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Water Treatment Technologies For Small Communities

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by

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INTRODUCTION

There are approximately 200,000 public water systems in the United States. Approximately 31% are community water systems which serve primarily residential areas and 91% of the population [1]. Of the 60,000 community water systems that serve about 219 million people, 51,000 were classified as 'small' or 'very small'. The tens of thousands of very small regulated community systems (less than 500 population served) will have difficulty in complying with the large number of regulated contaminants or in instituting Best Available Technology (BAT).

Regulations promulgated under the Safe Drinking Water Act and its Amendments (SDWAA) apply to all drinking water systems which have at least fifteen connections or regularly serve an average of at least twenty-five individuals daily at least 60 days out of the year. Bringing small water systems into compliance, given their current problems and the pending regulations, will require flexibility in terms of technology applications and institutional arrangements. The most significant requirements for small systems in the United States are low construction and operating costs, simple operation, adaptability to part-time operation, low maintenance, and no serious sludge problems. In addition to small central systems there are numerous private homeowners, non-community, and transient water consumers potentially at risk from contaminated drinking water.

Small systems (<3,300 people served) are the most frequent violators of federal regulations and accounted for nearly 89% of the violations posted. These violations consisted of both reporting violations and actual SDWAA Maximum Contaminant Level

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(MCL) violations. Most of the violations fall into the monitoring and reporting (M/R) categories. The small and very small system violations account for approximately 6 million consumers. In most cases, the violations are short term (less than two months).

Because of the litany of problems associated with small systems, many state and federal programs have been established to assist them to come into compliance with current and anticipated regulations. For example, programs have been established to train 'trainers' in the latest methods and technology that are available to aid small utilities. Another concept that is being investigated is the 'composite correction program' that provides specific guidelines or rules for bringing water-treatment facilities into compliance with some of the drinking-water regulations. Unfortunately, for systems serving fewer than 500 people , which account for 93% of MCL and 94% of M/R violations, these programs have achieved limited success. Most of the problem systems are microsystems and serve 25-100 people. They have severe financial and managerial problems and are owned and operated by loosely organized associations which do not qualify for or are not cognizant of finanacial assistance programs. Frequently the operators and managers of these systems are volunteers.

This paper will give a general overview of available technologies for small systems and present some research activities in the small systems area.

AVAILABLE TECHNOLOGIES

Filtration and Disinfection

The most important criteria of water treatment is to produce drinking water safe from microbial illness (2). Both surface water and ground water sources may be contaminated with pathogenic microorganisms. The U.S. Environmental Protection Agency's Surface Water Treatment Rule requires most systems supplied by a surface water source to install and operate approved treatment techniques which achieve at least 99.9 percent reduction (removal and/or inactivation) of *Giardia* cysts and 99.9 percent reduction of enteric viruses. While ground water sources tend to have lower levels of microbial contamination, EPA's Groundwater Disinfection Rule will require comparable levels of protection (inactivation) for groundwater sources(3).

There are several specific filtration processes for microorganism removal and chemical disinfection processes for inactivation that have been proven over time and are generally considered effective treatment methods (Table 1)(3). Filtration is desirable to remove not only microbes, but also turbidity (particulate matter) and dissolved materials ("precursors") that can consume disinfectants and produce problematic byproducts. While it is theoretically possible to completely eliminate microorganisms from source waters by filtration alone, the application of disinfection treatment and maintenance of a disinfectant residual is necessary in the distribution system to control the regrowth of bacteria, pipeline biofilms, and potential contamination from cross-connections.

Filtration can be accomplished using common processes such as conventional filtration, direct filtration, slow sand filtration, pressure filtration, diatomaceous earth (DE) filtration, and membrane filtration, or the less widely used technologies such as deep-bed multi-media filtration (small pressure filters), bag filtration and cartridge filtration. Historically, the most common processes mentioned above are most suitable as centralized drinking water treatment facilities, installed to serve a minimum size customer rate base via an appropriately sized distribution system. While the common treatment processes are successfully downsized for smaller applications (e.g., built on-site or factory constructed package plants installed in small communities), the other filtration processes, deep-bed multi-media, bag and cartridge are more suitable for the even smaller applications.

