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COST IMPACT OF SAFE DRINKING WATER ACT COMPLIANCE FOR COMMISSION-REGULATED WATER UTILITIES

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EXECUTIVE SUMMARY

This study was prepared for state public utility commissioners and their staff in response to the growing concern about the effect of the Safe Drinking Water Act (SDWA) on water utilities under their jurisdiction. Compliance with the SDWA is expected to have a significant impact on water utilities and the rates they charge for service.

A sensitivity analysis was developed for this report using a hypothetical water company to identify the costs associated with alternative treatment processes. A total of eighteen different treatment processes are considered, from conventional treatment to granular activated carbon (GAC) adsorption and reverse osmosis. Capital costs for these processes range from $100,000 to $3.25 million for a water plant with a designed capacity of one million gallons daily (MGD). The presence of multiple contaminants in some water sources may necessitate multiple treatment technologies. Because utilities and their regulators are concerned about financing and payback for capital improvements, the analysis employs three interest rates (6, 8, and 10 percent) and three amortization periods (ten, twenty, and thirty years). The results indicate how sensitive the costs of alternative treatment processes are to these factors. This type of information will likely be an integral part of utility management and regulatory decision making about SDWA compliance.

Eight case studies of small and medium-sized water systems, originally prepared for the United States Environmental Protection Agency (EPA), are reanalyzed using time-series data on system characteristics, including production levels, costs, and revenues. For assessing cost impacts, this study emphasizes the use of revenue-producing treated water, as opposed to merely treated water. Effects of the SDWA are detected in the trends of both capital and operating expenses. Annual capital costs associated with SDWA compliance range from $1/RPMG to $1,647/RPMG and annual operating costs range from $1/RPMG to $415/RPMG. Total compliance costs range from $3/RPMG to $2,062/RPMG, or $.01 to $2.06 per 1,000 gallons billed. In several cases, increases in overall system costs can be linked to SDWA compliance. An analysis of revenues and costs suggests that water systems practice full-cost pricing and water customers bear the added costs of the SDWA.

Although the results cannot necessarily be generalized, comparing the case studies provides evidence that SDWA compliance costs vary across water systems as a function of site-specific factors, including system size. An important cost determinant is the type of treatment technology implemented, which depends largely on the contaminant problem in the water supply. Another is whether all or part of a utility's water supplies require treatment. Some utilities will have limited discretion in determining the appropriate treatment and, for some, the best available technology may be a very expensive technology. The construction of a new filtration plant is more costly than the addition of air stripping towers. When comparable treatment processes are installed, the data reveal differences between utilities of different sizes. For example, two medium-sized and two small-sized systems each installed comparable filtration equipment. For the medium-sized utilities, the increase in absolute costs was only modest, but was significant relative to total

system costs. For the small systems the cost increase was substantially more in both absolute and relative terms.

In general, SWDA compliance cost impacts appear to be greater for smaller water systems. In some cases, the revised calculations of SDWA compliance costs differ significantly from those of the EPA. The use of revenue-producing water in this study for calculating per-unit costs is the primary reason for the difference. Because of the potential for substantial impacts on water systems and their customers, regulators may want to segregate SDWA compliance costs from other investments and expenses when reviewing a water utility's revenue requirements. In the long term, the SDWA may also affect regulatory decision making about rate design and management prudence.

A final analysis concerns the conversion of SDWA compliance costs into rates. Three elements of the ratemaking formula are affected: operating expenses, depreciation charges, and rate base. Regulators need to be convinced that investments related to SDWA compliance are prudently incurred and that costs of operation are reasonable. Also, rates must be just and reasonable. The key ratemaking issue that will likely emerge in conjunction with the SDWA is rate shock. There are numerous options for phasing-in SDWA compliance costs in order to mitigate rate shock.

In evaluating phase-in plans, regulators will want to consider their effects on both consumers and investors. Effects on consumers involve intergenerational income transfers and equity across customer classes. The income distribution effects of various phase-in plans are difficult to ascertain. Most options involve an intergenerational income transfer with present consumers benefiting at the expense of future consumers. Effects on investors involve cash flow, taxes, and the utility's financial viability. Nearly all phase-in plans create a deferred asset, the cost of which must be recovered in the future, and have the immediate effect of suppressing income and cash flows. This may be particularly harmful to a small utility that is financially distressed and having difficulty financing a new treatment technology.

In the short term, the water systems most likely to make major capital improvements to comply with the SDWA, resulting in substantial rate increases, are the medium-sized utilities. Medium-sized systems comprise less than 20 percent of the approximately 6,000 water utilities under commission jurisdiction. Large systems will benefit from economies of scale. It can also be anticipated that many of the very small (and often financially troubled) jurisdictional systems will apply for and receive two-year renewable exemptions from the EPA that postpone cost and rate effects of the SDWA, perhaps indefinitely. Of course, exemptions will not be granted if contaminants pose an unreasonable health risk and even small utilities are expected to make a good faith effort toward compliance with safe drinking water regulations.

