exhibiting a high level of quality assurance/quality control by the manufacturer to ensure confidence by many users
- signaling either by sounding an alarm or by shutting down when the unit no longer can achieve desirable removal efficiencies (e.g., if GAC breakthrough has occurred)
- being easy to install and maintain to encourage continued use
- having the ability to obtain performance certification
- being readily available and relatively inexpensive
- demonstrating an acceptable level of performance under real-agent exposure conditions[10]

The final characteristic can be accomplished via extensive testing using actual contaminants of concern.

POU/POE Treatment in a Proactive Role

For proactive scenarios, the POU/POE treatment devices could be used by consumers voluntarily with the expectation that the devices can provide a protective barrier if contaminants enter the distribution system. A caveat for the installation of POU/POE treatment devices in a proactive manner is that without knowing what the contaminant is, it is virtually impossible to anticipate what specific type of device (e.g., RO, GAC) should be used and what level of effectiveness can be expected.

One type of proactive scenario discussed in the AwwaRF study involved the installation of POU and/or POE treatment devices at highly vulnerable or potentially targeted locations (e.g., hospitals, schools, sports stadia, military bases, government buildings, airports) and/or at facilities that would be involved with immediate response actions (e.g., police and fire stations). For this type of scenario, POE treatment using a treatment train approach would be more cost effective than POU treatment because of the large volume of water being treated and the large number of taps that would need to be protected. Since the volume of water needing treatment could be thousands to tens of thousands of gallons per day, the size and extent of the treatment train for potentially targeted facilities could be comparable to that of a small- scale or packaged water treatment plant.[10] Additionally, more than one POE unit may be employed in a high-asset building where there are multiple tenants (e.g., one that is used for national communications/command/control and intelligence) and where there is public access, so that the entire building is provided protection at the point of entry. The redundant unit could provide additional protection in a particularly sensitive area of the building (e.g., a building with a regional command post for emergency response operations) and could provide an additional layer of protection against the introduction of contaminants of concern from within the building's water distribution system.

For cases in which a gap exists between current sub-par security conditions and an acceptable level of security, POU/POE treatment could be provided by the utilities for their users as an interim measure. Similarly, the central treatment plant may have a tenuous record of meeting the drinking water needs of its users under nonthreat conditions. In a related scenario, the public water supplier may decide that users should be provided with POU and/or POE treatment devices because of high vulnerability concerns that surpass the expectation of the utility's ability to address a contamination incident at the central treatment plant. In another scenario, there is a warning of an imminent risk and subsequently these devices are used to provide protection in anticipation of the impending incident. In this case, POU treatment devices would have to be distributed in sufficient quantities, encompass a sufficient area, and contain the most appropriate treatment capabilities that are commensurate with the threat.

POU/POE Treatment in Response to a Contamination Incident (Reactive Mode)

There are several conventional actions that water utilities could take in response to suspected or confirmed drinking water contamination. These actions include system flushing, hyperchlorination, temporary use of bottled water, a boil advisory, and a "do not use" order. A comprehensive set of response actions can be found in EPA's Response Protocol Toolbox, downloadable at ***http://www.epa.gov/safewater/watersecurity/pubs*** and summarized in Magnuson, et al.[35] The specific response actions should be implemented according to the needs of the situation at hand. In one case study, a distribution system serving about 30,000 people was compromised by a chemical that resulted in turbidity, taste, and odor problems. The public health department set strict remediation levels, and it took nine months for these to be achieved. During that time, water was brought in by trucks or distributed as bottled water, and bulk water was made available at certain locations for sanitary use. While ingestion was prohibited, showering and bathing could occur because there were no dermal or inhalation concerns. The utility remedied the problem by system flushing using heated water, and the discharge was allowed to go to storm sewers.[10]

