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Project Summary

Point-Of-Use Treatment to Control Organic and Inorganic Contaminants in Drinking Water

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Several communities using point-of-use (POU) treatment technology for drinking water contaminant removal were studied under a cooperative agreement between the U.S. Environmental Protection Agency (EPA) and the National Sanitation Foundation (NSF). Study sites included communities in Pennsylvania and New Jersey using POU activated carbon devices for reduction of volatile halogenated organics; Arizona and Illinois communities using POU activated alumina devices for fluoride reduction; and an Illinois community using POU reverse osmosis devices for fluoride and dissolved solids reduction. In addition, central treatment with activated alumina for fluoride reduction was evaluated at two operating plants in Arizona.

At all locations, POU devices provided effective treatment for several months of operation. Average estimated monthly costs per site for purchase, installation, and maintenance of treatment devices ranged from $4.25 to $6.23 for activated alumina and activated carbon treatment, and were $12.48 for reverse osmosis. Although most POU installations operated without problems from the time of installation, a few devices required unplanned service. Management of POU devices is necessary to ensure ongoing, effective treatment.

This Project Summary was developed by EPA's Water Engineering Research Laboratory, Cincinnati, OH, to announce key findings of research projects that are fully documented in three separate reports: "Defluoridation of Drinking Water in Small Communities" (EPA/600/2-85/110). "Point-Of-Use Reduction of Volatile Halogenated Organics in Drinking Water" (EPA/600/2-85/109), and "Management of Point-Of-Use Drinking Water Treatment Systems" (EPA/600/2-85/111) (see Project Report ordering information at back).

Introduction

Small communities with contaminated drinking water supplies often lack the financial resources and technical expertise to effectively deal with the problem. High initial capital costs can prohibit construction of a central treatment system for contaminant removal in many cases. Constructing a new well or connecting to a neighboring water supply may not be feasible. One alternative solution is treatment of contaminated water at the point-of-use (POU).

Although POU treatment may present an efficient, cost effective solution to drinking water contamination, there may be potential problems associated with losing the level of control associated with central treatment systems. When POU treatment is the selected alternative, a sound program for management of POU drinking water treatment systems is necessary to ensure that all sites receive the desired quality of drinking water.

Procedures

POU treatment was studied in several communities by monitoring existing installations or by installing and monitoring new devices. All POU study sites used a form of the line-bypass approach to treatment. Line-bypass devices are designed to treat only water intended for consumption. With this approach, the cold water line is tapped to provide influent to a treatment device. A separate tap for treated water is provided at the sink.

Site selection was based on community interest, quality of source water, logistics for water sampling, and the approach to treatment. POU devices were purchased from equipment manufacturers or distributors and installed by licensed plumbing contractors. Water sample collectors were selected and trained by NSF. Collection, preservation, and analysis of water samples were in accordance with prescribed EPA methods.

Bacteriological quality of predevice and postdevice water was monitored at all POU sites with Standard Plate Counts (SPCs) and coliform enumeration. To simulate water that would be consumed if the faucet were not allowed to run before water was drawn, samples were collected from unflushed, undisinfected taps. For comparative purposes, samples were collected from disinfected taps that were flushed for 2 to 3 min. In some cases, samples were also collected from taps that were flushed for 1L.

Cost information for POU treatment in the Illinois and Pennsylvania communities was based on actual cost data collected during the project. Cost data from other sites were supplied by equipment manufacturers and/or municipalities. Maintenance costs for POU devices were calculated using manufacturers' rated service volumes and the average volume of treated water.

In the Village of Silverdale, PA, 49 POU activated carbon (AC) devices, representing products from several manufacturers, were installed and monitored for 14 months of operation for control of volatile organic chemicals (VOCs), most notably trichloroethylene (TCE) and tetrachloroethylene (PCE). In the Lake Telemark subdivision of Rockaway Township, NJ, the township health department and a manufacturer of POU AC devices began a pilot demonstration in 1981 by installing and monitoring devices in 12 homes with wells contaminated with organics. Performance verification and review of cost data were included in this study.

