FINAL REPORT

Management of Point-of-Use Drinking Water Treatment Systems

NATIONAL SANITATION FOUNDATION
ASSESSMENT SERVICES

MANAGEMENT OF POINT-OF-USE DRINKING WATER TREATMENT SYSTEMS

by

Gordon Bellen, Marc Anderson, Randy Gottler
National Sanitation Foundation
PO Box 1468
Ann Arbor, MI 48106

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Project Officer

Steven Hathaway
Drinking Water Research Division
Water Engineering Research Laboratory
Cincinnati, OH 45268

WATER ENGINEERING RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

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FOREWORD

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water systems. Under a mandate of national environmental laws, the agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. The Clean Water Act, the Safe Drinking Water Act, and the Toxics Substances Control Act are three of the major congressional laws that provide the framework for restoring and maintaining the integrity of our Nation's water, for preserving and enhancing the water we drink, and for protecting the environment from toxic substances. These laws direct the EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Water Engineering Research Laboratory is that component of EPA's Research and Development program concerned with preventing, treating, and managing municipal wastewater discharges; establishing practices to control and remove contaminants from drinking water and to prevent its deterioration during storage and distribution; and assessing the nature and controllability of releases of toxic substances to the air, water, and land from manufacturing processes and subsequent product uses. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

Treatment of drinking water at the point-of-use (POU) is under consideration as an approach to comply with the National Primary Drinking Water Regulations (NPDWRs). To effectively administer, maintain, amd monitor a system of POU drinking water treatment devices, an entity responsible for managing the system is required. This document addresses many of the issues a small community would encounter when considering such an approach to drinking water treatment.

Francis T. Mayo, Director
Water Engineering Research Laboratory

ABSTRACT

When public and/or non-public drinking water supplies become contaminated, it is often difficult to find an efficient, cost effective method for treating the water. Many small communities often lack the financial resources and technical expertise to solve such a problem.

One alternative solution which has been receiving more attention in recent years is treatment of contaminated water at the home, or point-of-use. While point-of-use treatment may present an efficient, cost effective solution to drinking water contamination, there may also be potential problems caused by this approach with the loss of control assumed for central treatment systems. When point-of-use treatment is the selected alternative, a sound program for management of point-of-use drinking water treatment systems is necessary to assure that all homes receive the desired quality of drinking water.

This document discusses steps which small communities should consider to implement proper installation and ongoing monitoring and maintenance of point-of-use treatment devices to assure public health and compliance with applicable regulations. Assuming that a water quality district is to be formed, the text outlines issues requiring consideration in management of point-of-use drinking water treatment systems.

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SECTION 1.

OVERVIEW

The Safe Drinking Water Act (PL 93-523) was passed in 1974 to ensure the public health of drinking water consumers throughout the United States by providing national water quality guidelines. Pursuant to the Act, the National Interim Primary Drinking Water Regulations (NIPDWRs) were established in 1975. The regulations apply to public water systems, which are defined in the Act as "systems of piped water intended for human consumption, regularly serving at least 25 people or having at least 15 service connections." This definition applies to both publically and privately owned water systems. "Regular" service is defined as service provided at least 60 days per year (1).

Both community and non-community water systems are considered public water supplies. A community system is one which serves at least 25 year-round residents or has at least 15 service connections supplying water to year-round residents. Non-community systems have at least 15 service connections or serve water to a daily average of at least 25 people, but generally serve transient populations. Examples of non-community systems include hotels, motels, restaurants, campgrounds, and some schools, churches, and factories.

The NIPDWRs established maximum contaminant levels (MCLs) for drinking water constituents having known health effects. The current MCLs include some organic and inorganic chemicals, radionuclides, and microbiological contaminants. The U.S. Environmental Protection Agency (EPA) is currently in the process of revising the NIPDWRs in efforts to establish National Revised Primary Drinking Water Regulations, under the requirements of the Safe Drinking Water Act. During the revision of the NIPDWRs, several groups of contaminants will be considered, including volatile synthetic organic chemicals (VOCs), synthetic organic chemicals (SOCs), inorganic chemicals (IOCs), microbiological contaminants, radionuclides, disinfection by-products, and other SOCs, IOCs, and pesticides not considered previously (2).

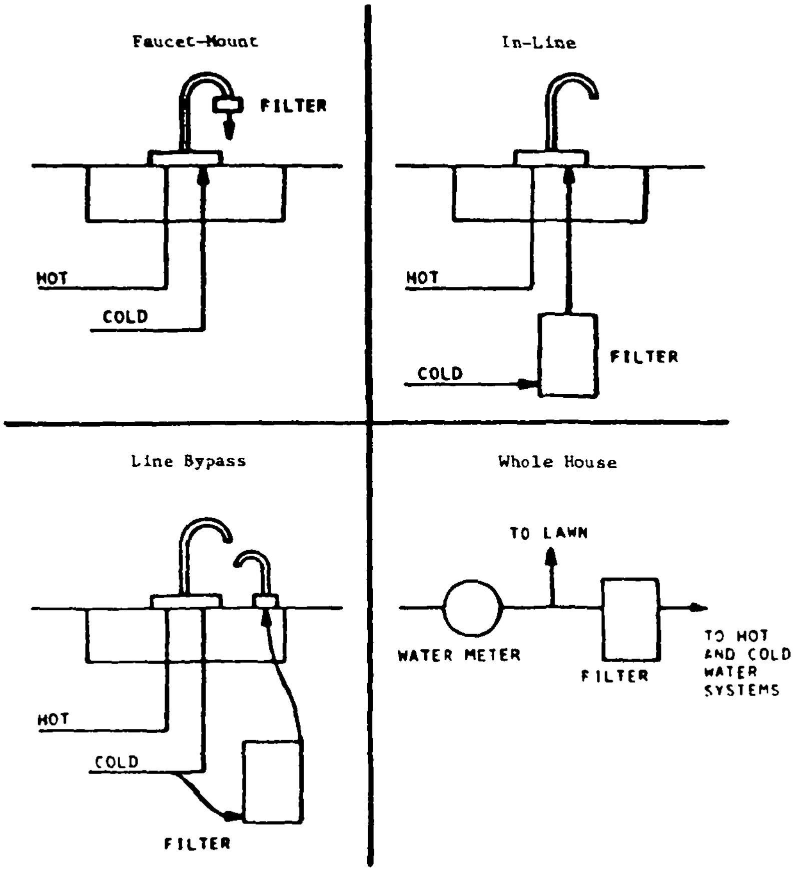
The Safe Drinking Water Act affects approximately 60,000 community water systems, 92 percent of which serve populations of 2500 or less (3). Many of these small systems are not in compliance with the MCLs, and face severe economic constraints associated with treatment of contaminated water supplies. The unit costs of constructing and operating small central treatment systems are very high. Compounding this problem is a lack of qualified personnel to operate small central plants.

Alternatives to treatment include developing a new well or surface water source, connection to a neighboring public water supply, purchasing bottled water for drinking and cooking, or hauling water from a nearby source. Constructing an alternate well or surface source, if possible, may be too costly. Small communities often draw their water from wells in the immediate vicinity, and access to a neighboring water supply of better quality may not be available. Bottled water may not be readily available (4). In many cases, treatment may be the only alternative.

If treatment is selected as a solution to a drinking water contamination problem, it may occur at a central plant or at the point-of-use (POU). Treatment is provided at residences or businesses using POU technology. POU treatment is currently used to control a wide spectrum of contaminants. A common application of this technology is for improving aesthetic water quality (i.e. to control taste, odor, and color). Another common application is to reduce levels of organic chemicals, including pesticides. POU technologies are also currently used to control turbidity, fluoride, iron, radium, cysts, chlorine, arsenic, nitrate, ammonia, and microorganisms. The alternative of decentralized treatment is under consideration by the EPA as a Generally Available Technology (GAT) to meet the requirements of the National Primary Drinking Water Regulations (2).

POU treatment approaches include batch process units, faucet-mounted devices, in-line devices, line-bypass devices, and whole-house treatment. A batch process device treats one batch of water at a time, is not connected to the water supply, and may rest on the kitchen countertop. Faucet-mounted devices are attached directly to the faucet or placed on the countertop with tubing connections to the faucet. In-line devices are installed between the cold water supply and the kitchen faucet, and generally treat the entire kitchen cold water supply. With the line-bypass approach, the cold water line is tapped to provide influent to a treatment device, which may be installed under the kitchen sink; a separate drinking water tap is provided. Line-bypass devices are designed to treat only water intended for consumption. Whole-house treatment has been proposed for contaminant removal (5) where potential health risks associated with skin contact and inhalation exist (6). With such a system, all water entering the home is treated. Simplified schematics of POU treatment approaches appear in Figure 1.

A sound program for management of POU treatment systems is necessary to assure that a desired level of treatment is provided to all sites, that prescribed monitoring and maintenance is carried out, and that the system is in compliance with applicable regulations. This may be accomplished through formation of water quality districts, generally created by an ordinance or resolution of local/state governing bodies. These districts may resemble existing districts used for water, sewage, or solid waste disposal. A water quality district should be an independent corporate body, with powers exercised by a board of directors, which would assume responsibility for the fiscal and operational aspects of POU treatment applications within its area of jurisdiction.



Furnished by P. Regunathan, Everpure Corporation, Westmont, IL.

Figure 1. Approaches to point-of-use treatment.

For POU treatment to be considered as a means of compliance with regulations, regulatory agencies will most likely require the establishment of a clearly defined body to assume responsibility for the system. Also, formation of an officially sanctioned district may open avenues for funding not otherwise available.

A generalized process diagram for water quality district formation is presented in Figure 2. The developmental phase begins with identification of the particular water quality problem(s) encountered and evaluation of possible alternatives. Assuming that POU treatment is selected as a solution, cost estimates for equipment, installation, monitoring, and maintenance need to be developed. Access to homes for equipment monitoring and maintenance must be granted by homeowners, and scheduling and logistics need consideration.

The approval process may begin with a public hearing, where the issues, alternatives, and concerns of the public are addressed. If property owners wish to form a water quality district, a petition to officially establish the district may need to be submitted to the local health department and/or regulatory agency. If approved, the district may require technical assistance for selection, procurement, and installation of equipment; obtaining sources of funding; and setting up monitoring and maintenance procedures. A pilot study on the effectiveness of treatment equipment may be desired.

This document presents an overview of the key topics to consider when implementing a water quality district for treatment of contaminated water supplies at the point-of-use. These topics include:

- Institutional considerations;
- Advantages and disadvantages of POU treatment;
- Types of contamination problems;
- Available sources of information;
- Estimating treatment costs and financing;
- Equipment selection and installation;
- Equipment maintenance and monitoring;
- Disposal of waste materials; and
- Public relations and education.

The appendices include names and addresses of agencies and organizations to consult for technical, regulatory, and economic guidance.

Steps for District Formulation	Phase
. Identify problem	DEVELOPMENT
. Consult regulatory agencies	
. Water testing	
. Make preliminary plans and maps	
. Estimate costs	APPROVAL
. Hold public hearing	
. Property owner petition	
. District formed by resolution of county/state supervisors	
. Directors appointed	
. Agreement with town board and property owners for cost recovery	
. Obtain funding	OPERATION
. Pilot demonstration	
. Select equipment	
. Equipment Installation	
. Authorize payments	
. Monitoring and Maintenance	
. Feedback and Education	

Figure 2. Water quality district formation chronology.

SECTION 2.

INSTITUTIONAL CONSIDERATIONS

A key issue to the effectiveness of POU treatment on a group or community level is the development of a workable water quality district management program which is acceptable to regulatory authorities. The district would be established by the municipality as a legal entity to obtain funding, incur costs, and assume responsibilty for the treatment systems. A comprehensive management plan, including provisions for equipment monitoring and maintenance, will maximize the rate of acceptance of POU treatment plans by regulatory agencies.

If a water quality district is formed to achieve compliance with drinking water regulations, POU devices should be installed at each site serviced by the public water supply to assure that water used for drinking and cooking is in compliance with the regulations. Also, right of access to treatment devices must be granted at each site serviced by the supply so that prescribed maintenance and monitoring can be carried out.

Several options are available for a water quality district to administer the use and maintenance of POU treatment equipment. A board of directors may be appointed, elected, or be composed of community volunteers. It may serve the district well to have a representative from local government on the board, such as a treasurer or clerk. A three-member water board allows division of tasks into the following categories:

- Treatment works (equipment installation, monitoring, and maintenance);
- Financing (rate setting, budget, levy or assessment, financial assistance); and
- Administration (billing, correspondence, agency coordination, public relations, education).

Some possible approaches to equipment ownership and maintenance include the following:

- Municipality or district owns and operates the POU treatment equipment;
- Municipality or district owns the equipment and contracts maintenance to private enterprise;
- District leases equipment to municipality;

- Equipment is privately owned; or

- Equipment is owned by the water purveyor, which would be subject to regulation by a public utility commission.

Overview of State POU Policies

Because regulatory responsibility for drinking water quality is generally under the jurisdiction of at least one state agency and one local unit of government, it is often difficult to characterize a state as having a particular overall policy on POU treatment. In order to collect information concerning current state regulations, policies, and attitudes regarding POU treatment, a questionnaire was sent to 73 members of the Conference of State Sanitary Engineers (CSSE), representing all 50 states and three U.S. possessions. CSSE members were asked whether they regarded POU treatment as a feasible option, whether a policy existed in their respective states, what agencies had authority governing POU treatment, what contaminants were currently being removed with POU technology, and what criteria would be included in a state policy, were it developed. Responses were received from 32 states and two U.S. possessions; a summary appears in Table 1.

Of the respondents, 47 percent believed POU treatment to be a feasible option, 35 percent did not consider POU to be feasible, and 18 percent said that POU treatment should be used only as a last resort, interim measure, or in a very limited capacity. Three respondents stated that POU treatment was feasible only with adequate institutional control and responsibility for operation and maintenance of treatment devices. Of the states which did not consider POU treatment a feasible option, three did not recommend POU treatment on public water supplies, and one responded that POU was not to be used for compliance with drinking water regulations. Most concerns focused on potential problems with operation, monitoring, and maintenance of treatment devices. Because of limited experience with such systems, additional supportive research and experience are necessary before some jurisdictions will consider developing a POU policy.