Each of these conventional response actions has limitations. For example, while utilities can be experienced in flushing their systems for maintenance purposes, this approach has limited utility if contaminants have been introduced because a flushing pressure may not be forceful enough to reach those sections of the distribution system that have been impacted. It also may be necessary to continue the flushing action for months. For some contaminants, it may be necessary to physically scrape or even replace affected piping. Although hyperchlorination at an appropriate pH would be effective against some microbial contaminants and could render other potential contaminants less toxic (e.g., converting cyanide to cyanate), other contaminants would not be affected, and chlorination byproducts, albeit short-term, would result. In addition, the taste and odor of the water would not be as pleasing to the consumer. While a "do not use" order could allow continued water usage for sanitation and firefighting purposes, it would be necessary to bring in bulk or bottled water to meet drinking, bathing, cleaning, and cooking needs for the impacted community.[10]

General Considerations

In order to properly instruct the public on what type of POU or POE device to employ, ideally the likely contaminant would be identified. Other factors affecting the decision to use these units in an emergency would be the availability of the devices; complications associated with initiating the purchase of the units, which may involve procurement obstacles; the logistics of getting them to the public being impacted; and the identification of which segments of the public should be outfitted first. With regard to procurement complications, the SDWA (provision 42 USC Section 300i and Section 300j; ***http://ehso.com/ehso.php?URL=http%3A%2F%2Fwww.epa.gov/region5/defs/html/sdwa.htm***) does give the EPA Administrator and other public health officials emergency powers to respond to situations of "imminent and substantial endangerment to health." For example, one type of response could include the expedited purchase and distribution of treatment equipment such as POU or POE devices.[10] Concurrent with these decisions would be operation and maintenance considerations, the anticipated level of performance of the devices, and an overall management of their use during the emergency. Once implemented, continued use of POU/POE treatment may be appropriate until the situation has been abated either through successful decontamination of the

The SDWA (42 USC 300i) states that "notwithstanding any other provision of this subchapter, the Administrator, upon receipt of information that a contaminant which is present or is likely to enter a public water system ... or that there is a threatened or potential terrorist attack (or other intentional act designed to disrupt the provision of safe drinking water or to impact adversely the safety of drinking water supplied to communities and individuals), which may present an imminent or substantial endangerment to the health of persons, and that appropriate State or local authorities have not acted ... the Administrator may take action that is deemed necessary to protect the health of such persons."

water supply or through a connection to an alternative drinking water source. POU treatment devices can also serve as a polishing step when decontamination is in its final stages but is not yet totally complete.

Since some POU treatment devices can be easily installed, they offer a relatively rapid response alternative that would provide at least some protection during an emergency, even if the contaminant has not yet been identified and continues to impact the system intermittently. For example, there are faucet-mounted RO/GAC units that are certified to meet ANSI/NSF Standard 58 and can be installed by a homeowner in minutes. For an emergency affecting a small area of the distribution system, a utility could have a sufficient number of these units on hand for distribution, subject to the limitations below. This type of device can be effective against metals, salts, cysts, etc. and can provide about eight gallons of water per day. Therefore, water beyond what is needed for daily drinking can be treated and stored to meet longer-term needs. The limitations of this strategy would be the costs to maintain this inventory and possible lack of consumer confidence in the unit's performance ability, since the type of unit in the inventory may not be effective against the actual contaminant used.

Mobile treatment units could be employed in response to a contamination incident or if service has been interrupted, as they have been in past flood emergencies. However, their effectiveness would be uncertain since they have not been tested against potential contaminants of concern, with the exception of the TSWG mobile product (see page 21). Also, the implementation of ROWPUs for a security-related application may be problematic since many of the units are now deployed in Afghanistan and Iraq, these units are aging, and there could be a logistical challenge as many of the remaining units are not located near large population centers. Some of the availability constraints may be met by the private sector, although the uncertainty regarding removal of contaminants of concern would remain. For example, one manufacturer can provide trailer-mounted units that treat the water by means of demineralization, softening, filtration, RO, and chemical decontamination. According to this manufacturer, a temporary service can be established within 36 to 72 hours, with flow rates of 500 gpm for raw water and 200 gpm for seawater. Other companies also meet similar treatment needs: desalination units that treat at a rate of 1,300 to 500,000 gpd and ultrafiltration units that can remove 0.1 μm particles. One company claims it can provide emergency water by ultrafiltration at 1.67 MGD.[34]