Arizona communities using POU activated alumina (AA) devices for fluoride reduction included Thunderbird Farms and Papago Butte Ranches, where separate distribution systems are provided for irrigation and domestic water. A portion of the domestic water is bypassed and treated with AA for potable uses. Domestic water boards for both communities provide installation, monitoring, and maintenance of treatment devices. POU treatment with AA for arsenic and/or fluoride reduction was studied at two Arizona institutions, the Ruth Fisher Elementary School located near Tonopah and the You & I Trailer Park located new Wintersburg.

At the three Illinois project sites, the public water systems are supplied by well water with high fluoride, alkalinity, and dissolved solids. Project demonstrations included installation and monitoring of 10 POU AA devices in Parkersburg and 40 POU AA devices in Bureau Junction. In Emington, 47 low-pressure POU reverse osmosis (RO) devices were installed and monitored for 8 mo. These sites were the first applications of POU fluoride reduction at the community level in Illinois.

Central AA treatment plants, located at Gila Bend and Palo Verde, AZ, provided a basis for comparison of two small, but different sized, central facilities. The Gila Bend plant has been operating since May 1978; the Palo Verde plant has been operating since December 1979. In addition, a pilot study was performed in North Myrtle Beach, SC, to estimate AA central treatment costs. A summary of all project sites appears in Table 1.

Table 1. Site Summary

Site	Treatment Approach	Treatment Process	Application
Gila Bend, AZ	Central	AA	Fluoride Reduction
Palo Verde, AZ	Central	AA	Fluoride Reduction
North Myrtle Beach, SC	Central	AA	Cost Estimate for Fluoride Reduction
Thunderbird Farms, AZ	POU	AA	Fluoride Reduction
Papago Butte, AZ	POU	AA	Fluoride Reduction
Ruth Fisher School, AZ	POU	AA	Fluoride Reduction
You & I Trailer Park, AZ	POU	AA	Fluoride & Arsenic Reduction
Parkersburg, IL	POU	AA	Fluoride Reduction
Bureau Junction, IL	POU	AA	Fluoride Reduction
Emington, IL	POU	RO	Fluoride & Dissolved Solids Reduction
Silverdale, PA	POU	AC	Organics Reduction
Rockaway Township, NJ	POU	AC	Organics Reduction

Results and Discussion

Volatile Halogenated Organics Reduction

The major VOCs in Silverdale's water supply were TCE and PCE. POU devices reduced concentrations of these contaminants to nondetectable levels (<0.001 mg/L) in 87 percent of the samples collected over 14 mo. The mean volume treated during this period was 340 gal; maximum volume treated was 1130 gal. Devices were still in operation at the end of the study.

Breakthrough, defined as detection of the same VOC in consecutive post-device samples from the same site at concentrations above 0.001 mg/L, did not occur for any device for TCE or PCE during 14 mo of sampling. However, trace concentrations of VOCs were detected intermittently in postdevice samples from each model type; concentrations were generally below 0.005 mg/L. The most frequently measured post-device VOC was chloroform. Although the mean influent chloroform concentration was 12 times less than the mean TCE concentration, chloroform may break through before TCE. This is supported by isotherm data typical for activated carbon.

The capital cost for POU AC treatment in Silverdale ($289) was an average cost of purchasing devices from several manufacturers (in quantity) and equipping them with product water meters. Maintenance costs included an average monthly repair cost per site of $1.43. Some POU devices required no maintenance during the study.

In the Lake Telemark subdivision of Rockaway Township, 12 POU AC devices were installed on private well water supplies in October 1981. Only one of 21 postdevice samples collected from October 1982 through October 1983 contained detectable VOCs (0.004 mg/L TCE and 0.002 mg/L PCE). Eight sites were sampled during the 24th month of operation with no detectable VOCs in effluent samples. After 2 yr of service, the average cumulative volume treated was approximately 1650 gal, based on readings taken from a flow indicator on the device. A device sampled after reaching its estimated treatment capacity of 2000 gal produced water with no detectable VOCs.

Equipment costs of POU AC devices in Rockaway ($225) were negotiated by the community during an initial phase of the pilot demonstration. No maintenance was reported during the 2-yr pilot demonstration period. A summary of results from demonstrations of POU AC devices in Silverdale and Rockaway Township appears in Table 2.