Small-Scale Conventional Treatment Systems

Conventional water treatment systems employing chemical addition (filtration aids), coagulation, flocculation, sedimentation, filtration and disinfection may be scaled down to sizes appropriate for small systems. As mentioned above, they are often the process of choice for centralized treatment due largely to their cost effectiveness and proven track record. Since they are custom designed to the site and for specific water quality criteria, they require the planning and design services of a professional engineer. When well-designed and properly operated, these systems can meet federal and state regulations for turbidity, filtration and disinfection, as well as minimize particulates, disinfection byproduct precursors and some chemical contaminants.

Slow Sand Filtration

Water treatment by slow sand filtration is one of the earliest treatment technologies, and remains a promising filtration method for small systems with low turbidity source waters. It is a simple and reliable process, relatively inexpensive to build, and can be operated by less skilled personnel. The process consists of percolating untreated water slowly through a bed of porous sand, with the water influent introduced over the surface of the filter and drained from the bottom. Properly constructed, the filter consists of a tank, a bed of fine filter sand, a layer of gravel to support the sand, a system of underdrains to collect the filtered water, and a flow control device to control the filtration rate. No chemicals are added to aid the filtration process.

A thin, biologically active skin layer (called a "schmutzdecke") forms on top of the filter sand during the initial operating period. This schmutzdecke of deposits, microorganisms and attendant biofilm must develop as part of a maturation process before the filter will function optimally. The biological processes in the schmutzdecke enhance removal of contaminants, and once established, maintenance is routine and product water is of adequate quality. No backwashing is required, though after several weeks or months (dependent on influent quality) the filter surface layer becomes clogged and filter flow capacity is reduced. This lost capacity is restored by removing (scraping off) an upper ½ inch (1.3 cm) layer of the filter sand, and returning the filter to service as quickly as possible to keep the biologically active microorganisms within the bed alive.

A disadvantage includes the relatively large land area required for the filter bed, necessitated by the low flow rates per surface area for proper operation. Flow rates may be 50 to 100-fold slower than conventional systems. Because of the low loading rates, storage for maximum peak daily demands is usually necessary.

A packaged slow sand filter is being evaluated at EPA's Test and Evaluation Facility (T&E) in Cincinnati, Ohio. This slow sand filter treats enough water to serve one to two households daily. The modular filters and storage tanks are fiberglass and constructed off-site such that additional tanks can be installed for higher demand situations. A filter blanket is used rather than a schmutzdecke.

Membrane Filtration

A developing technology with good prospects for small systems is membrane filtration. While reverse osmosis (RO) provides the highest level of membrane-based filtration purification, other types of membrane systems may provide suitable alternatives to RO. Semipermeable membranes can be designed with discrete size exclusions to allow selective removal of particulate matter including viruses and bacteria, lower-molecular weight organic contaminants and inorganic chemicals.

They may provide all the purification needed for specific drinking water treatment needs, and because they operate at lower feedwater pressures than most RO membranes, the operating costs are lower than RO as well.

Microfiltration (MF) can remove soluble and insoluble materials down to about 100,000 dalton molecular weight or about 0.1 micron in size. This can disinfect water of bacteria as well as protozoa, but not of all viruses. Generally, suspended particles and large colloids are rejected while small colloids, macromolecules and dissolved solids pass through the membrane. Pressure across the MF membrane is about 10 psi (0.73 k/cm^2).

Ultrafiltration (UF) will remove viruses and other materials down to about 10,000 daltons, though the molecular weight cut-off values range from 1,000 to 10,000, or between 0.005 and 0.1 microns. UF will reject colloids, proteins, microbiological contaminants and large organic molecules; however, all dissolved salts and smaller molecules pass through the membrane. Differential membrane pressures range from 10 to 100 psi (0.73 to 7.03 k/cm^2).