Nine states responding have an existing policy regarding use of POU treatment, and four states plan to develop or revise a policy. Nineteen respondents believed that such a policy was needed, including 12 states which currently have no policy. Present policies range from those authorities that basically do not allow POU treatment, or do so with considerable limitations, to those who take a cautious but open approach. Some existing state policies on POU treatment include:

- Application of plumbing codes providing for proper installation;

- Application of food and drug laws providing for truth in labeling of devices used for disease prevention (although this has not been directly implemented for POU devices, the state policy would include them);

TABLE 1. CSSE SURVEY SUMMARY

Question	Responses (number in parentheses)
Number of states and possessions responding:	States (32) Possessions (2)
Do you believe POU treatment to be a feasible option?	Yes (16) No (12) Last Resort(6)
Who in your state has or will have authority to permmit installation of POU treatment equipment?	State (27) Local (6) Local Only (1)
Can POU treatment be used in your state?	Conventionally (14) Experimentally (23)
POU treatment systems are currently used for:	Tastes & Odor (17) Color (5) Softening (4) Fluoride (4) Radium (1) Radon (1) Chlorine (1) Ultraviolet disinfection (1) Unknown (5) Organics (10) Pesticides (5) Turbidity/ Particulates (6) Iron (2) Ammonia (1) Arsenic (1) Cysts (1) Nitrate (1)
Criteria regarding POU treatment systems does/would include:	Monitoring (12) Maintenance (11) Efficacy (10) Capacity (9) Size (9) Whole-house vs. tap (9) Depends on contaminants (2) Registration of devices (1) Approval of engineering plans (1) Manufacturer's specifications (1) Notification to potential house buyer (1)

- Compliance of equipment to state public water supply construction standards;

- Use restricted to treatment for aesthetic purposes (taste, odor, or color);

- Use restricted to situations where treatment beyond drinking water quality is desired (food processing, dialysis water, pharmaceutical applications);

- Use restricted to private wells; and

- For use on a public water supply, state health department must first review and approve plans (two responses).

Five respondents stated that POU treatment equipment was to be used at the individual's discretion, and that equipment use could not be regulated. One state reported an informal and unwritten policy which leaves the choice to individual homeowners. Two respondents commented on the need to develop either a federal policy or a national approval mechanism to assure proper use of POU treatment equipment and to provide a standardized approach throughout the country.

None of the states from which responses were received have statutes placing a general prohibition on the use of POU treatment. In fact, there is no legal precedent for preventing an individual from using a POU device, providing there is no demonstrated adverse impact on the community. However, appropriate regulatory authorities are required to exercise discretion when considering use of these devices on public water supplies, or when individual wells are proven to be contaminated. For the most part, each potential application of POU technology is reviewed individually.

Statutory responsibility for drinking water quality was divided among those agencies responsible for public health and for environmental protection. Permitting of POU treatment systems in 27 states is accomplished, at least partially, through state agencies. While local agencies can establish policy and adopt regulations in six states, only one respondent reported that this authority rested exclusively with local agencies. In addition, there may be involvement by agencies enforcing plumbing codes, particularly with respect to installation of treatment devices.

The majority of respondents believed POU treatment should be used only when a traditional treatment system is not feasible or cannot provide drinking water of satisfactory quality. Fourteen states did report, however, that POU devices were being used by individuals on either private wells or public water supplies. This may be partially attributed to the inability of a regulatory agency to control private use. Experimental use of POU technology was reported in 23 states, six of which limited use to experimental applications only.

Current applications of POU technology include taste, odor, and/or color removal (22 responses); organics removal, including pesticides (15 responses);

reduction of turbidity and/or particulates (6 responses); fluoride reduction (4 responses); softening (4 responses); and iron removal (2 responses). One response was recieved for each of the following contaminants: ammonia, radium, radon, arsenic, cysts, chlorine, nitrate, and bacteria (ultraviolet light). Five states responded that applications were unknown because use was confined to either private wells or individual homes.

Criteria for POU treatment systems were virtually non-existent in the states responding. Of the authorities providing information, none reported established state criteria. However, 12 states reported that a provision for monitoring the units would be included in a state policy, if one is developed. The need for establishing a monitoring program is based on the general feeling that a homeowner may not have sufficient expertise to inspect the unit for proper performance, and may not replace system components when needed. Consequently, 11 respondents also felt some provision should be made for maintenance of treatment devices.

Other frequently mentioned criteria were treatment efficacy (10 responses), capacity of treatment devices (9 responses), and size of equipment (9 responses). These criteria could be met by manufacturers through performance data, conditions for use, and equipment specifications provided via sales literature. In addition, nine respondents stated that whole-house treatment versus single tap treatment was a criterion to consider for proper application of POU technology. Other criteria (1 response each) included implementing truth in advertising and/or labeling laws, registration of POU devices, approval of engineering plans, and a provision for notifying potential house purchasers that a POU device was installed in a residence. Two respondents mentioned that criteria would depend on the contaminant being removed and the conditions for use.

New York State Policy

One state which has developed POU policy and criteria is New York. An act to amend county and town law to include provisions for the creation and implementation of water quality districts has been approved in the State of New York (7). Although the legislation deals exclusively with POU treatment on private wells, the act covers the institutional considerations that a public water system would need to address in establishing a water quality district, and serves as a good example of a mechanism for forming a district.

The act authorizes counties and towns to create special districts, or water quality treatment districts. The districts may be formed by a resolution of the county board of supervisors upon petition, following a public hearing. The petition may be executed by one or more owners of taxable real property in the proposed district. A copy of the petition is sent to the state health department. Before the public hearing, maps and plans showing the location of the benefitted properties and estimated costs for improvements must be submitted to and approved by the state health department.

The purpose of the district is to procure and install POU treatment devices, assist agencies in finding sources of contamination, implement remedial measures to reduce contamination, conduct public meetings, issue annual reports, and assure maintenance of treatment devices and protection of the public. The district may be composed of either contiguous or noncontiguous parcels of property.

The town or county board of supervisors may establish or appoint a supervisory board or officer for the district. The officers are required to develop estimates for costs of monitoring, testing, and operation of treatment devices; to estimate anticipated revenues and expenditures; and to determine the amount each parcel of property is to be charged. An agreement between the town board and property owners is to be reached before procurement and installation of treatment devices. The district may authorize annual installments, subject to existing tax laws covering collection and enforcement of payments. Property owners must grant a right of access to the district for sample collection, monitoring, and maintenance of treatment devices.

Summary

In summary, institutional issues which should be considered when establishing a water quality district include:

- Determining whether the purpose of the district is for compliance with drinking water regulations or for reduction of non-regulated and/or secondary contaminants;

- Establishing a legal entity to obtain funding, incur costs, and assume responsibility for POU treatment systems;

- Granting the right of access to all sites serviced by the water supply; and

- Including clearly defined provisions for equipment ownership, installation, monitoring, and maintenance.

SECTION 3.

POINT-OF-USE AND CENTRAL TREATMENT COMPARISON

Treatment Costs

Central treatment is cost effective as long as the capital and operating costs can be spread over a large number of customers. As community size decreases, per capita capital and operating costs for central treatment systems increase at an accelerated rate. Economies of scale often prevent the construction of central treatment plants for contaminant removal for small water systems.

As an example, the relationship between monthly customer cost and average daily flow for small communities using central activated alumina treatment (for reduction of fluoride) is depicted in Figure 3 (8). As average daily flow decreases, the monthly customer costs increase dramatically. POU treatment would become more cost effective at low total daily flows. Because no capital intensive treatment facility is required, costs for POU treatment may be significantly lower than costs for central treatment in small communities.

When a public water supply has an existing central treatment and distribution system, treatment alternatives may include upgrading the treatment plant or installing POU devices in residences and businesses. When no central treatment and distribution system exists, as with a group of private wells, POU treatment provides a substantial cost advantage. However, monitoring and maintenance would be more costly for a system of private wells because of variable water quality.

Operations

Many small central systems have unlicensed plant operators, who may only be available on a part time basis. Small water systems typically cannot afford the services of full time, experienced plant operators. This inability to retain qualified full time personnel may compound problems associated with central treatment on a small scale; the tight control of finished water quality associated with central systems may not be realized.

A major concern of regulatory agencies with POU treatment is the loss of control in monitoring treatment effectiveness and assuring routine maintenance. POU treatment presents logistical difficulties in regular sampling of all operating units, while homeowners are generally not trained in operation and maintenance of treatment devices. If replacement parts such as media cartridges are not replaced prior to exhaustion, the device will no longer provide treatment, or, in extreme cases, the contaminant level in the

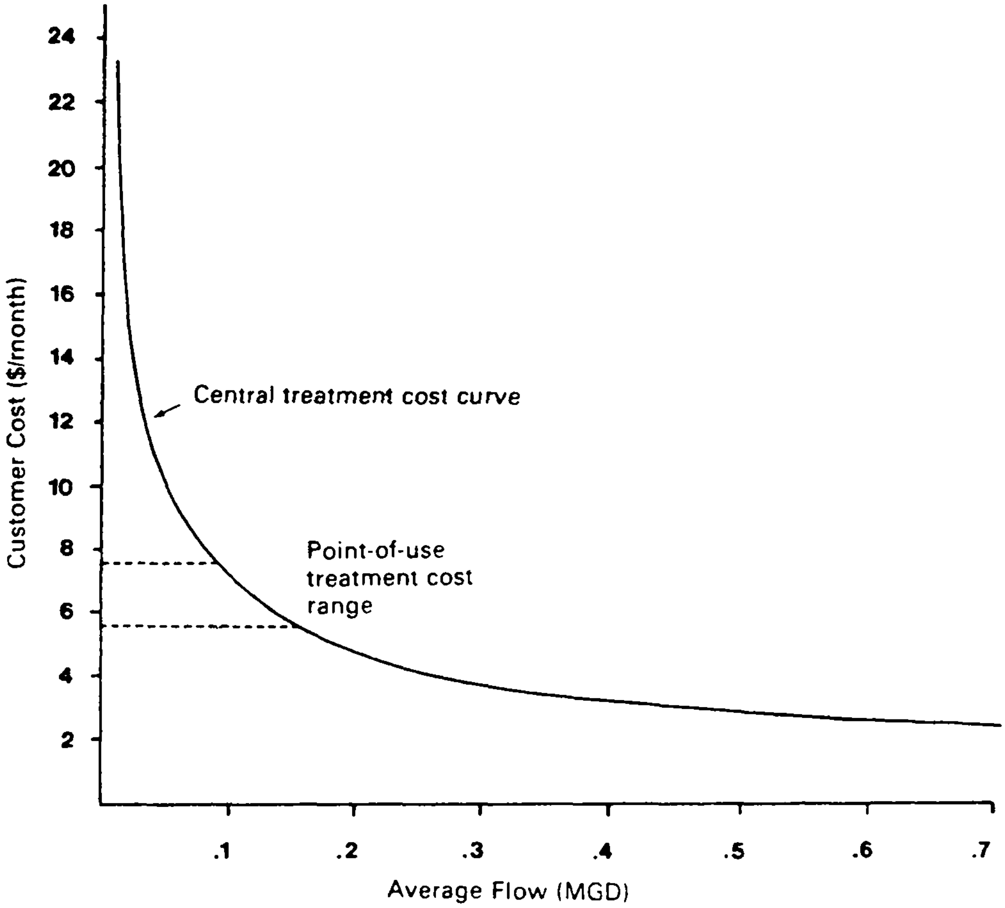


Figure 3. Central and POU treatment costs for activated alumina.

postdevice water may actually increase as contaminants leach from the media into the water. A sound program for POU treatment device monitoring and maintenance is essential to deal with the more complex logistics of POU treatment.

Poor source water quality may significantly degrade POU treatment efficiency, and pretreatment may not be possible or economical. For example, fluoride sorption on activated alumina from water with high alkalinity cannot be optimized with POU treatment. At high alkalinity, the rate of hydroxide ion displacement by fluoride is depressed and in such a case, the activated alumina will have a reduced fluoride reduction capacity. Full knowledge of source water quality is required to consider and size treatment techniques.

POU treatment may provide a drinking water of overall quality superior to that achievable with central treatment. An example is removal of trihalomethanes, which may be reduced to a lower level than economically feasible with central treatment (9). Another advantage to treatment at the point-of-use is that contaminants from the distribution system, such as disinfection and corrosion by-products, may be controlled.

Another operational consideration with POU treatment is the susceptability of media beds to microbial growth (10-13). Standard plate count organisms have been detected in POU treated water samples in higher numbers than in corresponding untreated water samples for treatment devices employing activated carbon, activated alumina, and reverse osmosis (8,13). It has not been established that the increased microbial densities in POU treated water will cause health problems.

Bacterial colonization of media beds is not unique to POU treatment systems. Central treatment systems, however, normally provide disinfection after treatment. Disinfection after POU treatment may be provided by ultraviolet light, ozone, or halogen compounds, but such post-disinfection will increase the costs and complexity of POU treatment.

Flexibility of Treatment

When treatment is desired for a specific segment of a population, POU may present a cost effective, viable alternative. For example, infants are adversely affected by nitrate levels which do not affect other members of a household (14). In areas of high nitrate levels, households without infants may not require treatment. Treatment focused on need is an important advantage of the POU treatment alternative.

Some organic chemical compounds (e.g. benzene) may be equally or more dangerous when inhaled or absorbed through the skin than when ingested (6). For these types of compounds, whole-house treatment should be considered.

POU treatment may also provide a good emergency response technique for temporary problems such as a Giardiasis outbreak or transient chemical contamination of a water supply. It can also be used to treat water to drinking water quality on a temporary basis while more permanent solutions are being investigated, planned, and implemented.

Summary

To summarize, treatment for a drinking water contamination problem may be provided at a central plant or at the point-of-use. Central treatment has the following associated advantages and disadvantages when compared to POU treatment:

Advantages of Central Treatment:

- Positive control of water quality through operation, maintenance, monitoring, and regulatory oversight;
- All water is treated to drinking water standards;
- For large communities, economies of scale for both capital and operating costs; and
- Flexibility of operation - ability to extend treatment cycles by blending water from more than one reactor.

Disadvantages of Central Treatment:

- Capital and operating costs may be prohibitive for small communities;
- Lack of trained plant operators and high operator turnover rates, especially for small systems; and
- Significantly more water will be treated to drinking water quality than may be needed for drinking and cooking.

POU treatment has the following associated advantages and disadvantages when compared to central treatment:

Advantages of POU Treatment:

- Only water intended for consumption may need to be treated;
- Costs per customer may be significantly lower for small communities;
- Provides a means for private well owners to treat their water to assure continual supply;
- Treatment may be focused on need;
- Some forms of treatment may provide greater contaminant reduction than with central treatment.

Disadvantages of POU Treatment:

- Greater complexity associated with control of treatment, monitoring, routine maintenance, and regulatory oversight;

- Life and efficiency of treatment units are dependent on source water quality;
- Monitoring costs will be higher than with central treatment; and
- Media beds may be susceptible to microbial growth.

SECTION 4.

TYPES OF CONTAMINANT PROBLEMS

Types of contaminant problems encountered in community drinking water supplies may be in the form of inorganic or organic dissolved constituents, physical suspensions, or biological agents. Inorganic contaminants may include nitrate, fluoride, arsenic, radionuclides, or heavy metals; organic contaminants are often volatile halogenated organic compounds or other synthetic organic chemicals. Physical contaminants include turbidity and suspended particulates or foreign objects. Biological contaminants may include bacteria, algae, cysts, and protozoa.