Specific Scenarios for Reactive POU/POE Implementation

In one scenario, a contaminant has been intentionally introduced into the distribution system such that it continues to leach slowly over time. Examples would include substances with high octanol/water coefficients that could be difficult to dissolve away from the inside surfaces of distribution piping and microbial contaminants that could colonize these surfaces. Response actions would first involve investigation and precautionary measures and then likely flushing and hyperchlorination. Depending on the level of concern, a boil advisory or a do-not-use order may be issued, in accordance with the SDWA's Public Notification Rule (40 CFR Parts 9, 141, 142, and 143; ***http://www.epa.gov/safewater/pws/pn/pnrule.pdf***) , which requires water utilities to inform the public when NPDWRs have been violated or when there is a risk to public health. Once contamination is confirmed, the utility could elect to bring in bottled water or a mobile treatment unit or begin to evaluate the implementation of POU/POE treatment as a supplementary step.

In another scenario, the central treatment system has been contaminated and there is no available dependable bottled water source or the contamination has migrated beyond the point where conventional treatment means can be effective. For this case, POU/POE treatment offers a means of protection until the central treatment system is brought back on line.

Finally, there could be a decision on the part of a homeowner to use POU/POE treatment at a location within the distribution system during the final stages of cleanup, even though the water is deemed safe to drink. Similarly, after the cleanup has been completed, the homeowner may continue to use POU/POE treatment because he or she is not convinced that the water is safe to drink. While the use in these scenarios would not be mandatory from a utility's or EPA's perspective, POU/POE implementation could be driven more by perception of what is safe to drink than by what is deemed safe to drink based on post-incident evaluations of the drinking water supply.

Monitoring and Forensics Roles

As technologies capable of detecting specific contaminants or contaminant groups continue to develop and become more sophisticated, incorporating this feature into POU treatment devices used by consumers at various locations throughout the distribution system may provide a means for improving the ability to minimize the effects of a distribution system incident. Another potential role for these devices involves examining them from a forensics perspective after an incident to determine the cause of the contamination. A current AwwaRF study is testing various extraction techniques and methods that would simultaneously elute bacterial, viral, and parasitic agents from GAC POU devices. Specific microbial contaminants undergoing extraction tests include *Escherichia coli*, *Bacillus subtilis*, bacteriophage PP7, and the MS-2 virus. The results of this study are expected by December 2005.[7]

Practical Considerations for Widespread POU/POE Use

The available inventory of POU and POE treatment devices will be one factor in considering widespread use, either proactively or reactively. The current supply of POE units is insufficient to protect all potentially vulnerable assets and facilities. Another factor is the need for a backup energy supply to enable continued operation of the unit during an emergency. A third factor is the need for skilled personnel to operate and maintain these units. A final factor has to do with potential liability concerns for a water utility if the units fail due to problems beyond the utility's control.

With regard to response time, the need to mobilize a large number of units and trained personnel during an emergency can make the widespread implementation of a POU or POE installation program impractical when potential impacts from contamination are imminent, except in very small communities or if only a small portion of the distribution system has been affected. The reasons for the time delays include limited product inventories, limited skilled installers, complex logistics, and limited production capacity. For example, it can take between one and two weeks to protect a community of 1,000 homes with properly installed under-the-faucet type devices; in communities of 10,000 homes it may take substantially more time. Assuming inventory and logistics are not constraining factors, the time delays can be shortened by supplying residents with pitcher filter-type devices if it is determined that such devices will be effective against the contaminant(s) of concern. While skid-mounted POE devices could arrive at a vulnerable facility or residence within a matter of hours, the same issues regarding inventory, installation, production capacity, and logistics limit response actions at a multitude of facilities or residences.