An ultrafiltration (UF) package plant at the T&E consists of a bag pre-filter, optional disinfection, and UF membrane. The unit is 3 feet wide, 7 feet tall, and 12 feet long capable of producing approximately 15 gpm on a continuous basis. A similar unit has been in operation at a research site in West Virginia for over a year. This system is used to provide water to twenty-five homes.

Nanofiltration (NF) can remove chemicals to about 200 daltons with a molecular weight cut-off of 100 to 5,000 or 0.001 to 0.005 microns, though the amount of rejection varies with molecular structure. It is reported that salts with monovalent anions (such as calcium chloride) have rejections of 20 to 80 percent, where salts with divalent anions (magnesium sulfate) have rejections of 90 to 98 percent. As a result, NF systems can remove color and total organic carbon from water, as well as hardness, radium and total dissolved solids. Transmembrane pressures range from 50 to 130 psi (3.5 to 9.1 k/cm^2).

Reverse osmosis filtration can remove almost all inorganic chemicals and, when used in conjunction with activated carbon, most organic chemicals as well. Membranes usually have cut-offs of less than 50 daltons. RO systems have been in wide use in centralized treatment. New applications are continually being developed, and as RO becomes more and more common, the drinking water industry has become more comfortable with the different RO membrane operating parameters and reliability considerations.

Chemical Contaminant Removal

For inorganic contaminants and radionuclides, conventional treatment alone may be effective. Reverse osmosis(RO), ion exchange, activated alumina and granular activated carbon (GAC) have specific applications, and aeration can be most effective for radon removal (Table 2)(3). For most organic contaminants currently regulated by the U.S. EPA, packed-tower aeration and GAC have been specified as BAT. Reverse osmosis removes some organics, and when used in conjunction with GAC, can be superior to other single-process treatment applications. The appropriateness of RO is dependent upon source water quality and disinfection requirements. Table 3 shows the expected performance for various technologies for removing organics from drinking water (3).

As various treatment options are considered, there are operational conditions such as operational skill required, level of maintenance required, and energy requirements that also have to be considered. Table 4 gives an example of these requirements for some of the technologies discussed (1).

PERFORMANCE OF EXISTING SMALL SYSTEMS

A joint field study was conducted by the American Water Works Association and the United States Environmental Protection Agency to evaluate existing small community systems utilizing package plant technology (4). A geographic and technological cross-section of 48 package plant systems were evaluated through an examination of historical water quality and financial records, site visits, and analysis of raw and finished water quality samples taken during the visits. Results indicated that most of the systems were performing adequately; however, a few were exceeding turbidity or inorganic contaminant standards. Standardized levels of operator certification, use and knowledge of technical assistance, and good management practices were lacking in many of the systems. In addition, several would have difficulty meeting portions of the Disinfectant and Disinfection Byproducts Rule or the Enhanced Surface Water Treatment Rule.

INTERNATIONAL ACTIVITIES

In 1993, a new technology initiative, Environmental Technology Initiative (ETI), was developed to yield environmental benefits and increase exports of "green" technologies (5). One of the components of ETI is the U.S. Technology for International Environmental Solutions (U.S. TIES) program. This program was designed to enlist greater participation of the U.S. private sector in achieving U.S. environmental objectives overseas.

Three drinking water projects have been initiated by EPA's Water Supply and Water Resources Division in Cincinnati, Ohio. These projects were selected for countries where it appeared that the greatest potential for success and creation of a market for U.S. products would occur. These three projects are located in Ecuador, Mexico, and China. Each of these countries has similar types of drinking water concerns with problems that are also unique to their country. Below is a description of the demonstration sites and the treatment that will be used at these sites.

ECUADOR

- Hospital Rodriguez Zambrano in Manta - The existing water system at the hospital consisted of a two inch diameter line which goes into two 66,000 gallon tanks. Chlorination was done in these tanks by the addition of liquid chlorine (Chlorox). Aeration was used to mix the liquid chlorine. A swimming pool-type color comparator was used to monitor the chlorine residual. Immediately after chlorine addition, high residual levels were detected which quickly dissipate to non-detectable levels.