The appendix of this report is a descriptive table listing the eighty-three contaminants for which SDWA standards will be established by the EPA during the next few years. For each contaminant, the table provides its source and/or common use, an explanation of how it gets into drinking water supplies, a summary of potential health effects on humans, and possible treatment methods. The treatment technology required, and therefore the cost of SDWA compliance to a utility and its ratepayers, will depend largely on the contaminant present in the water source.

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FOREWORD

The U.S. Congress amended the Safe Drinking Water Act in 1986. The implications for state commission regulation of water utilities are numerous. This report assesses the cost and rate impacts of the 1986 legislation and discusses their implications for regulated water systems of various sizes and for different water treatment technologies. This report is a follow-up to our July 1988 report, Surface Water Treatment Rules and Affordability.

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CHAPTER 1

INTRODUCTION

In June 1986, the United States Congress amended the Safe Drinking Water Act of 1974.[1] Implementation of the amended Safe Drinking Water Act (SDWA) will continue to occur in stages over the next few years. Compliance with the SDWA is anticipated to have substantial cost and rate impacts on many water utilities under the jurisdiction of state regulatory commissions.

The key elements of the 1986 amendments to the SDWA include the development by June 1989 of new standards for eighty-three contaminants (at present there are standards for twenty-five contaminants), the designation of the best available technology for each regulated contaminant, and the addition after 1989 of twenty-five new contaminants every three years. In addition, the Environmental Protection Agency (EPA) is combining filtration and disinfection regulations into one set of standards for surface water treatment. The SDWA will result in the filtration of nearly all surface water supplies and the disinfection of many currently untreated ground water supplies.[2]

Problem Statement

This research focuses on the potential treatment cost and subsequent rate impacts of the SDWA on water utilities of various sizes that are under the jurisdiction of state public utility commissions. Preliminary analyses indicate that many of the EPA cost impact estimates may be low, and thus generally unreliable, for commissions to project costs for a specific water system. In addition, minimal information exists regarding the costs of alternative technologies available for treating the contaminants regulated under the SDWA.

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[1] The Safe Drinking Water Act was enacted in 1974 as PL-93-523 and amended in 1986 as PL-99-339.

[2] Wade Miller Associates, Infrastructure Issues in Water Supply (Washington, D.C.: National Council on Public Works Improvement, May 1987).

The cost and rate impacts of the SDWA should vary with system size and treatment complexity. The complexity of treatment in meeting SDWA standards involves a selection among various treatment technologies. These technologies include conventional processes such as coagulation (alum and ferric sulfate), sedimentation, filtration (direct, membrane, oxidation, slow sand, and earth), lime softening, ion exchange, oxidation disinfection, chlorination, chloride dioxide, chloramines, ozone, and bromine. The alternative technologies include granular activated carbon (GAC) adsorption, powdered activated carbon (PAC) adsorption, resin adsorption, activated alumina, aeration (packed column, diffused air, spray, slot tray, and mechanical), cartridge filtration, electrodialysis, reverse osmosis, ultrafiltration, and ultraviolet light. There is no single technology that will remove all eighty-three contaminants proposed under the SDWA. However, treatment processes such as GAC are broad-spectrum technologies.

The treatment technologies required will depend upon the specific contaminants occurring on a regular basis in the particular water supply. Therefore, each water utility will be unique with respect to its choice of technologies. As a consequence, the cost impact on each water utility will also be unique. Earlier studies indicate that the operating and capital cost of treating contaminated water is an inverse function of water system size.[3] Given economies of scale in water provision, the cost impact of SDWA will be substantial on small water utilities, particularly those serving less than 1,000 in population. The installation, operation, and maintenance of complex control processes will result in substantially higher unit costs for smaller water utilities than for larger water utilities. There is an economic regulatory concern about whether small water utilities can finance SDWA compliance costs.[4]

The EPA's regulatory focus, however, is on the water supply sector in the aggregate and thus on larger water systems, most of which are publicly-owned. This macro approach tends to generate relatively low costs of SDWA compliance

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[3] Robert C. Gumerman, Russell L. Culp, and Robert M. Clark, "The Cost of Granular Activated Carbon Adsorption Treatment in the U.S.," American Water Works Association Journal 71 (November 1979): 690-696.

[4] Richard P. McHugh, "Impact of the Safe Drinking Water Act," American Water Works Association Journal 70 (December 1978): 666-669.

because larger systems are better able to spread compliance costs over a large customer base. Furthermore, the large systems tend to be more in compliance with the SDWA than many smaller systems. By contrast, with regard to the water industry, the primary responsibility of state commissions is regulating relatively small investor-owned utilities. As a result, commissions must take a micro approach focusing on affordability and other rate issues associated with SDWA compliance. In brief, compliance costs may be much larger proportionately for a small water utility than for a large water utility.