There are some other factors that could affect widespread use. If the EPA were to advise the use of POU treatment as a response action, there also could be liability assumed by the Agency. This liability would have to be weighed against the percentage of those likely protected by the order to use the devices. On a case-by-case basis, the Agency would have to decide whether the potential liability risk was worth taking. In addition to liability concerns, there are quality control (QC) concerns. Because the performance among devices from the same manufacturer may vary, this uncertainty may affect a decision to distribute a large number of units from the same manufacturer in response to a biological contaminant where there could be little margin for error. Depending on what is known about the contamination incident, such QC concerns may factor into determining whether a certain type of POU device should even be employed as a response action.

Potential Implementation of POE Treatment in a Reactive Decontamination Role

The portability and capability for modification and adaptation make mobile POE treatment technologies applicable for collecting and rendering safe many types of chemically, biologically, or radiologically contaminated "wash-off" or "hose-down" water. Such contaminated water is typically created when clean, safe water is employed to remove external contaminants from affected citizens, emergency responders, equipment, vehicles, and/or buildings, facilities, and infrastructure. In instances when only contaminated water is available, these portable units could produce safe and clean "wash-off" and "hose-down" water, as well as volumes of safe emergency drinking water for affected citizens and emergency responders. This practice would reduce the volume of contaminated water requiring additional, specialized treatment. Use of these mobile units, therefore, could reduce both the volume and the transportation and disposal costs associated with the disposal of decontamination water containing contaminants of concern. Because of post-treatment contaminant leaching concerns, use of these devices in association with decontamination efforts could still necessitate eventual disposal of components or the entire system once the POE device nears removal capacity or when the contamination event has ended.[10, 13]

Post-Incident Considerations for POU/POE Treatment Devices

Disposal Considerations and Residuals Management

Disposal costs for POU/POE devices under normal operating conditions (e.g., neither proactive nor reactive terrorist-related use scenarios) are typically negligible because of the small size and volume involved. They represent a small contribution to the overall waste stream as media and resins are usually taken for disposal along with household garbage or may be taken off-site by vendors for regeneration (as in the case of GAC filters).

The Action Plan[3] recognizes the need for an evaluation of the ultimate disposal of POU/POE treatment devices that have become contaminated with chemical, biological, or radiological material. The waste material would include media, resins, distillation residuals, and the solid surfaces of the devices that come in contact with the incoming drinking water stream. Although residuals generated in residences are exempt from federal regulations such as the Resource Conservation and Recovery Act (RCRA), state and local regulations could determine that the residuals are hazardous. (For example in California, media that now contain arsenic removed during treatment may fail a Waste Extraction Test.) For POU/POE devices installed in commercial or business operations, the waste products would be exempt from RCRA if the mass generated did not exceed 100 kilograms per month. In the case of liquid wastes generated by POU and POE treatment devices that incorporate RO or IE in the overall treatment train, disposal may be allowed at publicly owned treatment works (POTWs) upon approval by plant operators, via an on-site septic system subject to a permit requirement from a state or local agency, or via an injection well, provided the wastes do not exceed 60 pCi/L of radium-226 and radium-228 and 300 pCi/L of uranium. Some states may have additional restrictions for disposal of radioactive wastes.[13]

However, because of the toxicity and uncertainty about fate and transport associated with many contaminants of concern, state and local authorities might not allow disposal of solid wastes in a sanitary landfill or liquid wastes to be discharged to a POTW, nor is it likely that impacted media would be regenerated or recycled. Therefore, an operating assumption regarding disposal costs is that the devices would have to be taken to a hazardous waste disposal facility or secure landfill.