Water from the tanks was pumped by three 20 HP pumps through a four inch diameter pipe and distributed with a 60 psi pressure system. Water usage at the hospital is variable with a maximum of 26,000 gal/day. The hospital has 220 beds with an average of 8,672 patients/year and 594 employees. The number one disease in Manta is diarrhea. The number one disease causing death is malnutrition and the fifth is diarrhea.

Modification of treatment consists of using one of the existing 66 gallon tanks for raw water accumulation and storage. The second tank is used for storage of disinfected water. An ozone system is located between the two tanks with ozone inducted to the raw water supply as it flows from one tank to the other. Two backwashing filters containing sand, anthracite, and garnet media are used for particle removal prior to the second tank. Chlorine is injected prior to entering two existing pressure tanks.

- Monteoscuro - This community has 150 families with 120 connected to a water system served by a well. The well is one year old and the water is described as salty. There is a 13,000 gallon storage tank 3,800 yards from the well. This community has a state-supported medical center that has been in operation since 1984. Diarrhea is very common among the families who are members of the clinic and good records are kept on these families.

The water supply at Monteoscuro contains a significant particulate load that has to be reduced. This has been accomplished by using a manual backwashing filter containing sand, anthracite, and garnet media. After filtration, primary disinfection of the water supply is done by using a Teflon coil UV unit. The UV unit is located at the protected wellhead area and powered from the same source as the existing pump, thus ensuring that when electricity is available to pump water from the well to the existing storage tank, it is also available for the UV unit. Post-disinfection with chlorine provides a residual in the distribution system.

A majority (60% to 70%) of the Monteoscuro residents currently boil their water for disinfection. Propane fuel is used at a cost of approximately $1.20 per household every three weeks. This amounts to about $20.80 per household per year. Assuming there are 78 households (120 households times 65%) that boil their water, the total costs to the community per year is $1,622.40. One might think that the use of UV is an expensive alternative. By using the above information and assuming that eight UV bulbs costing $50 per bulb is used and assuming that the average bulb life is one year, the annual UV bulb replacement costs will not exceed $400 for the community. Also, electrical consumption will be low; about the equivalent of eight 40 watt light bulbs. Therefore, by using UV, disinfection cost should be reduced by over 50%.

MEXICO

- Jilotepec - This water system serves a population of approximately 3,500 people with a flow of approximately 120 gpm. The town is served by two separate distributions: a) surface water which is approximately 40%, and b) spring water which is approximately 60% of the water supply in town.

Jilotepec is in a valley and the water that is supplied comes from the mountains overlooking Jilotepec. The surface water that would be treated in this project flows from a small impoundment area to a tank that is several hundred feet higher in elevation than the town. The current treatment is chlorination only. This particular site provides a challenge to logistics of getting treatment package technology up the side of a mountain as there is not a roadway compatible for vehicular traffic. The surface water is very susceptible to changing conditions during the rainy season and appeared to be moderately turbid during the initial site visit. Water is chlorinated as it enters a tank and then is provided to the town via a gravity feed system. Treatment will consist of modular filtration followed by chlorination.

- Ixhuacan de los Reyes - The community of Ixhuacan de los Reyes is suppled with water from Rio San Jose. This community of approximately 2,600 people has a water demand of approximately 85 gpm. Water from the river, which is located higher in elevation than Ixhuacan, flows by pipeline down the side of the mountain and enters a rectangular presedimentation tank that is split into two chambers which would allow operation of either side individually or parallel. From this first presedimentation tank the water then flows into a second rectangular sedimentation basin and flows by gravity several hundred yards down the side of the mountain into a typical stone storage tank. No chemical treatment occurs until chlorine is added at this point and the water then flows from the outlet of the stone tank to the city of Ixhuacan. Treatment will consist of modular filtration followed by chlorination.