Table 2. *POU Activated Carbon Studies*

	Silverdale, PA	*Rockaway Township, NJ*
Participating Sites	*49*	*12*
Service Area Type	*central system with single family homes*	*private wells at single family homes*
Mean Treated Water Use (gpd)	*1.0*	*2.3 est.*
Trichloroethylene (mean mg/L)[1]		
Predevice	*0.080*	*0.125*
Postdevice	*<0.001*	*<0.001*
1,1,1-Trichloroethane (mean mg/L)[1]		
Predevice	*0.001*	*0.092*
Postdevice	*<0.001*	*<0.001*
Costs		
Capital ($)[2]	*289*	*255*
To Customer ($/month)[3]	*5.98*	*4.23*

[1]Samples containing <0.001 mg/L were assigned a value of 0.0009 mg/L for calculation of the mean.
[2]Average of five manufacturers; includes equipment + installation costs.
[3]Capital, amortized at 10% for 20 years + maintenance.

Activated Alumina Defluoridation

Several treatment runs from the AA central treatment plants were evaluated by collecting and analyzing water samples and by reviewing plant records. Fluoride exchange capacities ranged between 1840 and 2600 grains/ft^3 (4210-5950 grams/m^3) for Gila Bend and between 2260 and 3540 grains/ft^3 (5170-7890 grams/m^3) for Palo Verde. Average media attrition rates per regeneration were 1.2 percent of bed volume for Gila Bend and 2.8 percent for Palo Verde. Most media attrition appeared to occur during regeneration.

Although the plant at Palo Verde demonstrated higher fluoride exchange capacity than at Gila Bend, operating costs were also higher. Central treatment production costs (amortized capital costs plus operating costs) per 1000 gal were $0.45 for Gila Bend and $5.37 for Palo Verde. Higher chemical consumption rates (i.e., stronger regenerant) and very low production contributed to the higher cost. The use of part-time, inexperienced operators at Palo Verde resulted in inefficient operation at times.

At North Myrtle Beach, a pilot demonstration was performed to develop a cost estimate for construction and operation of central treatment facilities. Because North Myrtle Beach's water supply consists of 10 wells in dispersed locations, the proposed system was a group of 10 small (200,000 gpd) central plants. Estimated production costs were $0.57 per 1000 gal.

At Thunderbird Farms, several POU AA devices reduced influent fluoride levels effectively for periods exceeding 2 yr. Other AA devices operating at Thunderbird Farms had shorter service lives, attributed to media cementing and/or short-circuiting. At the You & I Trailer Park, raw water fluoride concentration was 15.7 mg/L and arsenic was 0.086 mg/L. A POU AA device effectively treated 2500 gal (330 bed volumes) before fluoride breakthrough, demonstrating the highest exchange capacity observed for POU devices (2300 grains/ft^3). Influent arsenic and silica concentrations at Arizona POU sites generally were reduced to nondetectable levels beyond fluoride breakthrough.

POU AA devices installed in Parkersburg and Bureau Junction were equipped with valves; this allowed partial bypassing of raw water to provide optimal fluoride concentrations by blending treated and untreated water. Valve settings were controlled with a colorimetric test kit during sample collection.

The effect of raw water alkalinity is demonstrated in the data from Illinois sites, which included a pilot demonstration in Emington. The higher alkalinity at Parkersburg caused fluoride breakthrough at a lower mean cumulative bed volume (110 bed volumes) than at Emington (190 bed volumes). Breakthrough at Bureau Junction, with the lowest alkalinity, was not observed until 350 bed volumes. Part of the reduced capacity at Emington must be attributed to the accelerated flow (370 gpd) during the pilot study.

Maintenance costs for POU AA devices were based on replacing the alumina cartridge when treated water fluoride levels reached the local Maximum Contaminant Level (MCL). For Arizona, the MCL was 1.4 mg/L, and for the Illinois communities, it was 1.8-2.0 mg/L. Summaries of results from Arizona and Illinois POU AA sites appear in Table 3 and Table 4, respectively.

Low-Pressure Reverse Osmosis

POU RO systems installed in Emington used a spiral-wound polyamide RO membrane operated at line pressure. Pretreatment included granular activated carbon (GAC) followed by a 5-μ prefilter. Product water was stored in a 2-gal pressurized tank. Reject water was bled through a capillary tube to the home drain line. Product water from the storage tank passed through a GAC polisher before being dispensed.