The cost components would consist of a disposal fee (i.e., based on the weight of the POU/POE units) and the cost of transportation (i.e., based on the distance to the disposal site). A second operating assumption has to do with the transportation cost, which will depend on the proximity of the disposal site. For estimation purposes, assume that the average disposal cost, including transportation, at a hazardous waste disposal facility is $500 per ton (i.e., $0.25 per pound) and that POU devices range from 10 to 20 pounds, while POE units range from 100 pounds at a residence to 1,000 pounds at a potentially targeted facility to 10,000 pounds for a military base. Given these assumptions, the unit cost for disposal as hazardous waste for POU treatment devices will vary from $2.50 to $5.00. (Also, given the relatively small size of these devices and the concern that residues may leach out after a terrorist incident has ended, decontamination is not likely to be considered an option.) POE unit disposal costs will vary from $25 to $250 in most cases and $2,500 for those from large facilities.[38] If the device is contaminated with a radioactive material, the disposal cost could increase by a factor of 10 or more.[39]

Liquid wastes are generated by POU and POE treatment devices that use RO, IE, and possibly GAC as well if there is a backwashing feature. In these cases, it is unlikely that conventional disposal options would be considered during an intentional contamination incident. There could also be additional costs associated with impacts to indoor plumbing and the sewerage conveyance system by wastewater containing contaminants of concern (see next section). If a POE product has the ability to detect a potential contamination incident, theoretically it could divert this wastewater to a holding tank. It is assumed that this diverted waste would be considered hazardous, with a disposal cost ranging from $5 to $10 per gallon.[38] Again, if the liquid waste is radioactive, the disposal cost could increase by a factor of 10 or more.[39]

Decontamination Study of Post-Service Connections

There is a current project that has some relevance to the feasibility of decontaminating a POU or POE treatment device as an alternative to disposal. The National Institute for Standards and Testing is conducting a decontamination study regarding post-service connections that include small pipes within a building or residence and appliances such as hot water heaters, water softeners, water filters (e.g., POU and POE treatment devices), dishwashers, clothes washers, and ice makers. The project goals are to determine contaminant accumulation rates in various appliances and develop a predictive model, and to develop decontamination methods for various potential contaminants that will help facilitate the restoration of a water supply system.[40]

Costs of POU/POE Devices

Reactive Scenario

For comparison purposes, the installation costs shown below apply to implementation of these devices in response to a water security incident and typically do not include those costs associated with training installers or any overall project management. While additional costs (e.g., those associated with monitoring) could be incurred as these devices are being used during an emergency, the costs below assume a brief period of use and then removal and disposal.[10, 16, and 29]

The following are basic assumptions leading to the cost estimates (in 2005 dollars):

- EPA and the AWWA have estimated a per capita consumption rate of water from POU treatment devices of 1.3 gpd, with a peak of 0.5 to 1 gpm. Given an average per capita use of water per average household, POE units would treat about 165 gpd, as well as meeting peak demands of 5 to 10 gpm.
- Discount rates for a large number of units may apply (potential volume discounts, which are not reflected below, can achieve cost reductions of about 30 to 50 percent); however, the bulk discount rate may be offset by costs associated with increased demand during an emergency.
- Because of the uncertain cost adjustment associated with a potential markup during an emergency, the costs shown below do not include such a markup and are intended only to provide a basis of comparison for their implementation in response to a contamination event.
- From a treatment train perspective, assume the RO units are comparable to the one shown in Figure 5. However, because of potential dermal, inhalation, and nonprotected tap concerns, the maximum benefit would be realized by using this combination at the point of entry.
- Installation costs for POU/POE units can vary depending on whether extensive carpentry or electrical work by licensed professionals is necessary. In general, it is assumed that POU units will be installed at one tap per household and POE units will be installed inside of the house or facility being serviced. Installation generally adds from $50 to $150 to the purchase cost (units with UV are twice as expensive to install); the installation time for an RO/carbon tap-mounted unit is minimal and the technology can treat 10 gpd. The installation time for an RO/carbon under-the-sink device is 1 to 2 hours. This technology can treat 10 to 40 gpd. The installation time for a UV POE device is 1 to 2 hours and this technology can treat about 8 gpm.
- For the costs shown below, a 10 percent general contingency factor is included.