The SDWA allows the EPA to grant variances and exemptions.[5] Water utilities are eligible for variances when, despite the installation of the best available technology (sometimes called BAT), SDWA standards are not satisfied due to poor water quality. Exemptions from implementing the BAT may be granted depending upon system characteristics. For example, exemptions of up to three years can be granted to systems that can demonstrate either that they cannot complete the necessary capital improvements within the three-year period, or that they are in the process of becoming a part of a regional water system.[6] Small systems serving fewer than 500 connections are eligible for two-year renewable exemptions. The vast majority of water utilities under commission jurisdiction appear to be eligible for these potentially perpetual exemptions.[7] However, an exemption may be granted as long as a water system can demonstrate that it is making satisfactory progress (making a "good faith" effort) toward meeting SDWA standards and that the exemption does not pose an unreasonable health threat.

The SDWA also incorporates specific requirements for periodic monitoring of regulated and unregulated contaminants. The frequency of monitoring will depend in part upon whether any contaminants are discovered during initial monitoring and whether the water system is considered vulnerable to future contamination. The timetable for initial monitoring

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[5] John E. Dyksen, David J. Hiltebrand, and Robert F. Raczko, "SDWA Amendments: Effects on the Water Industry," American Water Works Association Journal 80 (January 1988): 30-35.

[6] Michael B. Cook and David W. Schnare, "Amended SDWA Marks New Era in the Water Industry," American Water Works Association Journal 78 (August 1986): 66-69.

[7] Patrick C. Mann, G. Richard Dreese, and Miriam A. Tucker, Commission Regulation of Small Water Utilities: Mergers and Acquisitions (Columbus, Ohio: The National Regulatory Research Institute, October 1986).

varies with system size. Water systems serving populations in excess of 10,000 were required to begin monitoring in January 1988, water systems serving populations from 3,300 to 10,000 must begin monitoring by December 1989, and water systems serving populations less than 3,300 must begin monitoring by January 1991.

For investor-owned water utilities, the cost of SDWA compliance can be recovered through a formal ratemaking process. SDWA compliance costs will affect three components of revenue requirements: expenses, depreciation, and rate base. State commissions, through rate base regulation, must be satisfied that capital costs meet the prudent investment standard and that operating costs meet the reasonableness standard. Once approved, these expenses can be allocated to water customers, assuming that the rates charged also meet standards of justness and reasonableness. If water service bills increase substantially, there is a distinct possibility of rate shock. No matter how essential they may be from a public health perspective, or how prudent or reasonable from a ratemaking perspective, SDWA compliance costs may cause dismay among some ratepayers and state regulators.

Research Approach

The National Regulatory Research Institute (NRRI) has provided some preliminary estimates of the cost and rate impacts of SDWA on jurisdictional water utilities.[8] The NRRI study employed data for nineteen water utilities (all relying on ground sources) in four states. None of the nineteen water utilities served populations in excess of 10,000. Applying EPA estimates of SDWA compliance costs for systems of various sizes facing specific contamination problems, the results of the NRRI study indicate that water utilities can experience a wide range of price increases from SDWA implementation, depending upon system size and number of contaminants to be treated. It is anticipated, based upon this analysis, that implementation of

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[8] Vivian Witkind Davis, G. Richard Dreese, and Ann P. Laubach, A Preliminary Review of Certain Costs of the Safe Drinking Water Act Amendments of 1986 for Commission-Regulated Ground Water Utilities (Columbus, Ohio: The National Regulatory Research Institute, November 1987).

the SDWA will force small water utilities to increase rates substantially more than large water utilities.

This report examines potential SDWA cost impacts on water utilities under the jurisdiction of state commissions. It begins in chapter 2 with a sensitivity analysis of compliance costs for a hypothetical water system, which makes it possible to estimate the capital costs of various technologies while employing different amortization (payback) periods and different interest (financing) rates. Chapter 3 presents case studies of eight water systems that have implemented one or more of the alternative technologies likely to be considered by the EPA for SDWA compliance. The case studies are analyzed in terms of their implications for the costs of SDWA compliance, including capital costs and operating costs. They are also used to assess impacts on revenues and revenue-cost ratios in order to assess whether the costs of SDWA compliance are being passed along to water customers. Chapter 4 consists of a comparative analysis of the eight systems, with some general observations drawn from the case study findings. Chapter 5 turns to several issues confronting state commissions in converting SDWA compliance costs into water rate adjustments. This last research component examines the issue of phasing-in SDWA compliance costs as well as the issue of how regulators can ensure that necessary costs are translated into equitable water rates.

The appendix of this report is a descriptive table listing the eighty-three contaminants for which SDWA standards will be established by the EPA during the next few years. For each contaminant, the table provides its source and/or common use, an explanation of how it gets into drinking water supplies, a summary of potential health effects on humans, and possible treatment methods. The treatment technology required, and therefore the cost of treatment, will depend largely on the contaminant present in the water source.