Fluoride rejection averaged 86 percent, with total dissolved solids rejection (TDS) averaging 79 percent. Relatively large ranges of rejection percentages were observed for all analytes. This phenomenon did not correlate with site, use rate, or collection date, but appeared to be due in part to a pressure drop across the prefilter assembly. Flow rates were measured for several RO devices during a site visit. Ranges of product and reject flow rates were 1.3 to 4.4 gpd and 16.1 to 27.8 gpd, respectively. Water temperatures and pressures (measured at hose connections) did not correlate with flow rates. Iron deposits in the well and distribution system fouled some GAC prefilters, creating head loss across the pretreatment assembly. One GAC prefilter which had been fouled with iron deposits was removed, flushed, and reinstalled. The resulting 33 percent production rate increase was accompanied by a 29 percent increase in solids rejection, implying a constant flux of solids across the RO membrane, i.e., more water was produced for essentially the same mass of solids, resulting in higher quality water.

The capital cost for POU RO at Emington ($540) was an average of several manufacturers' quotes for devices, with and without pressurizing pumps, based on purchase of 40 to 50 units. The average installation cost per unit of $68 (performed by an equipment dealer) was included.

Costs for central RO treatment at Emington were estimated by soliciting a quote; they included approximately $60,000 for a central RO system (including mechanical and electrical installation) and $60,000 for a concrete block building. Estimated operating costs per 1000 gal of product water included chemicals ($0.10), power for pumps ($0.36), membrane replacement every 5 yr ($0.18), and prefilter cartridge replacement ($0.02). Monthly customer costs were based on the design flow of 16,500 gpd. A summary of the Emington RO demonstration appears in Table 5.

Bacteriological Sample Results

Standard Plate Counts (SPCs) from the AC sites indicated microbial colonization of the carbon bed. In Silverdale, unflushed postdevice samples had mean densities two orders of magnitude higher than corresponding predevice samples. If 1L of water was flushed from the line before sampling, postdevice samples had mean densities only one order of magnitude higher than predevice samples. Samples of water collected after 2 min of flushing had SPC densities comparable to samples of water from the distribution system. In Rockaway, flushing and disinfecting the tap reduced SPCs by one order of magnitude. Data collected during the study did not indicate colonization of AC devices by coliform organisms. Positive coliform results in Silverdale were obtained from 4 of 176 postdevice samples collected from flushed, disinfected taps. Postdevice re-

Table 3. *Arizona POU Activated Alumina Studies*

	Thunderbird Farms	Papago Butte	Ruth Fisher School	You & I Trailer Park
Participating Sites	8	1	1	1
Service Area Type	central system with single family homes	subsystem for several families	institution	institution
Influent Fluoride (mg/L)	2.6	2.6	4.4	15.7
Influent Alkalinity (mg/L as $CaCO_3$)	200	200	80	40
Mean Treated Water Use (gpd)	1.4	18.5	8.5	5.5
Volume to Breakthrough[1]				
(gallons)	>1540	9500	1000	2500
(bed volumes)	>410	1270	270	330
Costs				
Capital ($)	225	350	360	230
To Customer ($/month)[2]	4.44	4.60	12.00	6.27

[1]Defined as the point where postdevice fluoride concentration reached the local MCL.
[2]Capital, amortized at 10% for 20 years + maintenance.

Table 4. *Illinois POU Activated Alumina Studies*

	Parkersburg	Bureau Junction	Emington
Participating Sites	10	40	1
Service Area Type	central system with single family homes	central system with single family homes	pilot study
Influent Fluoride (mg/L)	6.6	6.0	4.5
Influent Alkalinity (mg/L as $CaCO_3$)	1000	540	880
Mean Treated Water Use (gpd)	0.6	0.8	370
Volume to Breakthrough[1]			
(gallons)	400	1300	700
(bed volumes)	110	350	190
Costs			
Capital ($)	273	285	273 est.
To Customer ($/month)[2]	6.23	4.25	5.38 est.

[1]Defined as the point where postdevice fluoride concentration reached the local MCL.
[2]Capital, amortized 10% for 20 years + maintenance.