Purchase and installation costs for various home POU and POE devices:[10, 14, 16, and 29]

- RO POU units (no UV capability): $400 to $750
- RO POU units (with UV capability): $600 to $950
- RO/GAC units (faucet-mount): $50
- RO/GAC units (under-the-sink): $300
- RO POE: $5,000 and $20,000
- UV POE: $1,000
- Specialty media for arsenic removal POU units (NSF certified units are more costly): $300 to $650
- CX POE: $3,300
- GAC POU end-of-faucet (no UV capability): $10 to $30

- GAC POU under-the-sink units (no UV capability): $500
- GAC POU under-the-sink units (with UV capability): $750
- GAC POE (with UV capability): $3,000

The cost of renting an RO POU unit (with no UV capability)is $20 per month. This includes installation, operation and maintenance, and contingency costs.

Mobile treatment unit cost:[34]

In emergency situations, there are commercial mobile treatment units available that incorporate technologies similar to the ROWPUs. An approximate cost to provide adequate treatment at a rate of 500 gpm using primarily an RO system would be about $10,000 for setup and an additional $1,500 to $3,000 for each day of operation.

Proactive Scenario

The costs for maintenance and replacement of parts apply to a proactive use of these devices. For example, maintenance/part replacement costs likely will occur after one year for RO faucet-mounted units and UV POE devices and after two to four years for RO under-the-sink units. An additional 25 percent in installation costs should be added to the costs shown above if the units are deployed proactively to account for permitting, pilot-testing, and legal and engineering costs.[16, 29] Additional proactive scenario costs are as follows:

Maintenance:

- The annual operating and maintenance costs for RO POU units, including labor and replacement parts, can range from $150 to $250 per year, depending on whether UV is included and whether there would be volume discounts.
- The annual operating and maintenance costs for specialty media POU units, including labor and replacement parts, can range from $100 to $150 per year as the replacement cycle can be from 12 to 24 months.
- The annual operating and maintenance costs for CX POE units consists primarily of biannual salt delivery for regeneration and radium monitoring. The estimated cost is about $200 per year.
- The annual operating and maintenance costs for GAC POU units, including labor and replacement parts, can range from $200 to $300 per year, depending on whether UV is included, whether the cartridges are replaced annually or biannually, and whether volume discounts would apply.

Monitoring and laboratory analysis:

If the units are being used solely by homeowners as a proactive step because of homeland security related concerns, no monitoring or analysis is necessary. However, if the units also are being used to meet federal requirements, the utility must test the POU/POE units annually to ensure compliance with the NPDWR. After the first year, one third of all units would be sampled each year.

Total amortized costs at 7 percent for a 10-year life expectancy (proactive, household use only):

- $200 to $400 for RO POU units
- $200 to $300 for rented RO POU units
- $150 to $250 for specialty media POU units
- $75 for pitcher filters
- $100 to $150 for GAC units (under-the-sink)
- $600 to $650 for CX POE units
- $250 to $300 for rented GAC POU units without UV
- $350 to $400 for rented GAC POU units with UV

Large Facilities and Institutions:

Refer to Table 1 for a comparison of approximate capital and annual operating and maintenance (O&M) costs for different POE treatment technologies. While MF/UF and RO/UV/GAC offer the greatest protection against the largest variety of potential contaminants, all four treatment systems have limitations against certain contaminants. Therefore, costs must be weighed against the desired level of protection.[10]

Table 1 Comparative POE Treatment Costs at Large Facilities/Institutions[10]