- Francisca I Madero Public Elementary School- The Francisca I Madero Public Elementary School is located in a small suburb near Cordoba and serves approximately 300 children who attend the school daily. The water supply for the school is a hand-dug well, approximately 30 feet deep, five feet in diameter and has a stone or brick interior wall. It is covered but not sealed to prevent foreign material from entering the well. This water then is pumped from the well to rooftop cisterns which is open to airborne contamination. This provided pressure for the system inside the school. Currently, the children are advised to bring water or beverages from their homes.

The treatment for the school will consist of using a MIOX electro-chemical unit to disinfect the drinking water.

CHINA

The proposed on-site demonstrations will be performed in collaboration with the Institute of Environmental Geology under the Ministry of Geology and Natural Resources, the People's Republic of China. It is initially agreed that when these on-site demonstration proposals are approved, the Institute of Environmental Geology will seek Chinese grants to perform the necessary analytical work either in their own laboratories or local universities such as the Geological Sciences graduate school. In addition, with the small community demonstrations, an epidemiological study comparing the health rates of the case study site vs. nearby communities with untreated water will be conducted by local graduate students.

One demonstration project is expected to take place in Zibo City in the Shandong Province to demonstrate the removal of industrial organics. Another demonstration may include the City of Chifeng where the raw water is contaminated with fluoride, agricultural chemicals, and industrial wastes.

SUMMARY

Providing safe adequate drinking water for small systems in the United States is no easy task. Appropriate treatment technology is determined in part by the costs, availability and proven effectiveness of the technology itself, and in part by the sum of the regulatory requirements specific to the localities in which these systems reside. The range of regulatory requirements includes both state and federal drinking water regulations as well as local and regional requirements for drinking water, wastewater, air quality, land use and construction. In addition, public perceptions, attitudes and interests can affect treatment choice. Both in-house and extramural research have been developed to evaluate and improve small systems treatment technology, taking other factors mentioned above into consideration.

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This paper has been reviewed in accordance with the U.S. Environmental Protection Agency's peer and administrative review policies and approved for presentation and publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the USEPA.

REFERENCES

1. Clark, R.M., Goodrich, J.A., and Lykins, Jr., B.W.,"Package Plants for Small Water Supplies - the US Experience", J. Water SRT-Aqua, Vol. 43, No.1,pp 23-34, 1994.

2. Lykins, Jr., B.W.,"Innovative Technologies for Treating Drinking Water for Small Communities", presented at the International Seminar on Ecological Effective Technologies for Water and Wastewater Treatment", Vologda, Russia, September 1993.

3. Macler, B.A., Goodrich, J.A., Robberson, W.M., and Clark, D.,"Treatment Technology for Small Drinking Water Systems in the U.S.", presented at the 3rd U.S.-Japan Governmental Conference on Drinking Water Quality Management, Cincinnati, Ohio, September 1992.

4. Campbell, S., Lykins, Jr., B.W., Goodrich, J.A., Post, D., and Lay T.,"Package Plants for Small Systems: A Field Study", J. American Water Works Association, Vol. 87, No. 11, pp. 39-47, November 1995.

5. Lykins, Jr., B.W.,"Utilization of Small Systems Treatment in Latin America and China", presented at the Water Quality Association's 22nd Annual Convention and Exhibition, Indianapolis, Indiana, March 1996.

TABLE 1. TREATMENT TECHNOLOGIES SUITABLE FOR FULL-SCALE CENTRAL USE BY SMALL SYSTEMS

Technology	Advantages	Disadvantages
Filtration		
Slow Sand	Operational simplicity and reliability, low cost, ability to achieve greater than 99.9 percent *Giardia* cyst removal	Not suitable for water with high turbidity, requires large land areas
Diatomaceous Earth	Compact size, simplicity of operation, excellent cyst and turbidity removal	Most suitable for raw water with low bacterial counts and low turbidity (less than 10 NTU), requires coagulant and filter aids for effective virus removal, potential difficulty in maintaining complete and uniform thickness of diatomaceous earth on filter septum
Reverse Osmosis Membrane	Extremely compact, automated	Little information available to establish operating parameters. Most suitable for raw water with less than 1 NTU; usually must be preceded by high levels of pretreatment, easily clogged with colloids and algae, short filter runs, concerns about membranes failure, complex repairs of automated controls, high percent of water lost in backflushing
Rapid Sand/Direct Filtration Package Plants	Compact, treats a wide range of water quality parameters and variable levels	Chemical pretreatment complex, time-consuming, cost