The NIPDWRs established maximum contaminant levels (MCLs) for drinking water constituents having known health effects. These include 10 inorganics, turbidity, coliform bacteria, six pesticides and herbicides, trihalomethanes, and radionuclides. The inorganics include: arsenic, barium, cadmium, chromium, fluoride, lead, mercury, nitrate, selenium, and silver. Turbidity is included in the MCLs because of its potential adverse impact on disinfection and/or microbial determinations. Organic contaminants with established MCLs include total trihalomethanes (TTHMs), and pesticides or herbicides such as lindane, methoxychlor, endrin, toxaphene, 2,4-D, and 2,4,5-TP (Silvex). The MCLs for these constituents are included in Appendix A.

All the MCLs apply to community water supplies; non-community supplies are required to comply with the MCLs for nitrate, coliform bacteria, and turbidity. The MCL for TTHMs currently applies to community water systems which use a disinfectant and serve more than 10,000 people.

Another group of regulations, the National Secondary Drinking Water Regulations (NSDWRs) were promulgated in 1979. Secondary maximum contaminant levels (SMCLs) were established for contaminants "which may adversely affect the aesthetic quality of drinking water such as taste, odor, color, and appearance and which thereby may deter public acceptance of drinking water provided by public water systems" (15). The SMCLs are not federally enforceable, but are intended as guidelines. Included in the secondary regulations are SMCLs for chloride, color, copper, corrosivity, foaming agents, iron, manganese, odor, pH, sulfates, total dissolved solids, and zinc. The SMCLs for these constituents also appear in Appendix A.

The U.S. EPA is considering several other drinking water contaminants for possible inclusion in the National Revised Primary Drinking Water Regulations

(NRPDWRs). Additional contaminants include inorganics, organics, including VOCs (16), microorganisms, radionuclides, and disinfection by-products. All contaminants under consideration for inclusion in the NRPDWRs are also included in Appendix A (2).

SECTION 5.

SOURCES OF INFORMATION

When considering POU treatment, an initial consultation with the local or state health department is recommended. The health department at the local level should be used as an initial source of guidance for both technical and regulatory matters. State agencies, such as the state environmental protection agency, department of natural resources, health department, or other agencies responsible for regulation of public water supplies should be consulted concerning drinking water regulations and proper application of treatment technology.

A list of state health departments is included in Appendix B, and a list of state public water supply contacts is provided in Appendix C. Because regulations and enforcement policies differ among states, state and local agenices will be more able to provide specific guidance than federal agencies. The local health department is a good initial source of information and/or referral.

The National Sanitation Foundation (NSF) is an independent, not-for-profit, third-party organization which develops voluntary public health consensus standards and tests products against those standards. The NSF has two standards for POU drinking water treatment devices, No. 42 (Aesthetic Effects) and No. 53 (Health Effects). Devices which remove contaminants included in the Primary Drinking Water Regulations are evaluated against Standard 53, and devices which remove contaminants included in the Secondary Drinking Water Regulations are evaluated against Standard 42.

Under the standards, treatment devices are performance tested against manufacturers' claims of contaminant removals. The standards also have requirements for materials, design, construction, hydrostatic performance, and product information. All testing and evaluations are conducted in accordance with a standard protocol. Manufacturing facilities are subject to at least one annual unannounced inspection. Products shown to conform with the requirements of the standard are published in an Annual Listing book and may display the NSF Seal. Copies of the standards and the Annual Listing book are available from NSF. Local health departments will usually have copies. Any NSF regional office (Los Angeles, Ann Arbor, Philadelphia, Atlanta, or Brussels) may be contacted directly to determine if a particular product is NSF listed. NSF can also provide technical assistance under contract to small communities considering POU treatment applications.

The American Water Works Association (AWWA) is a nonprofit organization of scientists, engineers, and water utility professionals dedicated to promoting research and education in all aspects of the water industry. The AWWA publishes many informative documents geared to the small water utility. Two examples are Basic Management Principles for Small Water Systems and Introduction to Water Quality Analyses. The AWWA Buyer's Guide, published annually, includes a complete list of publications and prices.

The National Water Well Association (NWWA), a group of professionals involved in hydrology, groundwater science, and water well technology, has sponsored the publication of a book covering aspects of water quality and treatment for home applications. The book, published in 1980 by McGraw-Hill, is entitled Domestic Water Treatment. The NWWA also publishes several journals, including Water Well Journal, Ground Water, and Ground Water Monitoring Review.

The Water Quality Association (WQA) is a nonprofit international trade association representing firms and individuals engaged in the design, manufacture, production, distribution, and sale of equipment, products, supplies, and services for providing drinking water, working water, and wastewater treatment at the point-of-use. The application of industry products encompasses homes, businesses, industry, and institutions. Membership in the WQA is voluntary. WQA promotes the individual right to quality water, and disseminates water quality information.

The U.S. Environmental Protection Agency (EPA) publishes documents such as the Manual of Treatment Techniques for Meeting the Interim Primary Drinking Water Regulations (EPA Office of Research and Development, Water Engineering Research Laboratory, Water Supply Research Division, Cincinnati, Ohio). The manual provides an overview of current treatment technologies and their application to removal or reduction of specific drinking water contaminants.

The National Demonstration Water Project is a nonprofit organization managing a national program for improvement of water supply and sanitation in rural communities, and publishes many useful documents, including Water and Sanitation Assistance Organizations (1983), a guide to federal, national, state, and local organizations.

Other sources of information include local consulting engineers, equipment manufacturers or distributors, and consumer information agencies and/or publications. Private nonprofit organizations such as the NWWA or the NSF, and trade associations such as the WQA may also provide technical guidance. A list of organizations and their addresses appears as Appendix D.

Summary

To summarize, local sources of information should be consulted first when considering POU treatment to solve a particular contamination problem. Available sources of information include:

- State or local health departments (Appendix B);

- State agenices responsible for public water supplies (Appendix C);

- Private nonprofit organizations and associations (Appendix D);
- Trade or manufacturer associations (Appendix D);
- Equipment manufacturers or distributors;
- Consumer information agencies or publications; and
- Local consulting engineers experienced in water supply and water quality.

SECTION 6.

ECONOMIC CONSIDERATIONS

The financial success of a POU treatment system depends on the ability to obtain financing for initial equipment investments, to generate revenue through water charges, to recover initial investments, and to fund ongoing operation and maintenance.

Obtaining Funding for Capital Expenses

Formation of an officially sanctioned water quality district may open avenues for funding not otherwise available. The district can act as a vehicle for the water system and for state/federal agencies to work together in obtaining funding. Availability of funding from federal and state sources should be investigated when considering system improvements. Direct contact with state drinking water program offices will help to identify state and federal funding programs.

A major advantage to formation of a district is the ability to issue bonds for initial equipment investments. State laws vary widely regarding the issuance and sale of revenue bonds. In some cases a popular vote may be required to approve the sale of revenue bonds (e.g., if the bonds are backed by the full faith and credit of the water authority or community). Each community has a debt levy limit, which is a percentage of the assessed value of the community. This limit varies with the county, city, township, and/or village. State law dictates the percentage of debt to be retired on an annual basis, and the time limit for the bonds. Bonds are generally approved and administered at the municipal level. Exceptions are the states of California, Michigan, North Carolina, and New Jersey, which have agencies at the state level responsible for bond administration.

For example, an improvement district in Arizona was formed to develop a potable water supply, which required treatment for reduction of an inorganic contaminant. The district was established by resolution of the county board of supervisors in response to property owner petitions, and was formed to incur operation and administration expenses. Three property owners were initially appointed to a board of directors; board members are now elected when a vacancy arises. The county clerk and treasurer are also clerk and treasurer for the improvement district, which by state mandate was to be a nonprofit entity. The district resolved that construction costs, including the costs of POU treatment, would be paid from the sale of improvement bonds. The water board obtained a $20,000 loan from a local developer to pay for initial legal fees, an engineering study, and a small contingency reserve.

The company bought Bond Anticipation Notes from the district. The notes were issued during construction to make partial payments to the contractor and cover contingencies. The bonds are payable over a 10 year period by special assessment (8).

As a public water supply, the Arizona community was also eligible for federal or state financial assistance. The board obtained a $1.5 million loan from the Farmer's Home Administration. The FHA money was used to purchase the district's improvement bonds upon project completion. Terms of the FHA loan were 30 years at an interest rate of five percent (8).

Several states, including Arkansas, California, Florida, Kansas, New Mexico, North Carolina, and Washington, have grant and loan programs for public water systems (18).

Local banks, credit unions, and finance companies are potential sources of funding. Equipment dealers may have arrangements with banks or finance companies for third-party or "indirect" loans, where the customer's purchases are funded by the bank through an equipment dealer. These arrangements may take many forms; rates and terms may vary with local regulations. Dealers may also provide "discounted" financing, where a portion of the interest on the initial investment is absorbed by the dealer. Some dealers work through national finance companies to work out an arrangement with customers. In addition, smaller local finance companies are emerging which are geared to local investments, such as water conditioning equipment. One larger manufacturer of POU treatment equipment has developed an arrangement where equipment is supplied free to the dealer, the customer is billed directly by the manufacturer, and the dealer receives a portion of the interest paid by the customer (17).

Local regulations, such as usury laws which put a ceiling on interest rates for loans, will affect the availability of financing. Homestead laws, which prevent creditors from repossessing items in the home, will also affect availability and terms of loans (17).

An alternative to purchasing water treatment equipment is a lease or rental agreement with an equipment dealer or supplier. Some rental agreements may include an option to buy the equipment. Leasing and rental agreements become more attractive to the customer when interest rates climb. The leasing fee may include equipment monitoring and maintenance.

Recovering Costs

Methods of recovering capital expenditures for equipment and installation include property assessment, taxation, service fees, or a combination thereof. If the system is intended for compliance with drinking water regulations, payments must not be optional, and all properties serviced by the water supply must be assessed. Methods of cost recovery will depend on local regulations and tax laws.

For the Arizona community discussed earlier, debt retirement of the five percent FHA loan is accomplished through semi-annual payments from property owners. The amount paid by each homeowner was determined on a property assessment basis. Each December, a principal and interest payment is due, and each June, an interest payment is due. A five percent penalty is added to late payments.

A successful management plan involves not only recovering capital expenses through assessments and/or taxes, but includes generating revenue through water charges to recover operating, maintenance, and administration expenses. The existing water rate schedule must be reviewed, and the additional cost of POU equipment, including monitoring and replacement components, must be included in adjusted water rates. Any rate adjustments would have to comply with state laws for billing and rate setting.

Estimating Treatment Costs

A model for estimating costs of POU treatment involves amortizing capital and installation costs using the capital recovery factor (CRF), and estimating replacement costs. Cost estimates for POU treatment may be required before district formation, and will be necessary before obtaining funding and/or setting water rates. In addition, a simple model which estimates costs is desirable when considering types of treatment, a particular model of a POU device, and financing and/or leasing agreements.

The CRF converts the value of capital investments and interest paid on a loan to an annual cost. When this is added to estimated monitoring and maintenance costs, a total cost for POU treatment can be estimated for the district. The model used here is based on annual interest charges divided evenly over twelve months. Compounding interest is not considered for simplicity.

Estimated Annual Cost = (CRF x capital cost) + replacement and monitoring costs,

$$CRF = i\ (1 + i)^n \ /\ [(1 + i)^n - 1]$$

where,

i = nominal interest rate (percent)

n = time period of loan or expected life of replacement parts (years)

For example, suppose a water quality district were to purchase 50 POU treatment devices at a capital cost of $350 each (equipment plus installation). The district financed the capital expenditure of $17,500 at 8 percent over 10 years.

To estimate the annual capital cost per unit, the capital cost of $350 is multiplied times the CRF ($i = 8\%$, $n = 10$ years). First, the CRF must be calculated for the financing terms:

$$CRF = .08 \times (1.08)^{10} \ /\ [(1.08)^{10} - 1] \ = \ 0.149$$

Next, the capital cost is multiplied by the CRF:

($350) x (0.149) = $52.15

The cost of $52.15 represents an annualized capital cost per device. This translates to $4.35 per month per service connection.

Now, suppose that the treatment equipment included a $15 (estimated price in one year) prefilter, for which component replacement frequency was estimated to be once per year, and a $45 (estimated price in two years) media cartridge, which is expected to last two years. Estimated annual component replacement costs would be then be calculated:

Annual estimated component replacement costs:

$15 / 1	+	$45 / 2	=	$37.50
(prefilter, replaced once per year)		(cartridge, replaced once per 2 years)		

The estimated annual component replacement costs of $37.50 translate to $3.13 per month per service connection.

Estimated monthly capital and component replacement costs for this example would be:

$4.35 (capital) + $3.13 (replacement) = $7.48 per service connection

In 10 years, the capital costs would be completely amortized, and only component replacement costs would remain.

A reserve of spare device components should be on hand from the onset of a POU treatment program. These costs, plus the costs of monitoring and administration, should be considered before financing and cost recovery mechanisms are arranged.

Favorable prices for equipment purchases, installation, and/or maintenance may be negotiated with an equipment dealer or supplier when purchasing in quantity. This is another advantage of forming a water quality district before purchasing equipment.

Monitoring Costs

Monitoring costs are site-specific and depend on several factors, including source water quality, type of treatment used, laboratory capability and proximity, local regulations, and whether sampling is subcontracted or provided by the community. For example, monitoring costs for POU defluoridation treatment include labor and analytical reagents for a field test. A typical colorimetric fluoride test costs approximately $0.25 for reagents. In the State of Arizona, a policy on POU defluoridation requires that treatment devices be installed in the right-of-way or public utility easement, with responsibility for hookup from the easement to a drinking water tap delegated to the homeowner. A fluoride test is required from each device once per quarter. Allowing 20 minutes for sample collection at the property line, performing the fluoride test, recording of results, and travelling between sites would give an average cost of $2.91 per quarter ($8.00 per hour labor). This is equivalent to $0.97 per month per service connection for monitoring POU defluoridation devices in Arizona.

Field notes from a demonstration of POU defluoridation in Illinois (8) indicated that new activated alumina installations took 45 to 60 minutes for initial setup. This included flushing the device and calibrating a bypass valve, which blended raw water with treated water to provide an optimal fluoride concentration in the effluent. Devices were installed under kitchen sinks or in basements. An average of 24 minutes were required for sample collection, testing, and recording of results. When bypass valve calibrations were necessary, collection time averaged 36 minutes. With comparable sampling frequencies and labor rates as the Arizona example, monitoring costs would range between $1.15 and $1.68 per month per service connection. These costs do not reflect the additional cost of travel for sample collection. Communities may significantly reduce monitoring costs with local, volunteer sample collectors.

Monitoring for POU defluoridation could be incorporated into the billing procedure. A sample bottle could be mailed to the customer with the water bill, or left with the customer during meter reading. The customer could mail or deliver the water sample to a central office for analysis. This approach would not be suitable for samples which had special requirements for handling, such as short holding times, refrigeration, and/or special collection procedures. The approach would also have to incorporate a means to follow-up and obtain samples from homeowners who do not cooperate.