Average flow, gpd	RO	GAC/UV	MF/UV	RO/UV/GAC
	Capital/O&M	Capital/O&M	Capital/O&M	Capital/O&M
50,000	$350,000/$40,000	$250,000/$20,000	$600,000/$40,000	$550,000/$40,000
100,000	$500,000/$50,000	$350,000/$25,000	$750,000/$50,000	$800,000/$50,000
250,000	$900,000/$85,000	$600,000/$40,000	$1,200,000/$80,000	$1,400,000/$75,000
500,000	$1,500,000/$125,000	$1,000,000/$60,000	$2,000,000/$100,000	$2,000,000/$100,000

Benefits and Limitations Associated With the Implementation of POU/POE Treatment for Water Security

POU/POE treatment devices can contribute to increased water security, subject to the circumstances of the water security concern and the limitations described below. The type of contaminant a terrorist might use cannot be known ahead of time, but the use of POU/POE treatment can serve in a protective role. When one of these technologies is being used for other reasons (e.g., aesthetics or to address a specific problem with the finished water), there could be an added, serendipitous security benefit if the device happens to be effective against the contaminant that was introduced into the distribution system. In addition, consumers may feel that by using these units, they have taken an action to increase their security against an intentional act. This sense of empowerment can also be a motivating force for using these devices in the first place.

In addition to the water security benefits described in "Benefits/Applicability of POU/POE Treatment," POU/POE treatment may have some collateral beneficial effects not necessarily related to protecting against intentional contamination of the distribution system. In one example, a microbial filter POU was used solely in the intensive care unit of a hospital to protect burn patients from opportunistic pathogens. In a more detailed evaluation, studies in Canada involving RO devices[10] and Milwaukee involving sub-µm filters and/or RO devices[37] indicated that there was a reduced incidence of gastrointestinal disease for homes that had POU treatment compared with those that did not. However, another study in the Davenport, Iowa, area did not show a significant benefit.[41] The lack of benefit in the Iowa study may be attributed to the fact that the subjects did drink water away from home and may have been exposed to pathogens in food, water, and other sources; therefore, it is possible that any true benefit from the active POU device was too small to be detected, especially if the municipal treatment plant was already providing safe drinking water.

Benefits/Applicability of POU/POE Treatment

Based on the discussion of POU/POE devices in this document, the benefits/applicability of POU/POE treatment can be summarized as follows:

- For certain contaminants, POU/POE treatment devices can serve a proactive role and perhaps be protective of human health.
- In an emergency situation, POU devices can reduce human exposure associated with chronic/subchronic effects caused by contaminants, even though these devices would not offer total protection from acute contaminants and all exposure pathways, particularly those other than ingestion.
- POE devices using RO plus GAC plus UV represents a promising technology combination for a large number, albeit not all, contaminants of concern.
- POE devices may be desirable as a means of protecting vulnerable or potential target facilities both proactively and also by reacting to a water

contamination emergency involving these facilities.

- POU devices could serve as an interim measure until a water treatment system has been decontaminated or an alternative supply has been put into service.
- POU devices could serve as a polishing step during the final stages of water treatment system decontamination.
- For long-term distribution system leaching scenarios involving a contaminant that can cause chronic toxicological and/or aesthetic effects, POU/POE devices may be appropriate.
- POU devices placed by utilities at critical points in the distribution system might play monitoring and forensics roles to either detect a contaminant or confirm a contaminant after the fact.

Limitations of POU/POE Treatment

The limitations of POU/POE can be summarized as follows:

- POU is not recommended in a post-contamination mode for infectious agents as these devices may slowly leach trapped, absorbed, or adsorbed contaminants over time. This effect is of particular concern for immunosuppressed individuals and other sensitive subpopulations.
- Nonpathogenic bacteria tend to accumulate in carbon POU devices and can adversely affect children and other susceptible individuals, especially when these devices are not well maintained.
- If POU rather than POE is used, the potential risk exists of using an untreated tap especially for an interval of time when a contaminant has been introduced but has not yet been detected.
- During a contamination incident, users of POU devices must be informed that only the faucet in their homes that is fitted with the POU device is to be used.
- Many POU/POE treatment devices are not effective against all possible contaminants. Choosing the appropriate device must be done carefully and would be assisted by accurate knowledge of the contaminant identity.
- There is limited historical information available on the performance of POU/POE treatment devices using chemical or biological agents or their simulants or surrogates.
- Except in small communities, widespread distribution of POU or POE devices that require minimal to several hours of installation time in a post-contamination mode may be too slow.
- POE treatment trains can be expensive ($5,000 to $20,000); POU devices generally cost $500 to $1,000 per unit, as discussed above.
- Widespread installation as a response action would likely not be done until flushing, hyperchlorination, and the use of bottled water were deemed impractical or inadequate.
- Bottled water may offer a higher confidence alternative to consumers during an emergency incident but would not address other uses for water.
- Additional technicians and installers may be needed for possible widespread installation scenarios.

Conclusions and Recommendations

3

POU/POE treatment devices can provide some water security benefits, especially if selectively deployed. For example, POE treatment devices could be employed at certain high-risk or sensitive facilities such as hospitals, military bases, police stations, and fire stations. While widespread proactive use of POU treatment devices is not recommended, they could have a water security application under circumstances where a limited population has been affected, the type of contamination is well understood, and the POU treatment technology has demonstrated effectiveness against that type of contamination. Prefiltration, RO, carbon adsorption, and UV disinfection represent the most promising combination of technologies that will likely be effective against the vast majority of potential contaminants, especially during an acute incident.

The following short-term considerations should be taken into account when weighing the risks and benefits for the particular situation:

- Consider the installation of POE devices that use SBAC, RO, and UV for all facilities that would be of critical value during an attack (e.g., hospitals, fire departments, police stations) and all high-risk targets (e.g., government buildings, military bases).
- Continue the testing of POU/POE treatment devices against actual contaminants of concern. This testing will help inform the Agency and the public regarding which devices are effective in either a proactive or reactive manner.
- Compile and periodically update an informational database, reflecting the test results on the efficacy of each type of device against various contaminants. This information would provide guidance regarding the use of devices with the highest likelihood of success.
- Compile and periodically update an inventory database of manufacturers and distributors of various POU and POE treatment devices to include production capacity, number of devices and replacement cartridges in stock, delivery time estimates, and, where available, testing and certification status for contaminants or classes of contaminants of concern.
- Include a distribution plan as part of local emergency response preparation for POU treatment devices to provide short-term protection in the event an incident occurs in the community. This distribution plan would be dependent upon the informational database developed as part of the previous recommendation.

The following strategies should be considered but require further analysis to determine whether implementation of the strategy is to be recommended:

- Investigate whether POU devices may have some value being readily attachable to a faucet and being available for engagement by the homeowner once a warning has been issued about a potential or confirmed emergency. To prevent use of the device in non-emergency situations that would raise maintenance costs and concerns, there could be a carefully considered lockout feature.
- Consider the potential benefits of a proactive and random distribution of POU treatment devices from a post-contamination forensics perspective. If technology permits, there is the potential for these devices to provide sensing points for collection and transmission of water quality data in the distribution system, that could be part of a more extensive contamination warning system.
- Research the development of a consumer kit that could provide a bridge response action during an emergency. This kit would contain such items as different modular units employing various treatment technologies. For example, there would be a prefiltration module, an SBAC module, an RO module, and possibly a UV module as well. The kit would also include adaptors so that the modules could be properly attached to a faucet. The parts of the kit would not be used until the responsible authority specified what module or combination of modules should be used in

the short-term. Consumer use of the modules on a routine basis could be a drawback to this recommendation.

- Consider the implications of decontamination and disposal of treatment devices once they have served their purpose. Issues to consider include routine versus incident-specific use, the type of contaminant captured or retained, and the most effective methods for decontamination and disposal of the device and its contents.

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