TABLE 1. TREATMENT TECHNOLOGIES SUITABLE FOR FULL-SCALE CENTRAL USE BY SMALL SYSTEMS (CONTINUED)

Technology	Advantages	Disadvantages
Disinfectant		
Chlorine	Very effective; has a proven history of protection against waterborne disease, widely used, variety of possible application points; inexpensive, appropriate as both primary and secondary disinfectant.	Potential for harmful halogenated by-products under certain conditions
Ozone	Very effective. No THMs formed.	Relatively high cost. More complex operations because it must be generated onsite. Requires a secondary disinfectant, other by-products.
Ultraviolet Radiation	Very effective for viruses and bacteria, readily available, no known harmful residuals, simple operation and maintenance for high quality waters	Inappropriate for surface water, requires a secondary disinfectant
Organic Contaminant Removal		
Granular Activated Carbon	Effective for a broad spectrum of organics	Spent carbon disposal
Packed Tower Aeration	Effective for volatile compounds	Potential for air emissions issues
Diffused Aeration	Effective for volatile compounds/radionuclides	Clogging, air emissions, variable removal efficiencies
Advanced Oxidation	Very effective	By-products
Reverse Osmosis	Broad spectrum removed	Variable removal efficiencies, wastewater disposal
Inorganic Contaminant Removal		
Reverse Osmosis	Highly effective	Expensive waste removal
Ion Exchange	Highly effective for some inorganics	Expensive waste removal
Activated Alumina	Highly effective for some inorganics	Expensive waste removal

TABLE 2. REMOVAL EFFECTIVENESS FOR NINE PROCESSES BY INORGANIC CONTAMINANT

Treatment	Contaminant																				
	Ag	As	As^{III}	A^{V}	Ba	Cd	Cr	Cr^{III}	Cr^{VI}	F	Hg	$Hg^{(o)}$	$Hg^{(I)}$	NO_3	Pb	Ra	Rn	Se	$Se^{(V)}$	$Se^{(III)}$	U
Conventional treatment	H	-	M	H	L	H	-	H	H	L	-	M	M	L	H	L	-	-	M	L	M
Coagulation - aluminum	H	-	-	H	-	M	-	H	-	-	M	-	-	-	H	-	-	-	-	-	-
Coagulation - iron	M	-	-	H	-	-	-	H	H	-	-	-	-	-	-	-	-	-	-	-	-
Lime softening	-	-	M	H	H	H	-	H	L	M	-	L	M	L	H	H	-	-	M	L	H
Reverse osmosis & electrodialysis	H	-	M	H	H	H	H	-	-	H	H	-	-	M	H	H	-	H	-	-	H
Cation exchange	-	L	-	-	H	H	-	H	L	L	-	-	-	L	H	H	-	L	-	-	H
Anion exchange	-	-	-	-	M	M	-	M	H	-	-	-	-	H	M	M	-	H	-	-	H
Activated alumina	-	-	H	-	L	L	-	-	-	H	-	-	-	-	-	L	-	H	-	-	-
Powdered activated carbon	L	-	-	-	L	M	-	L	-	L	-	M	M	L	-	L	-	-	-	-	-
Granular activated carbon	-	-	-	-	L	M	-	L	-	L	-	H	H	L	-	L	H	-	-	-	-
Aeration	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	H	-	-	-	-

H = High = > 80% removal
M = Medium = 20-80% removal
L = Low = < 20% removal
"-" = indicate no data were provided