CHAPTER 2

SDWA COMPLIANCE COST ESTIMATES FOR A HYPOTHETICAL WATER SYSTEM

This chapter examines the potential cost impact of SDWA compliance on water utilities under the jurisdiction of state public utility commissions. The limited availability of empirical data makes it difficult to model treatment costs, while at the same time heightens the need for cost estimation. The focus of the chapter is on a hypothetical water system for which the capital costs of alternative treatment technologies are estimated. The analysis incorporates several different amortization periods and different interest rates. Amortization periods determine the "payback" for utility investments, and interest rates determine the cost of financing the capital required to make these investments.

Water Treatment Technologies[1]

Conventional treatment is the most frequently used type of filtration. It includes chemical addition, rapid mixing, coagulation, flocculation, sedimentation, followed by filtration and disinfection. To remove suspended particles from raw water, a coagulant such as aluminum sulfate is added to the water and dispersed by means of rapid mixing. The water then flows into a flocculation basin where the coagulation process continues at a controlled rate, producing floc. The water next enters a sedimentation basin where, during a detention period of one to four hours, the floc settles out and most

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[1] Adapted from Vivian Witkind Davis and Ann P. Laubach, Surface Water Treatment Rules and Affordability: An Analysis of Selected Issues in Implementation of the 1986 Amendments to the Safe Drinking Water Act (Columbus, Ohio: The National Regulatory Research Institute, July 1988): 12-14, which is based on Environmental Protection Agency, Office of Drinking Water, Technologies and Costs for the Treatment of Microbial Contaminants in Potable Water Supplies (Washington, D.C.: U.S. EPA, April 1987), Revised Draft Final: III-1 to III-40.

turbidity is normally removed. The water then is treated by rapid sand filters and/or dual media or multi-media filters to remove remaining particles and further reduce turbidity. Rapid sand filtration, referring to the speed with which the water passes through the filters, necessitates the use of chemical coagulation to assure the removal of particles. In dual-media and multi-media filtration, layers of sand and other media such as anthracite coal are used in combination. Disinfection is the final step in the conventional treatment method.

Three other kinds of filtration--direct, diatomaceous earth, and slow sand--can be installed and operated at generally lower cost than conventional filtration, but usually require relatively high quality water to work effectively. Direct filtration usually does not use sedimentation basins in the process, but only chemical coagulation and mixing followed by dual-media or mixed-media filtration and disinfection. Simple direct filtration is an effective treatment method if the raw water has low turbidity levels in all seasons. Additional steps in the direct filtration process can help make treatment more reliable if raw water quality is variable.

Diatomaceous earth filtration is also useful for raw water that has low turbidity levels. In its most basic form, this kind of filtration is accomplished by passing raw water through a diatomite filter. During the filtration process, the permeability of the filter is maintained by adding more diatomite, known as body feed. For diatomaceous earth filtration to be used widely for water quality treatment, various forms of pretreatment, such as coagulation and settling, probably will be required.

Slow-sand filtration uses biological and physical mechanisms, rather than chemical processes, to remove suspended particles from water. The pores between the sand particles are much smaller than for rapid-sand filtration and the water passes through the filter at a much slower rate. The water is disinfected prior to delivery to customers. Slow-sand filtration has been successful in water systems that have consistently low turbidity levels, although in combination with chemical pretreatment it is effective for a much greater range of turbidity.

Package filtration plants normally use the same treatment methods as conventional filtration. They are factory-assembled, mobile units often used in remote areas such as parks that do not have access to a public water supply. They also serve some community water systems. Package filtration is a low-cost alternative to conventional filtration and usually does not require a full-time operator.

The inventory of treatment methods is expanding as technological innovations permit, adding to the complexity of complying with the SDWA. In general, conventional treatment encompasses processes such as coagulation (alum and ferric sulfate), sedimentation, filtration (direct, membrane, oxidation, slow sand, and earth), lime softening, ion exchange, oxidation disinfection, chlorination, chloride dioxide, chloramines, ozone, and bromine. This inventory has been augmented by alternative technologies including granular activated carbon (GAC) adsorption, powdered activated carbon (PAC) adsorption, resin adsorption, activated alumina, aeration (packed column, diffused air, spray, slot tray, and mechanical), cartridge filtration, electrodialysis, reverse osmosis, ultrafiltration, and ultraviolet light. GAC is an example of a broad-spectrum technology that can remove multiple contaminants. Although the SDWA can be expected to stimulate the development of alternative treatment processes, at this time there is no single technology that will remove all eighty-three regulated contaminants.[2]

A Hypothetical Water System

The hypothetical water system created here has an average demand of 0.5 million gallons daily (MGD). A survey of operating data periodically collected by the American Water Works Association indicates that many water utilities having an approximate average demand of 0.5 MGD serve populations in the range of 3,000 to 7,000. One can, therefore, presume that the hypothetical system serves a population of approximately 5,000 and has annual of revenues of at least $100,000. This system is actually much larger than most water systems regulated by state commissions. As indicated recently in a NRRI survey, approximately 60 percent of the water utilities under commission jurisdiction have annual revenues of less than $15,000.[3] Thus, estimates for

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[2] The appendix to this report provides information on the eighty-three contaminants to be regulated by the EPA under the SDWA, including possible treatment technologies.