Representative costs of selected laboratory analyses obtained during field demonstrations of POU treatment with granular activated carbon, reverse osmosis, and activated alumina (8,13) appear in Table 2. These cost ranges are typical of certified analytical laboratories. Laboratories may also provide sample collection services.

The sampling frequency chosen by the community or regulatory agency will affect monitoring costs. Unlike relatively inexpensive inorganic analyses, analyses for VOCs generally cost more than replacement activated carbon cartridges. Consequently, it would be more cost effective to replace activated carbon cartridges before they became exhausted than to fully use cartridge capacity by closely monitoring for breakthrough.

It is recommended that communities considering POU treatment conduct a pilot study by operating the device on the communitiy water supply at a continuous flow until breakthrough of the contaminant occurs. This pilot study will establish the device's capacity for that particular source water, and could be completed in several days for most types of treatment. Raw water should be monitored during normal operation to assure consistency of source water

TABLE 2. TYPICAL ANALYTICAL COSTS

Analyte	Cost
VOCs	$50
Total trihalomethanes	$40
Standard plate count	$6-15
Total coliform	$5-10
Fluoride	$7-12
Heavy metals	$7-15 each
Nitrate	$7-15

TABLE 3. THUNDERBIRD FARMS IMPROVEMENT DISTRICT BUDGET—1983-84 FISCAL YEAR

Operational Expenses:	
Manager's wages	$6,000
Laborer and meter reader	1,000
Clerk	8,000
Engineering and attorney	7,000
Secondary water purchases	1,000
Repair and equipment rental	1,000
Power	15,000
Office and mailing	1,200
Transportation/mileage	600
Parts and supplies	3,000
Contract repairs	1,500
Advertising	80
Telephone	75
Water testing	250
Contingency reserve	1,000
SUBTOTAL	46,705
Delinquency adjustment (+15%)	7,005
TOTAL	$53,710
Income:	
Water charges	$42,300
New installations	3,513
Carry-over	7,897
TOTAL	$53,710

quality. Once the service life of a device has been demonstrated, sample collection may be suspended (after initial setup) for a specified volume or time. This will significantly reduce monitoring costs.

Budgeting

As an example of an operating water quality district budget, Table 3 presents the fiscal 1983-84 budget of the Thunderbird Farms Domestic Water Improvement District, located in Southwestern Arizona. The district is responsible for supplying domestic (raw) and potable (POU treated) water to property owners. As can be seen from Table 3, approximately 79 percent of the district's projected 1983-84 expenses are covered by water charges. The charge for new installations is required in advance from new customers, and includes the cost of a POU defluoridation device and installation. Cartridge replacement costs are incorporated into the fixed water rate of $1.50 per 1000 gallons. Each fiscal year's budget is subject to the approval of the county board of supervisors. The average monthly charge for water at Thunderbird Farms is $15.00.

Administrative Costs

Routine administrative costs, including record keeping, billing, and inventory control, would be incurred by a community establishing a POU water quality district. Using the budget in as Table 3 as a model, average monthly administrative costs can be estimated. The Clerk works approximately 200 hours per month maintaining 1500 records, including water, maintenance, and assessment (debt retirement) accounts. This amounts to 0.133 hours per month per record. Assuming the district operates on a quarterly billing basis, estimated labor is 0.40 hours per record per quarter. At a labor rate of $8.00 per hour, maintaining each record costs approximately $3.20 per quarter for administrative labor.

Projected expenses for telephone, postage, and miscellaneous supplies for the Improvement District's 643 customers are $1,275 for fiscal 1983-84. This amounts to $0.495 per customer per quarter.

Total administrative costs for each member of the Thunderbird Farms Improvement District are $3.70 per quarter, or $1.23 per month, based on a labor rate of $8.00 per hour. Districts may reduce administrative costs with voluntary labor and/or more active homeowner participation.

Summary

In summary, economic considerations in establishing a water quality district include:

- Obtaining sources of financing for the capital expenses of equipment purchase and installation;
- Generating revenue through water charges;
- Recovering costs of initial investments; and

- Supporting ongoing equipment monitoring and maintenance.

Potential sources of funding include:

- Federal and state grants or loans;
- Revenue bonds;
- Banks, credit unions, and finance companies; and
- Equipment dealers or suppliers.

SECTION 7.

EQUIPMENT SELECTION

Selection of appropriate equipment to solve a particular contamination problem involves many considerations. The bacteriological and chemical quality of the raw water must be considered. If the water is aggressive (causes corrosion readily), some equipment applications may be inappropriate. The presence or absence of competing ions, such as sulfate for nitrate removal with ion-exchange, must be determined. Consultation with the state agency responsible for public water supplies is strongly recommended to ensure application of the appropriate treatment technology. Public or private water quality professionals should be consulted before equipment is selected.

POU treatment is currently used to control a wide spectrum of contaminants. A common application is to reduce levels of organic contaminants. POU technology may also be used to control turbidity, fluoride, iron, radium, chlorine, arsenic, nitrate, ammonia, and microorganisms, including cysts. A water's aesthetic parameters (i.e. taste, odor, or color) may also be improved with POU treatment.

Types of POU treatment include adsorption, ion-exchange, reverse osmosis, filtration, chemical oxidation, distillation, and disinfection (chemical addition, ultraviolet light, and ozone). A list of drinking water contaminants and appropriate applications of POU treatment technology appears in Table 4.

Activated carbon (AC) is regarded as the best process for reduction of a broad spectrum of organic chemical contaminants (19). AC removes organic contaminants through a process called adsorption. Adsorption of an organic molecule from water onto carbon occurs predominantly from physical attractive forces between the organic molecule and the carbon, and is influenced by the solubility of the molecule and its affinity for the carbon surface. AC is a good adsorbent because it provides a large surface area per unit volume. Factors which affect the performance of AC devices include quantity and type of carbon, internal flow patterns, flow rate (or contact time), and raw water quality.

A knowledge of these adsorption principles, coupled with performance information for a specific device, may be used to predict breakthrough behavior and establish an effective monitoring plan. Many good references on AC treatment are available (5,10,19-22).

TABLE 4. POU TREATMENT TECHNIQUES[1]

Treatment Type	NIPDWR Contaminants	Other Contaminants
Reverse Osmosis[2]	Arsenic[3], Barium, Cadmium, Chromium, Lead, Mercury, Silver, Fluoride, Nitrate, Selenium, Radium, Some organics, herbicides, and pesticides	Total dissolved solids, Copper, Chloride, Sulfate foaming agents, corrosion
Cation Exchange	Barium, Cadmium, Chromium III, Lead, Mercury	Copper, Zinc, Iron[4] Manganese[4]
Anion Exchange	Nitrate, Selenium VI, Arsenic III, Arsenic V, Chromium VI, Radium	Chloride, corrosion, Sulfate
Activated Alumina	Fluoride, Arsenic, Selenium IV	-
Direct (Mechanical) Filtration	Turbidity	Cysts
Activated Carbon	Organics, Organic Mercury	Color, foaming agents, taste, and odor
Distillation	Metals, high molecular weight organics	Total dissolved solids, Chloride, Sulfate

[1] Taken from the "Statement of the Water Quality Association to the EPA," December 13, 1983.

[2] Results of reverse osmosis treatment may vary between pressurized and non-pressurized units, membrane type, and configuration.

[3] Arsenic (+3) is poorly removed with reverse osmosis.

[4] Low levels.

Ion-exchange involves passing water through a bed of ion-exchange resin, which may be for cations (positively charged molecules) or anions (negatively charged molecules). The contaminant is electrostatically attracted to the resin, which gives up (exchanges) a particle of similar charge having a lesser attractive force for the resin. When the resin is exhausted (filled with the contaminant), it is replaced or regenerated.

Water softeners are common examples of ion-exchange devices, which exchange sodium ions for those causing water hardness (primarily calcium and magnesium), and are regenerated with brine solution. The presence of other ions, which may interfere with the ion-exchange treatment process, must be considered. An example is the presence of sulfate in a water supply contaminated with nitrate. The sulfate ion may be more attracted to the ion-exchange resin than the nitrate ion.

Treatment with activated alumina (AA) may be described as an "exchange/adsorption" process, resulting from electrostatic attraction between the alumina surface and the contaminant and the sorptive properties of the AA granules, which, like AC, have a large surface area per unit volume. The process is dependent on the pH of the water. At high pH (or high alkalinity), fluoride and arsenic reduction is impaired, because hydroxide ion is more favorably sorbed to the alumina.

Reverse osmosis (RO) is a process which uses pressure to pass water from a concentrated solution to a more dilute solution, reversing the natural process of osmosis. Raw water is passed through a semipermeable membrane. The membrane rejects dissolved molecules, which are discarded in a reject (concentrate) stream, usually connected to the drain. Product water (permeate) accumulates very slowly, usually in a storage reservior. Pressure for the RO system may be supplied externally with a pressurizing pump, or may be supplied by line pressure, depending on the type of unit and membrane type. The back pressure of the storage tank and the osmotic pressure of the raw water must be overcome for treatment to occur. RO systems may have several components to the system, including prefilters, the RO module, a polisher (typically AC), a storage tank, and/or pump. RO is used as a desalinization process for sea water, and is used for dialysis water and water for food and pharmaceutical preparations.

Distillation involves vaporizing the raw water and condensing the steam, which generally removes contaminants with a lower vapor pressure than the water. Electrical energy is usually used to heat the water to vaporization.

The presence of many different products on the market for a particular process results in the need for verification of treatment device performance. Standards to evaluate performance and reliability are avaliable. National Sanitation Foundation (NSF) Standards 42 and 53 are for drinking water treatment units making performance claims for aesthetic and health-related contaminants, respectively. The NSF standards are voluntary consensus standards established by representatives from government, user groups, and industry. Under the NSF standards, a device is tested against a manufacturer's claims of removal efficiency for each contaminant specified. The standards also address unit design and construction, including construction materials, and hydrostatic and mechanical performance. Product informational materials must also meet minimum requirements under the standards.

The American Society of Testing and Materials (ASTM) has established voluntary consensus standard test methods for operating characteristics of reverse osmosis membranes (D4194-82), a standard practice for determining operating performance of granular activated carbon (D3922-80), and standard test methods for operating performance of particulate mixed-bed ion-exchange materials (D3375-82).

The Water Quality Association (WQA), an organization representing the POU device manufacturing industry, has developed recommended industry standards for household and commercial water filters (S-200-73), as well as reverse osmosis systems (S-300-84).

Because of the multitude of products on the market today, verification of treatment device performance by an independent third party is desirable.

An equipment manufacturer's experience and the viability of the company should also be considered in selecting a particular product. Equipment warranties and the extent and time limits of coverage for each system component should be well understood before a product is selected. Another consideration is the extent of insurance coverage that the manufacturer has on the devices once installed.

The water quality district must address the issue of responsibility for property damage resulting from leaks from defective equipment, improper installation, or accidents. The district should have insurance coverage for consequential damage and liability. As a minimum, district insurance should cover the amount of the deductible on the resident homeowner's insurance policy, should the resident make a damage claim.

The effect of the treatment device on the water's taste, odor, or color should be considered, as greater public acceptance of the system will occur if the treatment imparts an improvement in the water's aesthetic quality. Taste, odor, and color are much more noticeable to the public than the presence of a contaminant not readily discernible. Most current applications of POU technology are for aesthetic purposes, such as taste and odor removal using activated carbon.

The type of waste generated by a POU device should also be considered. The important issues determining appropriate disposal of wastes from POU treatment include the physical state of the waste, the wates's toxic or hazardous properties, and the quantity of waste produced. Disposable media cartridges such as activated carbon cartridges will generally not constitute a significant waste contribution to a landfill. However, the type of contaminant removed and frequency of cartridge replacement may influence the method selected for cartridge disposal. Regulatory authorities responsible for solid waste disposal in the state should be contacted. If discarding cartridges with typical domestic waste products is not acceptable, licensed waste haulers can provide disposal on a contract basis. Some media may be returned to a manufacturer for regeneration; however, this is usually not cost effective for activated carbon in small volumes typical of line-bypass POU devices.

Ion-exchange media, which is more easily regenerated, may pose a different waste problem. The media is not typically discarded, but the chemicals used for regeneration are. These wastes may be considered hazardous if enough volume is produced.

If cartridges are returned to the manufacturer or a contractor for regeneration, the waste disposal will be handled by the regenerator. If regenerations are handled by the district, state waste authorities should be contacted.

The majority of the waste produced by a POU reverse osmosis device is concentrated in a reject stream which continually flows to waste down the kitchen drain. The wastes are typically inorganic and generally pose no greater chemical burden for a waste treatment system than if the POU device were not there. However, the continually flowing waste stream may pose a hydraulic burden to onsite waste systems (e.g. septic tanks) which are already operating at capacity. Low pressure reverse osmosis devices installed in an Illinois community produced an average of 30 gallons of reject water per household per day (8).

In general, waste disposal should be readily manageable with POU treatment. However, waste disposal should be considered when POU treatment is planned. A list of state solid and hazardous waste agencies is included in Appendix E.

When obtaining equipment prices from different manufacturers, a district should solicit quotes for a quantity of devices to get the most favorable price. Consideration should be given to the purchase of replacement components in quantity, and an adequate stock of spare parts should be maintained to assure that all households are provided with required service. Other considerations in selecting a product include proximity of the dealer or service representative and the availability of parts and services, including possible maintenance and/or monitoring services. Favorable rates for parts and services may be negotiated when initially purchasing treament devices.

An accelerated demonstration of performance is desirable. Such a demonstration permits evaluation of treatment efficacy, and allows estimation of the service life of prefilters, media cartridges, polishers, etc. The treatment effectiveness and capacity of a POU device may be affected by other contaminants in the water. Some effects may be predicted by a water quality professional, but demonstration of performance with a specific water supply is preferred.

An accelerated study involves the installation of a single treatment unit at a typical home or well site, and operation of the unit at a very accelerated rate, as compared to normal use (e.g. constant flow until breakthrough occurs). A water meter is installed with the unit to measure the total volume treated. Frequent sampling of treated water is performed, and samples are analyzed for the presence of the contaminant being removed. This process is usually not feasible with reverse osmosis (RO) systems because RO flow rates cannot be accelerated. In some cases, onsite analysis with a field test kit is adequate for an accelerated study; for some contaminants, such as organics or microorganisms, samples will require laboratory analysis.

Presence of the contaminant in higher concentrations in treated water, following the treatment of a given quantity of water, indicates the beginning of contaminant breakthrough through the treatment media. In the case of RO devices, fouling of prefilters or the RO module will result in little or no production of treated water. The device has reached its service life when the concentration of the contaminant in treated water reaches the MCL, or some other established value. Figure 4 depicts a general breakthrough curve which may be typical of adsorption, ion-exchange, or exchange/adsorption treatment processes. The slope (steepness) of the breakthrough curve depends on the type and concentration of the contaminant, the presence of other constituents in the raw water, and the treatment process used.