TABLE 3. PERFORMANCE SUMMARY FOR TECHNOLOGIES EXAMINED

Organic Compounds	Regulatory phase	Removal efficiency[a]				
		GAC	Packed-tower aeration	Reverse osmosis	Ozone oxidation (2-6 ppm)	Conventional treatment
VOCs						
Alkanes						
Carbon tetrachloride	I	++	++	++	-	-
1,1-Dichloroethane	I	++	++	+	-	-
1,1,1-Trichloroethane	I	++	++	++	-	-
1,2-Dichloropropane	II	++	++	++	-	-
Ethylene dibromide	II	++	++	+	-	-
Dibromochloropropane	II	++	+	NA	-	-
Alkenes						
Vinyl chloride	I	+	++	NA	++	-
1,1-Dichloroethylene	I	++	++	NA	++	-
cis-1,2-Dichloroethylene	II	++	++	-	++	-
trans-1,2-Dichloroethylene	II	++	++	NA	++	-
Trichloroethylene	I	++	++	+	+	-
Aromatics						
Benzene	I	++	++	-	++	-
Toluene	II	++	++	NA	++	-
Xylenes	II	++	++	NA	++	-
Ethylbenzene	II	++	++	-	++	-
Chlorobenzene	II	++	++	++	+	-
o-Dichlorobenzene	II	++	++	+	+	-
p-Dichlorobenzene	I	++	++	NA	+	-
Styrene	II	++	++	NA	++	-
PESTICIDES						
Pentachlorophenol	II	++	-	NA	++	NA
2,4-D	II	++	-	NA	+	-
Alachlor	II	++	++	++	++	-
Aldicarb	II	++	-	++	NA	-
Carbofuran	II	++	-	++	++	-
Lindane	II	++	-	NA	-	-
Toxophene	II	++	++	NA	NA	-
Heptachlor	II	++	++	NA	+	NA
Chlordane	II	++	-	NA	NA	NA
2,4,5-TP	II	++	NA	NA	+	NA
Methoxychlor	II	++	NA	NA	NA	NA
OTHER						
Acrylamide	II	NA	-	NA	NA	NA
Epichlorohydrin	II	NA	-	NA	-	NA
PCBs	II	++	++	NA	NA	NA

[a]++ = Excellent (70-100%). Excellent removal category for carbon indicates that the compound has been demonstrated to be adsorbable onto GAC, either in full- or pilot-scale application or in the laboratory. The data suggest that GAC can be a cost-effective technology.
+ = Average (30-69%)
- = Poor (0-29%)
NA = Data not available, or compound has not been tested by EPA Water Supply and Water Resources Division

TABLE 4. OPERATIONAL CONDITIONS FOR TREATMENT TECHNOLOGIES

Technology	Requirements		
	Operational skills	Maintenance	Energy
Granular activated carbon	Medium	Low	Low
Packed column aeration	Low	Low	Varies
Slow sand filtration	Low	Low	Low
Diatomaceous earth	Low	Medium	Medium
Reverse osmosis	Low	Medium	High
Chlorine	Low	Low	Low
Ozone	High	Medium	Varies
UV	Low	Low	Low

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16. ABSTRACT

Because of the litany of problems associated with small systems, many state and federal programs have been established to assist them to come into compliance with current and anticipated regulations. For example, programs have been established to train 'trainers' in the latest methods and technology that are available to aid small utilities. Another concept that is being investigated is the 'composite correction program' that provides specific guidelines or rules for bringing water-treatment facilities into compliance with some of the drinking-water regulations. Unfortunately, for systems serving fewer than 500 people , which account for 93% of MCL and 94% of M/R violations, these programs have achieved limited success. Most of the problem systems are microsystems and serve 25-100 people. They have severe financial and managerial problems and are owned and operated by loosely organized associations which do not qualify for or are not cognizant of finanacial assistance programs. Frequently the operators and managers of these systems are volunteers. This paper gives a general overview of available technologies for small systems and present some research activities in the small systems area.

17. KEY WORDS AND DOCUMENT ANALYSIS

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