[3] Mann, et al., Commission Regulation of Small Water Utilities: Mergers and Acquisitions.

the hypothetical water system must be viewed as conservative or minimum estimates for SDWA compliance costs. This is reinforced by substantial empirical evidence that SDWA compliance costs increase on a unit basis with decreasing system size.

The capital costs employed in the sensitivity analysis are derived from materials prepared by Camp Dresser & McKee Inc. for a 1987 workshop for the New Jersey Department of Environmental Protection.[4] The capital costs for the various treatment processes are for a water plant with a designed capacity of 1.0 MGD. Where a cost range was provided, the midpoint was selected as the capital cost estimate. Where the capital cost of the process varied with the contaminant or parameter, the most frequently mentioned capital cost was selected.

The treatment processes and capital costs in increasing order are:

PAC adsorption	$ 100,000
Air stripping	300,000
GAC adsorption	500,000
Ion exchange	650,000
Aeration	700,000
Earth filtration	750,000
Manganese greensand	850,000
Oxidation filtration	850,000
Steam stripping	850,000
Direct filtration	1,000,000
Alum coagulation	2,250,000
Conventional treatment	2,250,000
Ferric sulfate coagulation	2,250,000
Lime softening	2,500,000
Lime-soda softening	3,000,000
Membrane filtration	3,000,000
Reverse osmosis	3,000,000
Distillation	3,250,000

The formula for determining the annualized capital costs of each of the treatment processes is:[5]

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[4] Reported in Richard G. Dreese and Vivian Witkind Davis, Briefing Paper on the Economic Impact of the Safe Drinking Water Act Amendments of 1986 (Columbus, Ohio: The National Regulatory Research Institute, July 1987).

[5] Jack Hirshleifer, James C. Dehaven, and Jerome W. Milliman, Water Supply: Economics, Technology, and Policy (Chicago: University of Chicago Press, 1960).

$$k = \frac{Ci(1 + i)^n}{(1 + i)^n - 1}$$

where:

k = the annual payment over the service life of the capital expenditure necessary to pay interest and fully recover capital costs,

C = the capital expenditure required for compliance with the SDWA,

i = the appropriate interest (financing) rate, and

n = the useful or service life of the capital expenditure (proxy for the consumer payback period).

Accordingly, the formula may be read as saying that the annual payment needed to repay a loan financing a capital expenditure with compound interest on the unpaid balance (k), when divided by the capital expenditure (C), will equal the capital recovery factor. This factor (r) when multiplied by C will equal k. The capital recovery factor will vary with different financing rates (i) and different payback periods (n). Several studies concerning SDWA compliance costs have used an amortization or payback period of twenty years and an interest rate of 8 percent.[6]

Our analysis calculates the annualized capital costs (k) for the various treatment processes under three different payback periods (ten years, twenty years, and thirty years) and three different interest rates (6 percent, 8 percent, and 10 percent). Obviously, additional payback periods and interest rates could be used. However, the three payback periods and three interest rates provide sufficient insight into the annual capital costs of the various treatment processes that may be required to comply with the SDWA. They also provide sufficient insight into how sensitive these capital costs are to changes in payback periods and changes in financing rates.

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[6] Robert M. Clark and Paul Dorsey, "Costs of Compliance: An EPA Estimate for Organics Control," American Water Works Association Journal 72 (August 1980): 450-456; and "A Model of Costs for Treating Drinking Water," American Water Works Association Journal 74 (December 1982): 618-627.

Table 2-1 shows the annual capital costs, expressed in per million gallons (MG), assuming a payback period of ten years. Given such a financing period, the annualized capital costs range from $74/MG for PAC Adsorption (with a 6 percent financing rate) to $2,898/MG for Distillation (with a 10 percent financing rate). Obviously, given the existence of multiple contaminants, some water utilities may have to implement more than one of the treatment processes to comply with the SDWA.

Table 2-2 shows the annual capital costs, expressed in per million gallons (MG), assuming a payback period of twenty years. Given an equally long financing period, the annualized capital costs range from $47/MG for PAC Adsorption (with a 6 percent financing rate) to $2,091/MG for Distillation (with a 10 percent financing rate).

Table 2-3 shows the annual capital costs, expressed per million gallons (MG), assuming a payback period of thirty years. Annualized capital costs range from $39/MG for PAC Adsorption (with a 6 percent financing rate) to $1,889/MG for Distillation (with a 10 percent financing rate).

In conclusion, the EPA rules for implementing the SDWA will affect the choices of treatment technology made by water systems. The data for a hypothetical water system show that the costs of SDWA compliance can vary dramatically according to the type of treatment technology implemented. The choice of technology will depend greatly on the type of contaminant problem within a particular water system constraining, to an extent, the choice of treatment. The "best available technology" for treating a problem may at times be a "very expensive technology," especially in the eyes of those concerned with the cost and rate impacts of the SDWA.