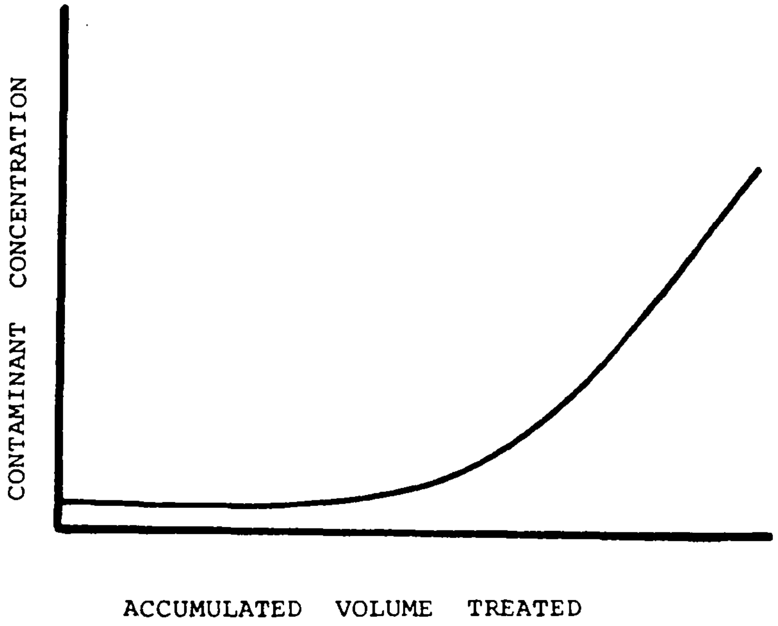


Figure 4. Typical contaminant breakthrough curve.

Table 5 presents some typical costs for purchasing POU activated carbon, reverse osmosis, and activated alumina devices.

These costs were obtained while establishing POU treatment districts for field demonstrations (8,13) and reflect average 1983 prices for quantity purchases. Costs for AC and RO devices were average prices, obtained from five to six manufacturers.

TABLE 5. TYPICAL EQUIPMENT COSTS FOR POU ACTIVATED CARBON, REVERSE OSMOSIS, AND ACTIVATED ALUMINA DEVICES

Treatment Type	Average Equipment Cost (1983)[1]
Activated Carbon	$220
Reverse Osmosis	$430
Activated Alumina	$200

[1] Includes fittings and drinking water tap. Does not include approximately $40 for a product water meter. Reflects prices for quantity purchases.

To determine when system components (i.e. those with established service lives) are nearing the end of their expected lives, the use of water meters on individual treatment devices for measuring the cumulative volume treated is recommended. The water meter should be installed after the treatment device for protection of meter parts. The nominal flow rate from the device must be determined prior to water meter selection. Water meters are commercially available for approximately $40-50 each. Meters are capable of flow measurement down to 1/4 to 1/8 gallon per minute. If a treatment device is equipped with a meter which measures cumulative flow, the meter's accuracy should be established or verified during the accelerated performance study.

Summary

To summarize, considerations in selection of equipment, assuming proper application of treatment technology, include the following:

- Consultation with the local health department and/or state regulatory agency;
- Quality of the source water and pretreatment requirements;
- Type of process(es) needed and compatability of components making up the treatment system;
- Experience and reputation of the manufacturer;

- Equipment warranties and extent of coverage;
- Testing by an independent third party;
- Aesthetic effect on water (taste, odor, and/or color);
- Accelerated demonstration of treatment efficiency;
- Discounts on quantity purchases;
- Ease of installation and servicing;
- Cost and projected service life of replacement parts;
- Availability of replacement parts and proximity of service representative;
- Use of product water meters;
- Type and amount of wastes generated; and
- Proper disposal of wastes.

SECTION 8.

EQUIPMENT INSTALLATION

Equipment installation may be performed by a factory-trained dealer or a plumbing contractor. Equipment dealers may be able to recommend plumbing contractors experienced with their particular product. All work must comply with local/state plumbing and building codes, and work should be performed by an appropriately certified individual. An installer may be an equipment dealer, a plumbing contractor, or a water utility staff person.

It is recommended that the equipment installer retain responsibility for the work for a specified period after installation to allow for minor adjustments, leak repair, and an inspection follow-up. A partial (e.g. ten percent) retention of installation fees is recommended until installations are inspected and approved by a district representative.

In soliciting quotes from installers, it is advisable to provide detailed descriptions or pictures of system components. The district may wish to itemize the types of kitchen sinks to be equipped with treated water taps and to indicate the presence or absence of sink sprayer holes. This has an effect on the amount of work involved in installing product water taps for line-bypass devices. If a hole does not appear in a sink which cannot be drilled, a long-reach faucet can be installed in the countertop adjacent to the sink. The issue of liability for damage to sinks or other property during installation should be addressed before work begins.

The size of treatment equipment and kitchen geometry will dictate whether devices are installed under the kitchen sink or in the basement. Many homeowners prefer basement installations because under-counter storage space may be limited. This may present more difficulty for the sample collector if treatment adjustments are required.

When soliciting quotes from plumbing contractors, it may prove economical to solicit both an hourly rate and a fixed rate per installation. The fixed rate will most likely include a "safety factor" to allow for contingencies, but has advantages over the hourly rate because the installation costs are known before installation begins, and verification of hours worked is not as critical.

The purchase of additional valves, fittings, and tubing may be necessary to complete many installations. The plumbing contractor may be given responsibility for the purchase of such additional materials; reimbursement should be contingent upon receipt of itemized invoices.

At each installation site the plumbing contractor should provide documentation including: 1) name of homeowner, 2) address of installation, 3) date completed, 4) time to perform installation (if paid on hourly rate basis), and 5) initial meter reading.

The district may wish the manufacturer or dealer to provide follow-up training in basic maintenance practices to a local plumber or water utility staff.

Table 6 presents average installation costs for several AC, RO, and AA devices based on some recent field demonstrations (8,13). The type of installer is also noted in the table. Installation costs may vary with the type of installer selected and local labor rates.

TABLE 6. TYPICAL INSTALLATION COSTS FOR POU ACTIVATED CARBON, REVERSE OSMOSIS, AND ACTIVATED ALUMINA DEVICES.

Treatment Type	Installation Cost Per Unit	Bid Basis	Installer
Activated Carbon	$33	per hour	water utility staff
Reverse Osmosis (low pressure)	$68	per hour	factory-trained dealer
Activated Alumina	$35	per hour	plumbing contractor
	$35	per unit	plumbing contractor

Summary

To summarize, factors important to selection and performance of an installation contractor include:

- Demonstrated experience in installing POU treatment devices;
- Conformance with applicable plumbing codes;
- Liability for property damage during installation;
- Accessibility for service calls;
- Contractor's responsibility for minor adjustments after installation;
- Quote basis (hourly rate versus per unit rate); and
- Documentation of installations.

SECTION 9.

MAINTENANCE

A well-defined maintenance agreement is essential for successful water quality district operation. This may be in the form of an on-demand contract with a local plumbing contractor, a service representative/dealer, a service company, or the water utility. Equipment maintenance may be provided for a limited time period as part of an installation warranty. An installation and service contract with an equipment dealer, service representative, or local plumbing contractor may prove economically beneficial because of the volume of serviceable units. Another advantage to this arrangement is that maintenance is performed by personnel familiar with the installations. The ability to provide prompt service when requested is an important consideration when selecting a maintenance contractor.

Replacement of System Components

Timely replacement of media, cartridges, filters, and/or modules must occur if the system is to provide water of desirable quality to all users and/or remain in compliance with the regulations. The use of water meters in conjunction with a monitoring program is recommended to help assure timely replacement. Operational life of system components is initially determined with product water meters and analysis of water samples. This may occur in an accelerated demonstration (except for RO devices) or during the initial phase of district operation.

The anticipated life of a POU device should be established for each community's unique water quality character. The life of the device is measured by the volume of water passing through the device until the contaminant(s) concentration in treated water reaches the local MCL, or a lower level set by the district. Raw water quality, which may affect service life of system components, should be monitored throughout district operation to assure that pilot study results remain valid.

Operational practices for the use of activated alumina POU treatment devices for defluoridation of otherwise potable water recommended (not mandated) by the Illinois EPA, after field demonstrations were performed, are presented as an example (26). Although these practices are specific for this type of treatment, some general guidelines for using and maintaining POU treatment for compliance with regulations may be applicable to other treatment approaches.

Recommended Operational Practices for the Use of Activated Alumina POU Treatment Devices for Defluoridation of Otherwise Potable Drinking Water

1. If the use of POU devices is intended to fulfill public water supply compliance requirements, then all homes serviced by the water supply must have devices. The requirement may be satisfied by means of an ordinance established by local government. The ordinance should stipulate that all homeowners must provide access for POU device sampling and maintenance.

2. All installations will include a water meter which will measure total volume through the POU device. All water used for drinking and cooking should be taken from the POU device.

3. A bypass line and control valve should be installed at the POU device so that treated and untreated water may be blended to achieve an optimum fluoride concentration of 1.0 mg/L. Valve adjustment should be performed every time a new or replacement cartridge is installed. Flush all new installations for 30 minutes (or approximately 50 gallons) before adjusting the valve.

4. The anticipated life of the POU device should be established for the water quality of the community. The life of the device is measured as the volume of water which passes through the device until the concentration of fluoride in the treated water reaches the local MCL.

5. The service life of the devices should be accurately established for 10 devices within the community. The standard deviation of the mean volume of water treated (mean service life) should be calculated. A computational formula for the standard deviation is:

   $$s = (n \Sigma V^2 - (\Sigma V)^2) / n(n-1)$$

   where n equals the number of devices and V equals volume of water treated for each of n devices. For example, if 3 devices have a measured life of 1175, 1205, and 1220 gallons, the standard deviation, s, would be:

   $$s = (3(1175^2 + 1205^2 + 1220^2) - (1175 + 1205 + 1220)^2) / 3(3-1)$$

   $$s = 23 \text{ gallons}$$

6. If the primary method for monitoring device life is meter readings, then the devices should be replaced when the volume treated is 3 standard deviations prior to the mean volume treated. For the example above, the replacement volume would be 1131 gallons:

   Replacement Volume = Mean Device Life - 3(Standard Deviation of Mean)
   The mean service life of the device is:

   $$(1175 + 1205 + 1220) / 3 = 1200 \text{ gallons}$$

Replacement Volume = 1200 - 3(23) = 1131 gallons

7. Establish a contract with the device supplier for regeneration of media cartridges, with fixed costs and time periods for regeneration.

8. Maintain a stock of replacement cartridges so that replacements can be made immediately at the end of service life with no loss of service to the homeowner.

An alternative to the statiscally-based cartridge replacement frequency would be increased sampling and testing, beginning at three standard deviations prior to the mean volume treated, until contaminant breakthrough was detected. Sampling frequency could be reduced until this point. Reduced sampling will not work, however, with POU devices treating water of variable quality. It is difficult, if not impossible, to calculate component replacement frequencies with water of variable quality.

For POU treatment with reverse osmosis, system components will require maintenance or replacement at various frequencies. Prefilters will most likely require replacement before membrane modules; timely replacement of prefilters is necessary, as pressure loss through fouled prefilters will reduce the production rate of treated water. If production rates decline, the quality of the treated water also deteriorates because the flux of dissolved solids across the RO membrane (and into the product water) is relatively constant. Consequently, for lower production rates, less water is produced for the same amount of dissolved solids, resulting in a higher dissolved solids concentrationin the product water. Some types of RO membranes (e.g. polyamide) are sensitive to chlorine, and require pretreatment with AC. Failure to replace the AC pretreatment cartridge before exhaustion will result in deterioration of this type of RO membrane.

In order to evaluate the condition of RO membranes after some period of operation, it is necessary to know how the membrane performs when first installed. This may be accomplished by measuring the production rate from the membrane, the water temperature, and the water pressure into the membrane module immediately after installation. These parameters must be measured without any pretreatment or posttreatment devices attached. After some period of operation, the process is repeated. Although influent temperature and pressure may be different, calculation of the theoretical optimal production rate is possible using manufacturers' tables. If the modules have begun to foul, the measured production rate will be less than the theoretical optimal (new module) production rate.

Consultation with regulatory agencies and equipment dealers is recommended to assure proper care and maintenance of all types of POU devices.

Summary

Equipment may be maintained through several arrangements, including:

- An on-demand contract with a local plumbing contractor;

- A maintenance agreement with an equipment dealer or service representative;
- An installation warranty; and
- Water utility personnel.

SECTION 10.

MONITORING

Monitoring of treatment devices is essential to assure that equipment is performing properly and the desired level of treatment is provided. A sample collection program must be site-specific, and depends on the number of devices in service, the type of contaminant(s) removed, treatment method(s) used, and the logistics of the service area. The local health department and state regulatory agency should be consulted regarding minimum sampling frequencies and types of analyses required.

Sampling Requirements

Collection and analysis of treated water samples for process control is necessary to assure that contaminants are being removed effectively. Sample collection and analysis will also be required if the water quality district is established for compliance with drinking water regulations. If the POU system is intended for compliance purposes, state requirements for monitoring will specify sampling frequencies to establish compliance, and may include specifications for performing and submitting records of onsite field analyses. Onsite analyses may be appropriate for such constituents as residual chlorine, fluoride, and turbidity. Contaminants such as organics, nitrates, metals, microorganisms, and radionuclides will most likely require analysis by a certified laboratory.

Submission of samples to a certified laboratory is necessary to assure that contaminants are being reduced to desired levels and to establish reliability of onsite analyses, if applicable. If sampling frequencies are mandated by the state to establish compliance, samples will be submitted to certified laboratories. The local health department or state regulatory agency should be consulted regarding minimum sampling frequencies, required analyses, and state analytical services offered.

Some analytical costs are significantly higher than media or cartridge replacement, as with VOCs. In these instances it is more cost effective to increase cartridge replacement frequencies (i.e. shorten cartridge life) and decrease sampling and analysis.

Routine microbiological sampling should be performed as mandated by the state for compliance with microbiological regulations. Two potential sources of bacteriological contamination are the source water and the installation procedure. Samples of treated water should be collected within one week after installation. If unacceptable levels of microorganisms are found, the device should be flushed and resamples collected. The health department should be consulted regarding microbiological sampling frequency and procedures for resampling. Disinfection of the POU system may be necessary. Disinfection of activated carbon is not possible by means available in the field. If necessary, the cartridge should be removed, and the rest of the system disinfected before a new cartridge is installed.

Sampling Methods

Sample collection includes the drawing of raw and product water, reading product water meters, performing required field analyses, transporting or shipping samples to an analytical laboratory, and maintening and submitting of records. Sampling techniques and sample preservation requirements differ significantly, depending on the contaminant to be analyzed. Basic sample types include inorganic, organic, and bacteriological samples. The water utility should consult the regulatory agency regarding state-approved sampling methods.