Table 5. *Emington, Illinois, POU Reverse Osmosis Study*

Participating Sites	47
Service Area Type	central system with single family homes
Mean Treated Water Use (gpd)	0.8
Mean Flow Rates (gpd)	
Product Water	2.9
Reject Water	22.5
Fluoride (mean mg/L)	
Predevice	4.5
Postdevice	0.6
Total Dissolved Solids (mean mg/L)	
Predevice	2530
Postdevice	520
POU Treatment Costs	
Capital ($)[1]	540
To Customer ($/month)[2]	12.48
Estimated Central Treatment Costs	
Capital ($)	122,000
To Customer ($/month)[2]	28.80

[1]Average of six manufacturers; includes equipment + installation costs.
[2]Capital, amortized at 10% for 20 years + maintenance.

samples were negative for coliform organisms. No coliforms were detected in postdevice samples collected in Rockaway.

Bacteriological samples collected at AA POU sites indicated microbial colonization of the alumina bed, though not as great as with activated carbon. At the Arizona sites, slight increases in SPCs through AA devices were observed. Flushing reduced SPCs by a small margin. No coliforms were detected in Arizona AA postdevice samples. In Bureau Junction, postdevice SPCs were highest when devices were first placed in operation, and decreased with use. There was no evidence of colonization of AA devices by coliform organisms. Out of 153 samples, coliforms were detected in 9 predevice samples and 4 postdevice samples. One unit maintained consistent positive coliform results and was removed from service. Resamples from other units were negative for coliforms. In Parkersburg, postdevice SPCs were highest when no influent chlorine residual was detected. Flushing and disinfecting taps reduced postdevice SPCs by an order of magnitude. No coliforms were detected in 80 Parkersburg postdevice samples.

SPC results from Emington (RO & AC) demonstrated an order of magnitude increase through the treatment system. Limited sampling from stages in the RO & AC system indicated that most bacterial growth was occurring in the AC polisher. Of 92 samples, coliforms were detected in 4 predevice and 11 postdevice samples. One site was resampled twice before postdevice samples were clear, and another site required disinfection of the RO system twice before resamples were acceptable. Resamples from other units were acceptable.

Summary and Conclusions

Both central and POU AA treatment are effective in reducing fluoride levels in otherwise potable water. POU treatment with AA appears to be cost competitive with central treatment for communities having 330 to 710 service connections. Raw water quality (i.e., alkalinity) and water comsumption determine the operational life of the POU AA device and have significant impact on costs. Low-pressure POU RO treatment was effective in reducing fluoride and total dissolved solids from a brackish groundwater supply. POU AC treatment devices effectively reduced concentrations of trichloroethylene, tetrachloroethylene, carbon tetrachloride, 1,1,1-trichloroethane, 1,1-dichloroethylene, 1,1-dichloroethane, and chloroform at influent concentrations studied.

Monitoring is required to ensure consistent performance on a community level. For AA devices, monitoring may be accomplished with field tests. For VOC reduction in most cases, it is more cost effective to replace AC cartridges prematurely than to pay for frequent analysis. For this method to be effective, relatively consistent source water quality is required.

Microorganisms, measured by the standard plate count method, were present in higher numbers in postdevice water than in predevice water. Variation of sampling techniques for collecting bacteriological samples from POU devices significantly affected results. Flushing taps can significantly improve bacteriological quality. The occurrence of coliforms in postdevice samples appeared to be associated with the bacteriological quality of the source water.

Recommendations

A sound program for management of POU treatment systems is necessary to ensure that the desired level of treatment is provided to all sites, that prescribed monitoring and maintenance are carried out, and that the system is in compliance with applicable regulations. This may be accomplished through formation of a water quality district, an independent corporate body. The district obtains funding, incurs costs, and assumes responsibility for the treatment system. The district may resemble existing districts created for water supply, wastewater discharge, or solid waste disposal. For POU treatment to be considered as a means of compliance with regulations, regulatory agencies may require the establishment of a clearly defined body to assume responsibility for the system. Formation of an officially sanctioned district may also open avenues for funding not otherwise available. The basic management functions of a water quality district include determination of the best treatment approach, equipment selection, coordination of equipment installation, monitoring and maintenance, district administration, and education and public notification.

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This Project Summary covers three separate reports, entitled:
"Point-of-Use Reduction of Volatile Halogenated Organics in Drinking Water," (Order No. PB 86-107 711/AS; Cost: $11.95)
"Defluoridation of Drinking Water in Small Communities," (Order No. PB 86-109 337/AS; Cost: $16.95)
"Management of Point-of-Use Drinking Water Treatment Systems," (Order No. PB 86-105 285/AS; Cost: $11.95)
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