TABLE 2-1

CAPITAL TREATMENT COSTS WITH A PAYBACK PERIOD OF TEN YEARS

	Financing Rate		
Treatment Process	6 percent	8 percent	10 percent
PAC adsorption	$ 74/MG	$ 81/MG	$ 89/MG
Air stripping	223/MG	244/MG	267/MG
GAC adsorption	372/MG	408/MG	445/MG
Ion exchange	483/MG	530/MG	579/MG
Aeration	521/MG	571/MG	624/MG
Earth filtration	558/MG	612/MG	668/MG
Manganese greensand	632/MG	694/MG	757/MG
Oxidation filtration	632/MG	694/MG	757/MG
Steam stripping	632/MG	694/MG	757/MG
Direct filtration	744/MG	816/MG	891/MG
Alum coagulation	1,675/MG	1,837/MG	2,006/MG
Conventional treatment	1,675/MG	1,837/MG	2,006/MG
Sulfate coagulation	1,675/MG	1,837/MG	2,006/MG
Lime softening	1,861/MG	2,041/MG	2,229/MG
Lime-soda softening	2,233/MG	2,449/MG	2,675/MG
Membrane filtration	2,233/MG	2,449/MG	2,675/MG
Reverse osmosis	2,233/MG	2,449/MG	2,675/MG
Distillation	2,419/MG	2,653/MG	2,898/MG

Source: Analysis by the authors using the Camp Dresser & McKee Inc. data reported in Richard G. Dreese and Vivian Witkind Davis, Briefing Paper on the Economic Impact of the Safe Drinking Water Act Amendments of 1986 (Columbus, Ohio: The National Regulatory Research Institute, July 1987).

TABLE 2-2

CAPITAL TREATMENT COSTS WITH A PAYBACK PERIOD OF TWENTY YEARS

	Financing Rate		
Treatment Process	6 percent	8 percent	10 percent
PAC adsorption	$ 47/MG	$ 55/MG	$ 64/MG
Air stripping	143/MG	167/MG	193/MG
GAC adsorption	238/MG	279/MG	321/MG
Ion exchange	310/MG	362/MG	418/MG
Aeration	334/MG	390/MG	450/MG
Earth filtration	358/MG	415/MG	482/MG
Manganese greensand	406/MG	474/MG	547/MG
Oxidation filtration	406/MG	474/MG	547/MG
Steam stripping	406/MG	474/MG	547/MG
Direct filtration	477/MG	558/MG	643/MG
Alum coagulation	1,074/MG	1,255/MG	1,448/MG
Conventional treatment	1,074/MG	1,255/MG	1,448/MG
Sulfate coagulation	1,074/MG	1,255/MG	1,448/MG
Lime softening	1,194/MG	1,395/MG	1,609/MG
Lime-soda softening	1,433/MG	1,674/MG	1,930/MG
Membrane filtration	1,433/MG	1,674/MG	1,930/MG
Reverse osmosis	1,433/MG	1,674/MG	1,930/MG
Distillation	1,552/MG	1,813/MG	2,091/MG

Source: Analysis by the authors using the Camp Dresser & McKee Inc. data reported in Richard G. Dreese and Vivian Witkind Davis, <u>Briefing Paper on the Economic Impact of the Safe Drinking Water Act Amendments of 1986</u> (Columbus, Ohio: The National Regulatory Research Institute, July 1987).

TABLE 2-3

CAPITAL TREATMENT COSTS WITH A PAYBACK PERIOD OF THIRTY YEARS

	Financing Rate		
Treatment Process	6 percent	8 percent	10 percent
PAC adsorption	$ 39/MG	$ 48/MG	$ 58/MG
Air stripping	119/MG	146/MG	174/MG
GAC adsorption	199/MG	243/MG	290/MG
Ion exchange	258/MG	316/MG	377/MG
Aeration	278/MG	340/MG	406/MG
Earth filtration	298/MG	365/MG	435/MG
Manganese greensand	338/MG	413/MG	494/MG
Oxidation filtration	338/MG	413/MG	494/MG
Steam stripping	338/MG	413/MG	494/MG
Direct filtration	398/MG	486/MG	581/MG
Alum coagulation	895/MG	1,095/MG	1,307/MG
Conventional treatment	895/MG	1,095/MG	1,307/MG
Sulfate coagulation	895/MG	1,095/MG	1,307/MG
Lime softening	995/MG	1,216/MG	1,453/MG
Lime-soda softening	1,194/MG	1,460/MG	1,743/MG
Membrane filtration	1,194/MG	1,460/MG	1,743/MG
Reverse osmosis	1,194/MG	1,460/MG	1,743/MG
Distillation	1,293/MG	1,581/MG	1,889/MG

Source: Analysis by the authors using the Camp Dresser & McKee Inc. data reported in Richard G. Dreese and Vivian Witkind Davis, Briefing Paper on the Economic Impact of the Safe Drinking Water Act Amendments of 1986 (Columbus, Ohio: The National Regulatory Research Institute, July 1987).