References for sampling techniques include Standard Methods for the Examination of Water and Wastewater, 16th edition (23), the Handbook for Sampling and Sample Preservation (24), and the Sample Collector's Handbook (25). The Sample Collector's Handbook provides a good introduction to water quality and sampling techniques for the layperson.

Consideration should be given to the extent of flushing performed on the system before sample collection. For treatment processes such as activated carbon adsorption, ion-exchange, and exchange/adsorption with activated alumina, water contained in the device during quiescent periods (non-use) has much more contact time with the treatment media than water passing through the system during use. Consequently, the first flush of water from the treatment device may not be representative of treatment system capabilities. Flushing these types of devices is recommended to allow the system to reach a "steady state" condition before a water sample is drawn. Flushing of POU reverse osmosis systems is not appropriate.

Flushing the device may also affect the results of bacteriological sampling from POU devices. Results from site demonstrations of POU AC and AA devices indicated a reduction in standard plate count bacteria of one to two orders of magnitude after the device was flushed for two to three minutes before sample collection (8,13).

Samples of treated water should be collected for analysis within one week of device installation or replacement. Required sampling frequency during a device's service life depends on local regulations and the type of treatment, but it is recommended that every operating unit be sampled at least twice during its operational life (beginning and end). One exception may be POU treatment with activated carbon for organics removal, because the cost of a replacement cartridge is often lower than laboratory analysis for the contaminant(s).

If sampling is used in lieu of estimated service life to determine when cartridge replacement is required, sampling frequency should be increased near the end of expected service life. The device's rated capacity may be used as an initial estimate of expected service life, but actual service life for each system component should be established for each specific source water. Product water meter readings may be used to determine when monitoring should be increased at a particular site. Meter readings may be provided to the utility by the homeowner on a monthly basis. Meter readings may also be performed by the sample collector or by water utility staff.

For process control samples (not for compliance), records of sample collection sites and dates, results of onsite analyses, and laboratory analytical results should be kept by the water quality district. For samples intended to establish compliance with regulations, federal and/or state requirements for retention of records should be followed.

Sample Collectors

Potential sample collectors include a "circuit rider" operator, a service representative, staff from an independent laboratory, health department staff, or water utility staff. Subcontracted sampling services from a dealership or independent laboratory may be too costly for some water utilities, and local health departments may not be able to provide staff for sampling.

For these reasons it may be necessary to select a community resident to perform sample collection. There are advantages with a local sample collector who is familiar with the community, especially if the sample collector must enter the residence or business. Local sample collectors have the advantage of knowing the community's residents. Coordination of convenient sample collection dates and times of day can be difficult, and is more readily accomplished by a local resident.

The sample collector must be adequately trained in collection procedures and performing field analyses with state-approved methods. Sampler training may be provided through state-sponsored training programs or through seminars conducted by organizations such as the American Water Works Association. A qualified individual, such as a licensed plant operator or health official, may also provide training.

Monitoring for some analytes could also be incorporated into the billing procedure. A sample bottle could be mailed to the customer with the water bill, or left with the customer during meter reading. The customer could mail or deliver the water sample to a main office for analysis. This approach would require the approval of appropriate regulatory agencies, and would only be feasible for analytes which did not have special sampling requirements. A follow-up procedure for non-respondents would also be needed.

Summary

The sample collector training program should include:

- Overview of treatment system and treatment objectives;

- Methods and procedures for performing field testing;

- Sample collection techniques;
- Sample preservation techniques;
- Record keeping and documentation, including completion of laboratory report forms;
- Product water meter reading;
- Procedures for transport and/or shipment to the laboratory;
- Basic troubleshooting; and
- Procedures for obtaining equipment servicing, including repair and replacement of system components.

Possible sample collectors include:

- Residents;
- Circuit riders (licensed operators under contract with several water systems);
- Service representatives;
- Water or health department staff; or
- Independent laboratory staff.

SECTION 11.

PUBLIC RELATIONS AND EDUCATION

Public relations and education are essential in promoting a water quality district, both to the general public and to regulatory personnel. Greater acceptance of a POU treatment program may be realized through town meetings, where concerns and questions from community residents and local/state officials may be addressed. If promoters of the water quality district begin with a sound educational and public relations program, chances of acceptance of the water quality district are improved. For a successful water quality district, each homeowner must assume responsibility to cooperate with the water utility and follow recommended procedures for care of the individual treatment system. This underscores the importance of good public relations and education.

An initial town meeting should be held to define the program, measure public opinion of alternative solutions, and address questions and concerns. Representatives from the health department and/or state regulatory agency should be present at the initial meeting.

Proponents of the district should be well prepared for the initial meeting. Some questions and concerns expressed by community residents during initial town meetings held in conjunction with a research project involving field demonstrations of POU devices (8,13) are included as examples of topics which may arise during an initial meeting.

Water Quality:

- How much contaminant is in the water?
- What is the source of the contaminant?
- What are the health effects and risk factors of the contaminant?
- How long has the water been contaminated?
- Does the contaminant have a taste?
- How long will the contaminant remain in the water?
- Will the water taste different?

Regulatory:

- How does the EPA know which communities have contaminated water?
- Is the community required by law to remove the contaminant from the water?
- What are the penalties for not complying with drinking water regulations?

Treatment:

- Why can't the water be centrally treated?
- Will the treated water be pure?
- How effective are water softeners in removing the contaminant?
- How effective is a water distiller?
- Does boiling reduce levels of TCE?
- Do faucet-mounted POU devices compare with under-sink installations?
- Can the contaminant come out in large "slugs" from the POU device?
- What are the interferences to treatment?
- Can you treat all the cold water in the house?
- What is the treatment media called?
- Are media particles harmful if they pass through the device?

Installation:

- Will there be one unit per house?
- Do the devices have to be upright?
- What happens if my sink is damaged?
- Does a licensed plumber have to install the devices?
- Does a separate faucet get installed at the kitchen sink?
- Why can't we just install one POU device at a central location?
- What is the target date for installation?
- What if you own your own well?

Maintenance and Monitoring:

- What maintenance is involved?
- How long does the unit last before replacement?
- Will the sample collector be someone familiar to the community?
- What are the monitoring requirements?
- How often will someone need to enter my house?
- What about sampling if we both work during the day?

Economics:

- How will we pay for the devices?
- What are the costs?

Town meetings should be continued at regular intervals throughout the program. Operating water quality districts often hold monthly meetings, where fiscal matters are discussed and public concerns and questions may be addressed.

Occasional newsletters are an effective tool in promoting good public relations by informing residents of the fiscal and operating status of the district. A newsletter may include notices of community meetings, fiscal and/or budget information, news of system improvements or problems, schedules for assessment or tax payments, advertisements, and personal articles. Articles which promote public education may also be included. The newsletter may be supported by a nominal suscription charge, publication of advertisements, part of the monthly fee, or by some combination.

Educational activities promote good public response, and should be implemented early in the development of a water quality district. Homeowner cooperation and participation is necessary to carry out a successful management program. Public education may be accomplished during town meetings with guest speakers and/or demonstrations. State or local government agencies may be able to assist in educational activities. A list of state agency coordinators for environmental educational programs appears as Appendix F. Organizations such as the National Sanitation Foundation, the Water Quality Association, the National Water Well Association, and the American Water Works Association may provide educational assistance as well (see Appendix D).

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APPENDIX A

CURRENT DRINKING WATER REGULATIONS

	NIPDWRs MCL[1]	NSDWRs SMCL[2]
Inorganics		
Arsenic (mg/L)	0.05	--
Barium (mg/L)	1.0	--
Cadmium (mg/L)	0.010	--
Chloride (mg/L)	--	250
Chromium (mg/L)	0.05	--
Copper (mg/L)	--	1.0
Iron (mg/L)	--	0.3
Lead (mg/L)	0.05	--
Manganese (mg/L)	--	0.05
Mercury (mg/L)	0.002	--
Nitrate (mg/L)	10.0	--
Selenium (mg/L)	0.01	--
Silver (mg/L)	0.05	--
Sulfate (mg/L)	--	250
Zinc (mg/L)	--	5.0
	MCL[1]	SMCL[2]
Physical Characteristics		
Color (units)		15
Corrosivity		Noncorrosive
Odor (threshold)		3
pH (units)		6.5-8.5
Total Dissolved Solids (mg/L)		500
Turbidity (NTU)	1.0 Based on monthly average unless: a. Doesn't interfere with disinfection b. Doesn't prevent maintenance of disinfectant in distribution system c. Doesn't interfere with microbiological determinations. OR 5.0 Based on an average for two consecutive days.	

	NIPDWRs MCL[1]	NSDWRs SMCL[2]
Organics		
Foaming Agents (mg/L)	--	0.5
TTHMs (mg/L)	0.10	--
Endrin (mg/L)	0.0002	--
Lindane (mg/L)	0.004	--
Methoxychlor (mg/L)	0.1	--
Toxaphene (mg/L)	0.0005	--
2,4-D (mg/L)	0.1	--
2,4,5-TP Silvex (mg/L)	0.01	--
Radionuclides		
Gross Alpha (pCi/L)	15	--
Gross Beta	<4 mrem/yr	--
Radium 226 & 228 (pCi/L)	5	--
Strontium 90 (pCi/L)	8	--
Tritium (pCi/L)	20000	--

Microbiological Contaminants	MCL[1]
Coliform	
Method:	
Membrane Filter	1/100 mL mean for month 4/100 mL, if less than 20 samples/month 4/100 mL, in 5% of samples if 20 or more samples/month
Fermentation Tube	
10 mL portions	≤ 10% of portions/month < 3 portions, if less than 20 samples/month < 3 portions, in more than 5% of samples, if 20 or more samples/month
100 mL portions	≤ 60% of portions/month < 5 portions, if less than 5 samples/month < 5 portions, in 20% of samples if 5 or more samples/month
Fecal Coliforms	0

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[1] US Environmental Protection Agency, "National Interim Primary Drinking Water Regulations", Federal Register; Volume 40, No. 248, December 24, 1975; Volume 41, No. 133, July 9, 1976; Volume 43, No. 28, February 9, 1978; Volume 44, No. 231, November 29, 1979.

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CONTAMINANTS UNDER CONSIDERATION FOR INCLUSION IN THE NATIONAL REVISED PRIMARY DRINKING WATER REGULATIONS (2).

Microbial Factors

Coliforms*
Turbidity*
Giardia
Standard plate count
Viruses
Legionella
Filtration requirement for surface waters
Disinfection requirement for groundwaters

Inorganic Chemicals

Arsenic*
Cadmium*
Lead*
Nitrate*
Silver*
Barium*
Chromium*
Mercury*
Asbestos
Sulfate
Corrosion
Copper
Nickel
Selenium*
Fluoride*

Organic Chemicals

Endrin*
Methoxychlor*
2,4-D*
Lindane*
Toxaphene*
2,4,5-TP*
cis- and trans-1,2-Dichloroethylene
Dichlorobenzene(s)
Aldicarb
Chlordane
Endothall
Carbofuran
Heptachlor
Styrene
Polychlorinated biphenyls (PCBs)
Dibromochloropropane (DBCP)
1,2-Dichloropropane
Pentachlorophenol
Alachlor
Ethylene dibromide (EDB)
Epichlorohydrin
Xylene
Toluene
2,3,7,8-TCDD (dioxin)
Chlorobenzene
Hexachlorobenzene
Ethyl benzene

Radionuclides

Radium 226*
Radium 228*
Gross alpha particle activity*
Beta particle and photon radioactivity*
Uranium
Radon

Disinfection By-products

Trihalomethanes*
Haloacid derivatives
Chloramines
Residual chlorine (?)
Dihaloacetonitriles
Halophenols
Chlorine dioxide and ions

*Included in NIPDWRs

APPENDIX B

STATE HEALTH DEPARTMENTS CONTACTS LIST

James W. Cooper, Director
Environmental Health Administration
State Department of Public Health
State Office Building
Montgomery, AL 36130

John Halterman
Environmental Quality Management
State Department of Environmental Conservation
Pouch O
Juneau, AK 99811

Chuck Anders
Assistant Director
Environmental Health Services
Department of Health Services
1740 West Adams
Phoenix, AZ 85007

Jerry G. Hill, Director
Bureau of Environmental Health Services
State Department of Health
State Health Building
4815 West Markham
Little Rock, AR 72201

Jack M. Sheneman, PhD
Food and Drug Branch
State Department of Health Services
714 P Street, Room 400
Sacramento, CA 95814

John A. Baghott, Director
Division of Consumer Protection
State Department of Health
4210 East 11th Avenue
Denver, CO 80220

Dr. Peter Gailbraith, Director
Environmental Health Services
State Department of Health Services
150 Washington
Hartford, CT 06106

Frederic L. Stiegler, Jr.
Program Director
Office of Food Protection
State Department of Health & Social Services
Administration Building
Delaware State Hospital
New Castle, DE 19720

Eanix Poole, Administrator
Environmental Health Program
Department of Health & Rehabilitative Services
1323 Winewood Boulevard
Tallahassee, FL 32301

Dr. J. Alley
Division of Physical Health
State Department of Human Resources
47 Trinity Avenue
Atlanta, GA 30334

Shinji Soneda
Division of Environmental Health
State Department of Health
Kinau Hale Building
1250 Punchbowl Street
Honolulu, HI 96813

Harold Matsura, Chief
Sanitarian, PO Box 916
Hilo, HI 96720

David Nakagawa, Chief
Sanitarian
Island of Maui
Wailuku, Maui

Theodore Inouye, Chief
Sanitarian
Island of Kauai, Lihue, Kauai
PO Box 3378
Honolulu, HI 96801

Lee W. Stokes, PhD
Administrator
Division of Environment
State Department of Health & Welfare
State House Mail
Boise, ID 83720

Roy W. Upham, DVM, MS, Chief
Division of Food, Drugs and Dairies
State Department of Public
Health
535 West Jefferson
Springfield, IL 62761

Ralph C. Pickard
Assistant Commissioner for
Environmental Programs
State Board of Health
1330 West Michigan
PO Box 1964
Indianapolis, IN 46206

Kenneth Choquette, Director
Health Engineering Unit
State Department of Health
Lucas State Office Building
Des Moines, IA 50319

Allan Akramson
Division of Environment
State Department of Health and
Environment
Forbes Field, Building 740
Topeka, KS 66620

Irving Bell, Director
Division of Consumer Health
Department of Human Resources
275 East Main Street
Frankfort, KY 40621

Ronald J. Hingle
Administrator
Food and Drug Control Unit
Office of Health Services and
Environmental Quality
State Office Building
325 Loyala Avenue
PO Box 60630
New Orleans, LA 70160