CHAPTER 3

CASE STUDIES OF EIGHT WATER SYSTEMS

To assess the operating and capital cost impacts of SDWA compliance, eight recently completed EPA case studies are reexamined and reevaluated in this chapter.[1] In each case, new treatment facilities had been constructed since 1980 to correct water quality problems that were in violation of existing and proposed changes in SDWA standards. Each case study contains several years of data on system activities, including operating and capital costs for water treatment.

The eight water systems in the analysis are in Idyllwild, California; Hartland, Wisconsin; LeRoy, New York; Potsdam, New York; Scottsdale, Arizona; Everett, Washington; San Juan, California; and Tacoma, Washington. Only one of the eight water utilities, Hartland, is regulated by a state utility commission. The Tacoma system is regulated by the Tacoma Public Utility Board. In addition, all but the Everett and San Juan systems are entirely metered, and all but the Scottsdale, Hartland, and Idyllwild systems obtain most of their water from surface sources. The other three systems tap wells for at least a portion of their water.

In calculating the incremental operating costs incurred by each utility in complying with the SDWA, a base year is employed. The base year is generally the year prior to the first complete year in which the new treatment plant was in operation. The operating costs of complying with the SDWA are those that exceed operating costs before the addition of the new treatment facility. The additional operating costs are computed by subtracting base year treatment costs from actual treatment costs in succeeding years. The

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[1] Bruce E. Burris and Robert C. Gumerman, Safe Drinking Water Act Cost Impacts on Selected Water Systems (Cincinnati, Ohio: Water Engineering Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, September 1987).

additional capital costs (interest plus depreciation) are simply the costs of the new treatment plant.

For each case study, SDWA compliance cost data and related calculations are displayed. The analysis is based on revenue-producing output in millions of gallons (RPMG), new treatment capital costs (TKC), and new treatment operating costs (TOC). Capital and operating costs are added to find total compliance costs (TC). The data were also used to calculate per-unit capital costs (TKC/RPMG) and per-unit operating costs (TOC/RPMG), the addition of which results in a measure of total per-unit costs (TC/RPMG). Average total costs and average total per-unit costs are based on the addition of average values for the cost variables. The use of averages mitigates the possibility that a utility can incur an unusually high capital or operating cost in a given year, even though the associated benefits are derived over several years. Unusually high costs in one year are often associated with lesser costs in other years. Averages also adjust for the occasional vagaries of utility accounting. For this analysis, therefore, the use of averages is regarded as both reasonable and realistic. Other analyses, of course, may reasonably use measures other than simple averages, depending on the unique circumstances of the water system (or systems) being investigated.

The original EPA calculations of compliance costs were based on treated water output, which is an inappropriate denominator in a regulatory context where there is tendency to spread compliance costs over all revenue-producing water rather than over treated water only. Our analysis recognizes the fact that different water sources for a utility may require different treatments at different costs but that these costs can be spread over all revenue sources, not just the water treated by a particular method.[2] Our analysis also disregards the distinction between revenue from treated water and revenue from untreated water.[3] It further assumes that the existing water rates are applied uniformly to the water utility's entire service area, eliminating the

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[2] For example, a utility might have only one well that requires special treatment at a high cost. Yet the treated water from that source becomes an indistinguishable part of the utility's total water supply that is being brought into compliance. In our analysis, the cost of treating the water from the well is spread across all revenue-producing water.

[3] Among the cases, this situation is especially applicable to Everett, Washington, which sells large quantities of untreated water to a paper mill.

complication of different rate structures for assigning new treatment costs only to the customers for which the new costs have been incurred.[4] Finally, the EPA cost calculations were based on the final year for which data were available whereas the revised calculations focus on an average over a period of years. As a result of these differences, this study's calculations of SDWA compliance costs diverge, in some cases substantially, from those of the EPA.

For each case, there is also an examination of whether the water utility has engaged in full-cost pricing, that is, whether it has charged adequate rates for recovering the full embedded costs of operating the water system.[5] This analysis also addresses the issue of whether additional treatment costs are passed on to water consumers. Data on annual water revenues were collected for the period during which cost data were available for each case. Annual revenues per million gallons (R/RPMG) and annual costs per million gallons (C/RPMG) were calculated and then used to compute a revenue-cost ratio (R/C). These data are also shown in a table for each case study.

Idyllwild, California

Idyllwild Water District (IW) serves a mountain resort community in southern California. IW has a designed capacity of 0.8 MGD, a water service area of three square miles, service connections in excess of 1,400, and a service population ranging from 2,800 permanent residents to 20,000 during peak vacation periods. The system produced 0.3 MGD in 1984. Wells (vertical and horizontal) are the source of 75 percent of IW supplies, with the rest drawn from surface sources. In 1984, 37 percent of water production was unaccounted-for and non-revenue producing.