Donald C. Hoxie, Director
Division of Health Engineering
State Department of Human Services
157 Capitol Street
Augusta, ME 04333

Harold C. Thomas, Chief
Division of Food Control
State Department of Health and
Mental Hygiene
201 West Preston Street
Baltimore, MD 21201

Nancy Ridley, PhD
Acting Director
Division of Food and Drugs
305 South Street
Boston, MA 02130

Lee Jager, Chief
Bureau of Environmental and
Occupational Health
State Department of Health
350 North Logan Street
PO Box 30035
Lansing, MI 48909

John Hesse, Acting Chief
Center for Environmental Health
Sciences
Michigan Department of Public Health
PO Box 30035
Lansing, MI 48909

Ray Thron, Director
Division of Environmental Health
State Department of Health
717 Delaware Street
Minneapolis, MN 55440

Joe D. Brown
Division of Environmental Health
State Department of Health
PO Box 1700
Jackson, MS 39215

Erwin P. Gadd, Director
Bureau of Community Sanitation
Missouri Division of Health
Broadway State Office Building
PO Box 570
Jefferson City, MO 65101

Donald Willems
Environmental Sciences Division
State Department of Health &
Environmental Sciences
W. F. Cogswell Building
Capitol Station
Helena, MT 59620

Jack L. Daniel, Director
Division of Housing and
Environmental Health
State Department of Health
301 Centennial Mall South
Third Floor
Lincoln, NE 68509

Catherine Lowe, Administrator
Nevada State Health Division
505 East King
Carson City, NV 89710

John R. Stanton, Chief
Bureau of Environmental Health
State Department of Health
and Welfare
Health and Welfare Building
Hazen Drive
Concord, NH 03301

Peter D. Stratton, MPH, Chief
Food and Milk Program
State Department of Health
Health-Agriculture Building
John Fitch Plaza
South Warren Street
Trenton, NJ 08625

Steven Asher, Director
Environmental Improvement Division
State Department of Health
PO Box 968
Santa Fe, NM 87504

Albert T. Squire, Director
Food Protection Section
State Department of Health
Tower Building
Empire State Plaza
Albany, NY 12237

James F. Stamey, Chief
Environmental Health Section
Division of Health Services/PO Box
2091
Raleigh, NC 27602

Kenneth W. Tardif, Director
Division of Environmental Sanitation
State Department of Health
Missouri Office Building
1200 Missouri Avenue
Bismarck, ND 58501

John Frazier, Chief
Bureau of Environmental Health
State Department of Health
246 North High Street
PO Box 118
Columbus, OH 43216

Mark S. Coleman
Environmental Health Services
State Department of Health
PO Box 53551
Oklahoma City, OK 73152

Ken Kaufman, Manager
Food Program
State Department of Human Resources
318 Public Service Building
Salem, OR 97310

Gary E. German, Chief
Division of Food Protection
Department of Environmental
Resources
9th Floor, Fulton Building
Third & Locust Streets
PO Box 2063
Harrisburg, PA 17120

Fred Siino
Division of Food Protection and
Sanitation
State Department of Health
75 Davis Street
Providence, RI 02908

E. Carl Fox, Chief
Bureau of Environmental Sanitation
State Department of Health
and Environmental Control
J. Marion Sims Building
2600 Bull Street
Columbia, SC 29201

Mike Barker, Director
Division of Environmental Quality
State Department of Water and
Natural Resources
Joe Foss Building
523 Capitol Avenue E.
Pierre, SD 57501

Sammy N. Smith
Division of Food and General
Sanitation
Bureau of Environment
150 Ninth Avenue North
Nashville, TN 37219

L. D. Thurman, Chief
Bureau of Environmental Health
Division of Food and Drugs
State Department of Health
1160 West 49th
Austin, TX 78756

Kenneth L. Alkema
Division of Environmental Health
State Department of Health
150 West North Temple
PO Box 2500
Salt Lake City, UT 84110

Kenneth M. Stone, P.E.
Division of Environmental Health
State Department of Health
60 Main Street/PO Box 70
Burlington, VT 05402

Herbert Oglesby
Assistant Commissioner
Office of Community Health Services
State Department of Health
James Madison Building
109 Governor Street
Richmond, VA 23219

Kenneth J. Merry, Chief
Office of Environmental Health
Programs
Division of Health MS LD-11
State Department of Social and
Health Services
Olympia, WA 98504

Robert P. Wheeler, Director
Environmental Health Services
State Health Department
1800 East Washington Street
Charleston, WV 25305

Lloyd Riddle, Director
Bureau of Environmental Health
State Department of Health & Social
Services
1 West Wilson Street
Madison, WI 53703

Howard Hutchings, Director
Environmental Health Program
State Department of Health & Social
Services
4th Floor, Hathaway Building
Cheyenne, WY 82002

APPENDIX C

STATE WATER SUPPLY CONTACTS

(from Conference of State Sanitary Engineers Directory of State Environmental Contacts, 1984.

Joe Alan Power
Public Water Supplies
Environmental Management Department
434 Monroe Street
Montgomery, AL 36130

Gary Hayden
Water Quality & Environmental Sanitation
Department of Environmental Quality
Pouch O
Juneau, AK 99811

Jim Walters, P.E.
Water Quality Control
Department of Health Services
1740 West Adams
Phoenix, AZ 85007

Bruno Kirsch, Director
Engineering Division
Department of Health
4815 West Markham Street
Little Rock, AR 72201

Pete Rogers, Chief
Sanitary Engineering Branch
Department of Health Services
714 P Street, Room 600
Sacramento, CA 95814

Rick Karlin
Water Quality Control Division
Department of Health
4210 East 11th Avenue
Denver, CO 80220

Raymond Jarema
Water Supplies
Department of Health Services
79 Elm Street
Hartford, CT 06106

Richard Howell
Bureau of Environmental Health
Jesse Cooper Building
PO Box 637
Dover, DE 19901

Glenn Dykes
Environmental Program - Water Management
Department of Environmental Regulations
2600 Blair Stone Road
Tallahassee, FL 32301

Gene Welsh
Water Protection Branch
Department of Natural Resources
270 Washington Street, SW
Atlanta, GA 30334

Thomas Arizumi
Drinking Water Program
Department of Health
1250 Punchbowl Street
Honolulu, HI 96813

Al E. Murray
Water Quality Bureau
Department of Health & Welfare
Statehouse
Boise, ID 83720

Roger D. Selburg
Division of Public Water Supplies
Illinois EPA
2200 Churchill Rd.
Springfield, IL 62704

C. Neil Ott
Division of Sanitary Engineering
State Board of Health
1330 West Michigan
Indianapolis, IN 46206-1964

Dennis Alt
Water Suply Section
Department of Water, Air and Waste Management
Wallace State Office Building
Des Moines, IA 50319

Gyula Kovach
Bureau of Water Protection
Department of Health and Environment
Forbes Field, Building 740
Topeka,KS 66620

John Smither
Division of Water
Natural Resources and Environmental Protection
18 Reilly Road
Frankfort, KY 40601

Frank Groening
Water & Sewage Services
Department of Health & Human Resources
PO Box 60630
New Orleans, LA 70160

Clough Toppan
Division of Health Engineering
Department of Human Services
State House, Station #28
Augusta, ME 04333

William Parrish
Division of Water Supplies
Environmental Health Division
Department of Health & Mental Hygiene
201 West Preston, 5th Floor
Baltimore, MD 21201

Illyas Bhatti,
Division of Water Supply
Department of Environmental Quality Engineering
One Winter Street
Boston, MA 02108

William Kelley, Chief
Division of Water Supply Services
Department of Public Health
3500 N. Logan
PO Box 30035
Lansing, MI 48909

Gary L. Englund
Section of Public Water Supplies
Department of Health
717 Delaware Street, SE
St. Paul, MN 55440

James C. McDonald
Division of Water Supply
Department of Health
PO Box 1700
Jackson, MS 39215

William Ford
Public Drinking Water Program
Division of Environmental Quality
PO Box 1368
Jefferson City, MO 65102

Steven Pilcher
Water Quality Bureau
Department of Health & Environmental Sciences
Cogswell Building
Helena, MT 59620

William A. Lee
Environmental Engineering
Department of Health
PO Box 95007
Lincoln, NE 68509-5007

James A. Maston
Public Health Engineering
Department of Human Resources
Consumer Health Protection Services
505 E. King Street
Carson City, NV 89710

Bernard D. Lucey
Water Supply and Pollution Control Commissioner
State of New Hampshire
Hazen Drive, PO BOX 95
Concord, NH 03301

Raymond Barg, Chief
Bureau of Potable Water
Department of Environmental
  Protection (CN029)
Division of Water Resources
Trenton, NJ 08625

Gustavo Cordova
Water Supply Section
Community Support Services
Health and Environment
Environmental Improvement Division
PO Box 968
Santa Fe, NM 87503

Michael E. Burke
Bureau of Public Water Supply
Department of Health
Office of Public Health
Corning Tower
Empire State Plaza
Albany, NY 12237

C. E. Rundgren
Water Supply Branch
Division of Health Services
PO Box 2091
Raleigh, NC 27602

Jack Long
Water Supply Program
State Department of Health
1200 Missouri Avenue
Bismarck, ND 58501

Robert S. McEwen
Office of Public Water Supply
Environmental Protection Agency
PO Box 1049
361 East Broad Street
Columbus, OH 43215

George McBryde
Water Facilities Engineering Service
Oklahoma Department of Health
PO Box 53551
Oklahoma City, OK 73152

James R. Boydston
Driking Water Systems
Department of Human Resources
PO Box 231
Portland, OR 97207

Fred Marrocca
Water Supplies
Department of Environmental
  Resources
Commonwealth of Pennsylvania
PO Box 2063
Harrisburg, PA 17120

John V. Hagopian
Division of Water Supply
Department of Health
Cannon Building
75 Davis Street
Providence, RI 02908

Max Batavia, P.E.
Water Supply Division
State Department of Health and
  Environmental Control
2600 Bull Street
Columbia, SC 29201

Mark E. Steichen
Drinking Water
Department of Water and Natural
  Resources
Joe Foss Building
523 Capitol Avenue East
Pierre, SD 57501

James W. Haynes
Division of Water Supply
Department of Public Health
Bureau of Environment
150 9th Avenue, North
Nashville, TN 37219

David McCochran
Environmental and Consumer Health
  Protection
Texas Department of Health
1100 West 49th Street
Austin, TX 78756

Gayle J. Smith
Bureau of Public Water Suplies
Division of Environmental Health
Utah Department of Health
560 S. 300 E.
Salt Lake City, UT 84110

Kenneth M. Stone
Environmental Health
Department of Health
60 Main Street
Burlington, VT 05401

Allen R. Hammer
Water Suupply Engineering
Department of Health
109 Governor Street
Richmond, VA 23219

James C. Pluntze
Water Supply and Waste
Department of Social and Health
  Services
Mail Stop LD-11
Olympia, WA 98504

Donald A. Kuntz
Environmental Engineering Division
Department of Health
1800 Washington Street, East
Charleston, WV 25305

Robert A. Baumeister
Bureau of Water Quality
Public Water Supply Section
Department of Natural Resources
PO Box 7921
Madison, WI 53707

Jake Strohman
Water Quality Control
Department of Environmental Quality
401 West 19th Street
Cheyenne, WY 82002

APPENDIX D

ORGANIZATIONS PROVIDING SERVICES

1. American Water Works Association
6666 West Quincy Avenue
Denver, CO 80235
303/794-7711

2. National Water Well Association
500 West Wilson Bridge Road
Worthington, OH 43085
614/846-9355

3. National Sanitation Foundation
3475 Plymouth Road
Ann Arbor, MI 48105
313/769-8010

4. National Demonstration Water Project
1725 DeSales Street, NW
Suite 402
Washington, DC 20036
202/659-0661

5. Water Quality Association
4151 Naperville Road
Lisle, IL 60532
312/369-1600

APPENDIX E

STATE SOLID AND HAZARDOUS WASTE AGENCIES

Environmental Protection Agency
Office of Solid Waste, February, 1985

(from Plastics Compounding, May/June 1985, pp. 87-88)

Alabama
Daniel E. Cooper, Chief, Land Disposal Program, Alabama Department of Environmental Management, Solid and Hazardous Waste Management Division, State Capitol, Montgomery, AL 36130

Alaska
Stan Hungerford, Air & Solid Waste Management, Department of Environmental Conservation, Pouch O, Juneau, AK 99811

Arizona
R. Bruce Scott, Chief, Bureau of Waste Control, Department of Health Services, State Health Building, Rooom 202, 1740 W. Adams Street, Phoenix, AZ 85007

Arkansas
Vincent Blubaugh, Director, Solid & Hazardous Waste Division, Department of Pollution Control & Ecology, 8001 National Drive, Little Rock, AR 72219

California
Richard Wilcoxon, Acting Chief, Hazardous Waste Management Branch, Department of Health Services, 714 P Street, Sacramento, CA 95814

Terry Trumill, Chairperson, State Solid Waste Board, 1020 9th Street, Suite 300, Sacramento, CA 95814

Colorado
Kenneth Waesche, Director, Waste Management Division, Colorado Department of Health, 4210 E. 11th Avenue, Denver, CO 80220

Orville Stoddard, Deputy Director, Waste Management Division, Colorado Department of Health, 4210 E. 11th Avenue, Denver, CO 80220

Connecticut
Stephen Hitchock, Director, Hazardous Material Management Unit, Department of Environmental Protection, State Office Building, 165 Capitol Avenue, Hartford, CT 06115

Michael Cawley, Connecticut Resource Recovery Authority, 179 Allyn Street, Suite 603, Professional Building, Hartford, CT 06106

Delaware
William Razor, Supervisor, Solid Waste Management Branch, Department of Natural Resources & Environmental Control, Box 1401, Dover, DE 19901

District of Columbia
Angelo Tompros, Chief, Department of Consumer & Regulatory Affairs, Pesticides & Hazardous Waste Management, Room 112, 5010 Overlook Avenue, S.W., Washington, DC 20032

Florida
Robert W. McVety, Administrator, Solid Waste Section, Department of Environmental Regulations, Twin Towers Office Building, Room 421, 2600 Blair Stone Road, Tallahassee, FL 32301

Georgia
John Taylor, Chief, Land Protection Branch, Environmental Protection Division, Department of Natural Resources, 270 Washington Street, S.W., Room 822, Atlanta, GA 30334

Hawaii
Melvin Koizumi, Deputy Director, Enironmental Health Division, Department of Health, Box 3378, Honolulu, HI 96801

Idaho
Robert Olson, Supervisor, Hazardous Materials Bureau, Department of Health & Welfare, State House, Boise, ID 83720

Illinois
Robert Kuykendall, Manager, Division of Land Pollution Control, Environmental Protection Agency, 2200 Churchill Road, Room A-104, Springfield, IL 62706

William Child, Deputy Manager, Division of Land Pollution Control, Environmental Protection Agency, 2200 Churchill Road, Room A-104, Springfield, IL 62706

Indiana
David Lamm, Director, Land Pollution Control Division, State Board of Health, 1330 W. Michigan Street, Room A-304, Indianapolis, IN 46206

Iowa
Ronald Kolpa, Hazardous Waste Program Coordinator, Department of Water, Air & Waste Management, Henry A. Wallace Building, 900 E. Grand, Des Moines, IA 50319

Kansas
Dennis Murphey, Director, Bureau of Environmental Sanitation, Department of Health & Environment, Forbes Field, Buliding 321, Topeka, KS 66620

Kentucky
J. Alex Barber, Director, Division of Waste Management, Bureau of Environmental Protection, Department for Natural Resources & Environmental Protection, 18 Reilly Road, Frankfort, KY 40601

Louisiana

Gerald J. Healy, Administrator, Solid Waste Management Division, Department of Environmental Quality, Box 44066, Baton Rouge, LA 70804

Glenn Miller, Administrator, Hazardous Waste Management Division, Department of Environmental Quality, Box 44066, Baton Rouge, LA 70804

Maine

David Boulter, Director, Licensing & Enforcement Division, Bureau of Oil & Hazardous Materials, Department of Environmental Protection, State House, Station 17, Augusta, ME 04333

Maryland

Bernard Bigham, Waste Management Administration, Department of Health & Mental Hygiene, 201 W. Preston Street, Room 212, Baltimore, MD 21201

Alvin Bowles, Chief, Hazardous Waste Division, Waste Management Administration, Department of Health & Mental Hygiene, 201 W. Preston Street, Baltimore, MD 21201

Ronald Nelson, Director, Waste Management Administration, Office of Environmental Programs, Department of Health & Mental Hygiene, 201 W. Preston Street, Room 212, Baltimore, MD 21201

Massachusetts

William Cass, Director, Division of Hazardous Waste, Department of Environmental Quality Engineering, 1 Winter Street, Boston, MA 02108

Michigan

Delbert Rector, Chief, Hazardous Waste Division, Environmental Protection Bureau, Department of Natural Resources, Box 30028, Lansing, MI 48909

Allan Howard, Chief, Office of Hazardous Waste Management, Environmental Services Division, Department of Natural Resources, Box 30028, Lansing, MI 48909

(Hazardous Waste, Liquid), David Dennis, Chief, Oil & Hazardous Materials Control Section, Water Quality Division, Department of Natural Resources, Box 30028, Lansing, MI 48909

John L. Hesse, Chief, Chemicals & Health Center, Michigan Department of Public Health, Box 30035, Lansing, MI 48909

Minnesota

Dale L. Wikre, Director, Solid & Hazardous Waste Division, Pollution Control Agency, 1935 W. County Road B-2, Roseville, MN 55113

Mississippi

Jack M. McMillan, Director, Division of Solid & Hazardous Waste Management, Bureau of Pollution Control, Department of Natural Resources, Box 10385, Jackson, MS 39209

Missouri
Dave Bedan, Director, Solid Waste Management Programm, Department of Natural Resources, State Office Building, Box 1368, Jeferson City, MO 65102

Montana
Duane L. Robertson, Chief, Solid Waste Management Bureau, Department of Health & Environmental Sciences, Cogswell Building, Helena, MT 59602

Nebraska
Mike Steffensmeier, Hazardous Waste Section, Department of Environmental Control, State House Station, Box 94877, Lincoln, NE 68409

Nevada
Verne Rosse, Director, Waste Management Program, Division of Environmental Protection, Department of Conservation & Natural Resources, Capitol Complex, Carson City, NV 89701

New Hampshire
Brian Strohm, Assistant Director, Division of Public Health Services, Office of Waste Management, Department of Health & Welfare, Health & Welfare Building, Hazen Drive, Concord, NH 03301

New Jersey
Michael DeBonis, Director, Solid Waste Administration, Division of Environmental Quality, Department of Environmental Protection, 32 E. Hanover Street, CN-027, Trenton, NJ 08625

New Mexico
Tony Drypolcher, Chief, Ground Water & Hazardous Waste Bureau, Environmental Improvement Division, New Mexico Health & Environment Department, Box 968, Santa Fe, NM 87504

Peter Pache, Program Manager, Hazardous Wastes Section, Ground Water & Hazardous Waste Bureau, New Mexico Health & Environment Department, Box 968, Santa Fe, NM 87504

New York
Norman H. Nosenchuck, Director, Division of Solid Waste, Department of Environmental Conservation, 50 Wolf Road, Room 209, Albany NY 12233

North Carolina
William L. Meyer, Head, Solid & Hazardous Waste Management Branch, Division of Health Services, Department of Human Resources, Box 2091, Raleigh, NC 27602

North Dakota
Jay Crawford, Director, Division of Environmental Waste Management & Research, Department of Health, 1200 Missouri Avenue, 3rd Floor, Bismarck, ND 58505

Ohio
Steven White, Chief, Division of Solid & Hazardous Waste Management, Office of Land Pollution Control, Ohio EPA, 361 E. Broad Street, Columbus, OH 43215

Oklahoma
H. A. Craves, Chief, Industrial & Solid Waste Services, Oklahoma State Department of Health, Box 53551, 1000 N.E. 10th Street, Room 803, Oklahoma City, OK 73152

Oregon
Ernest A. Schmidt, Administrator, Solid Waste Management Division, Department of Environmental Quality, Box 1760, 522 S.W. Fifth Avenue, Portland OR 97207

Pennsylvania
Donald A. Lazarchik, Bureau of Solid Waste Management, Department of Environmental Resources, Fulton Building, 8th Floor, Box 2063, Harrisburg, PA 17120

Rhode Island
John S. Quinn Jr., Chief, Solid Waste Management Program, Department of Environmental Management, 204 Cannon Building, 75 Davis Street, Providence, RI 02908

South Carolina
Robert E. Malpass, Chief, Bureau of Solid & Hazardous Wsate Management, South Carolina Department of Health & Environmental Control, J. Marion Simms Building, 2600 Bull Street, Columbia, SC 29201

South Dakota
Joel C. Smith, Administrator, Office of Air Quality & Solid Waste, Department of Water & Natural Resources, Joe Foss Building, Pierre, SD 57501

Tennessee
Tom Tiesler, Director, Division of Solid Waste Management, Bureau of Environmental Services, Tennessee Department of Public Health, 150 Ninth Avenue, N., Nashville, TN 37203

Texas
Jack Carmichael, Chief, Bureau of Solid Waste Management, Texas Department of Health, 1100 W. 49th Street, T-602, Austin, TX 78756

Harry Pruett, Director, Permits Division, Texas Department of Water Resources, 1700 N. Congress, Room 237-1, Box 13087, Capitol Station, Austin, TX 78711

Utah
Dale Parker, Director, Bureau of Solid & Hazardous Waste Management, Department of Health, Box 2500, 150 W. North Temple, Salt Lake City, UT 84110

Vermont
Richard A. Valentinetti, Director, Air & Solid Waste Programs, Agency of Environmental Conservation, State Office Building, Box 489, Montpelier, VT 05602

Virginia
William F. Gilley, Director, Division of Solid & Hazardous Waste Management,
Virginia Department of Health, Monroe Building, 11th Floor, 101 N. 14th
Street, Richmond, VA 23219

Washington
Earl Tower, Supervisor, Solid Waste Management Division, Department of
Ecology, Olympia, WA 98504

West Virginia
Timothy Laraway, Chief, Division of Water Resources, 1201 Greenbrier Street,
Charleston, WV 25311

Wisconsin
Paul Didier, Director, Bureau of Solid Waste Management, Department of Natural
Resources, Box 7921, Madison, WI 53707

Wyoming
Charles Porter, Supervisor, Solid Waste Management Program, State of Wyoming,
Department of Environmental Quality, Equality State Bank Building, 401 W. 19th
Street, Cheyenne, WY 82002

APPENDIX F

STATE EDUCATION AGENCY COORDINATORS FOR ENVIRONMENTAL EDUCATION

(from 1983 Conservation Directory, National Wildlife Federation, Washington, DC, 1983)

Alabama
Alabama Department of Education, 111 Colesium Boulevard, Montgomery, AL 36193; phone 205/832-5850

Alaska
Vocational Education, Alaska Department of Education, Pouch F, Juneau, AK 99811; phone 907/465-2980

Arkansas
Economic, Energy, Environmental, and Conservation Education, Arkansas Department of Education, Arch Ford Building, Room 404-B, Little Rock, AR 72201; phone 501/371-2791

California
Environmental/Energy Education, California Department of Education, 721 Capitol Mall, Sacramento, CA 95814; phone 916/323-2602

Colorado
Conservation Education Services, CDE/DOW, Colorado Department of Education, State Office Building, #435, 201 E Colfax, Denver, CO 80203; phone 303/866-5719

Connecticut
Connecticut Department of Education, PO Box 2219, Hartford, CT 06115; phone 203/566-4825

Delaware
Science/Environmental Education, Delaware Department of Public Instruction, Townsend Building, PO Box 1402, Dover, DE 19901; phone 302/736-4885

Florida
Office of Energy and Environmental Education, Florida Department of Education, Knott Building, Tallahassee, FL 32301; phone 904/488-6547

Georgia
Georgia Department of Education, State Office Building, Atlanta, GA 30334; phone 404/656-2575

Hawaii
Environmental Education, Hawaii Department of Education, 1270 Queen Emma Street, Room 1102, Honolulu, HI 96813; phone 808/548-5914

Idaho
Idaho Department of Education, 650 W State Street, Boise, ID 83720;
phone 208/334-2281

Illinois
Illinois State Board of Education, 100 N First Street, Springfield, IL 62777;
phone 217/782-2826

Indiana
Energy Eduction, Division of Curriculum, Indiana Department of Public
Instruction, Room 299, State House, Indianapolis, IN 46204; phone 317/927-0111

Iowa
Environmental Education, Curriculum Division, Iowa Department of Public
Instruction, Grimes Office Building, Des Moines, IA 50319; phone 515/281-3146

Kansas
Kansas Department of Education, 120 E 10th, Topeka, KS 66612;
phone 502/564-2672

Kentucky
Environmental Eduction, Kentucky Department of Eduction, Room 1829, Capitol
Plaza Tower, Frankfort, KY 40601; phone 502/564-2672

Louisiana
Science, Energy, and Environmental Education, Louisiana Department of
Education, PO Box 44064, Baton Rouge, LA 70804; phone 504/342-3420

Maine
Maine State Department of Educational and Cultural Services, State House
Station #23, Augusta, ME 04333; phone 207/582-1332

Maryland
Curricular Programs Section, Office of Curriculum Development, Maryland
Department of Education, 200 W Baltimore Street, Baltimore, MD 21201;
phone 301/659-2323

Michigan
Michigan Department of Education, PO Box 30008, Lansing, MI 48909;
phone 517/373-8793

Minnesota
Environmental Education, Minnesota Department of Education, 644 Capitol Square
Building, St. Paul, MN 55101; phone 612/296-4069

Mississippi
Science and Environment Education, Mississippi Department of Education, PO Box
771, Jackson, MS 39205; phone 601/354-6955

Missouri
Health, Physical Education, Safety, and Environmental Education, Missouri Department of Elementary and Secondary Education, PO Box 480, Jefferson, MO 65102; phone 314/751-2625

Montana
Social Studies, Environmental Education, Montana Office of Public Instruction, State Capitol Building, Helena, MT 59601; phone 406/449-3126

Nebraska
Nebraska Department of Education, PO Box 94987, Lincoln, NE 68509; phone 402/471-4329

Nevada
Nevada Department of Education, 400 W King Street, Capitol Complex, Carson City, NV 89710; phone 702/885-5700

New Hampshire
Science Education, New Hampshire Department of Education, 64 N Main Street, Concord, NH 03301; phone 603/271-3293

New Jersey
General Education Services, New Jersey Department of Education, Division of School Programs, 225 W State Street, Trenton, NJ 08625; phone 609/292-8777

New Mexico
Science and Conservation, New Mexico Department of Education, State Education Building, Santa Fe, NM 87503; phone 505/827-5391

New York
Environmental Education, New York State Department of Education, Room 314H, Albany, NY 12234; phone 518/474-5890

North Carolina
Division of Science, North Carolina Department of Public Instruction, Raleigh, NC 27611; phone 919/733-3694

North Dakota
Science and Mathematics, North Dakota Department of Public Instruction, State Capitol, Bismarck, ND 58505; phone 701/224-2265

Ohio
Office of Environmental Education, Ohio Department of Education, 65 S Front Street, Room 811, Columbus, OH 43215; phone 614/466-5015

Oklahoma
Oklahoma Department of Education, Oliver Hodge Building, 2500 N Lincoln, Oklahoma City, OK 73105; phone 405/521-3361

Oregon
Energy/Environment Education, Oregon Department of Education, 700 Pringle Parkway, SE, Salem, OR 97310; phone 503/378-2120

Pennsylvania
Environmental Education, Bureau of Curriculum Services, Pennsylvania Department of Education, 333 Market Street, Box 911, Harrisburg, PA 17108; phone 717/783-3958

Rhode Island
Rhode Island Department of Education, 22 Hayes Street, Providence, RI 02908; phone 401/277-2652

South Carolina
Environmental Education, South Carolina Department of Education, 803 Rutledge Building, Columbia, SC 29201; phone 803/758-2652

South Dakota
South Dakota Department of Elementary and Secondary Education, Kneip Building, Pierre, SD 57501; phone 605/741-2851

Tennessee
Conservation Education, Tennessee Department of Education, Tennessee Tech., Box 5077, Cookville TN 38501; phone 615/741-2851

Tennessee Department of Education, Memphis State University, Memphis, TN 38152; phone 901/454-2980

Texas
Science/Environmental Education, Texas Education Agency, 201 E 11th Street, Austin, TX 78701; phone 512/475-2608

Utah
Science Education, Utah State Office of Education, 250 E 500 South, Salt Lake City, UT 84111; phone 801/533-6040

Vermont
Science, Energy, and Environmental Education, Vermont Department of Education, 120 State Street, Montpelier, VT 05602; phone 802/828-3111

Virginia
Virginia Department of Education, Science Service, PO Box 6Q, Richmond, VA; phone 804/225-2651

Washington
Science and Environmental Education Programs, Office of the State Superintendent of Public Instruction, Washington, 7510 Armstrong Street, SW, Tumwater, WA 98504; phone 206/753-2574

West Virginia
West Virginia Department of Education, Capitol Complex, Room B-330, Building 6, Charleston, WV 25305; phone 304/348-7805

Wisconsin
Environmental, Energy, and Marine Education, Wisconsin Department of Public Instruction, 125 S Webster Street, Madison, WI 53702; phone 608/267-9266

Wyoming
Science/Mathematics/Environmental Education, Wyoming Department of Education, 241 Hathaway Building, Cheyenne, WY 82002; phone 307/777-6247