Prior to 1980, the water treatment facility consisted of rapid sand (pressure) filters and chlorination; this plant was constructed in 1960. Due to problems of bacteria and giardia, a package filtration plant was

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[4] It is possible, of course, for regulators to devise rate structures that distinguish between treated water for drinking and untreated water for other uses, such as industrial applications.

[5] James Goldstein, "Full-Cost Pricing," American Water Works Association Journal 78 (February 1986): 52-61.

constructed and placed in operation at the end of 1980. In 1984, treatment costs accounted for only 6 percent of total operating costs since only 25 percent of water produced was treated. Treatment costs accounted for 14 percent of total capital costs. In 1979, prior to the treatment process change, treatment costs accounted for 4 percent of both total operating costs and total capital costs. The first complete year of operation of the new treatment facility was 1981; therefore, the base year for calculating incremental operating costs is 1980. The capital costs (depreciation plus interest) of the new treatment facility were initially incurred in 1980.

The EPA reported that the total 1984 compliance cost for IW was $536 per treated million gallons. Table 3-1 reports the reanalyzed data. Annual capital compliance costs are calculated as $125/RPMG (a five-year average) and annual operating compliance costs are calculated as $133/RPMG (a four-year average). Thus, in the case of IW, the annual cost of meeting water quality standards with a package treatment plant was $258/RPMG, or about twenty-six cents per 1,000 gallons consumed. This was a fairly modest increase in absolute costs.

Given total system costs of $2,370/RPMG for IW in 1979, average annual compliance costs of $258/RPMG represent an increase of 11 percent over this base level. This compares to an increase in total system costs of $1,398/RPMG, or 59 percent, between 1979 and 1984. For IW, the cost increase attributable to the SDWA is less than that estimated for small systems.[6] However, the IW case does not refute the hypothesis that the cost impact of the SDWA on very small utilities will be substantially greater than the impact on larger utilities.

The ten largest consumers served by IW accounted for 14 percent of total billed usage in 1985. The water rates in effect at the time of our study were implemented in 1984 and represent a 30 percent increase over rates which had been in place since 1977. The IW rate structure involves a uniform commodity rate. Table 3-2 shows the revenue-cost ratios (R/C) for IW. The ratios vary from .81 to 1.63 and exceed 1.0 in nine of ten years. Thus, there is evidence that the added treatment costs have been passed on to IW consumers.

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[6] Richard G. Stevie and Robert M. Clark, "Costs for Small Systems to Meet the National Interim Drinking Water Regulations," American Water Works Association Journal 74 (January 1982): 13-17.

TABLE 3-1

WATER PRODUCTION AND SDWA COMPLIANCE COSTS FOR IDYLLWILD, CALIFORNIA

	Production	Compliance Costs			Cost Ratios		
Year	Revenue Producing Million Gallons (RPMG)	Capital (TKC)	Operating (TOC)	Total (TC)[1]	TKC/RPMG	TOC/RPMG	TC[2]/RPMG
1980	59	$7,295	n.a.	n.a.	$124	n.a.	n.a.
1981	60	8,435	$8,348	$16,783	141	$139	$280
1982	64	9,750	9,172	18,922	152	143	295
1983	62	7,865	7,568	15,433	127	122	249
1984	77	6,296	9,780	16,076	82	127	209
Average	64	$7,928	$8,717	$16,645	$125	$133	$258

[1] Calculated as TKC + TOC

[2] Calculated as (TKC/RPMG) + (TOC/RPMG)

Source: Bruce E. Burris and Robert C. Gumerman, Safe Drinking Water Act Cost Impacts on Selected Water Systems (Cincinnati: Water Engineering Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, September 1987), and calculations by authors.

TABLE 3-2

REVENUE-COST RATIOS FOR IDYLLWILD, CALIFORNIA

Year	Dollars of Revenue Per Million Gallons (R/RPMG)	Cost in Dollars Per Million Gallons (C/RPMG)	Ratio of Revenues (R/RPMG) To Costs (C/RPMG) (R/C)
1975	$2,858	$2,113	1.35
1976	3,044	1,943	1.57
1977	4,141	2,545	1.63
1978	4,646	2,975	1.57
1979	3,660	2,370	1.54
1980	4,547	2,788	1.63
1981	4,745	3,677	1.29
1982	3,574	4,428	0.81
1983	5,068	4,520	1.12
1984	4,902	3,769	1.30

Source: William D. Whitener, General Manager, Idyllwild Water District, and calculations by authors.

Hartland, Wisconsin

The Village of Hartland (VH), located in southeastern Wisconsin, has a designed capacity of 1.4 MGD, and a service area of three square miles. It has service connections in excess of 1,500, and serves a retail population of 6,200. The system produced .9 MGD in 1985. Unlike the other systems examined, VH is regulated by the Wisconsin Public Service Commission. Three wells provide all of VH supplies and 37 percent of treated water output was unaccounted for and non-revenue producing.

Water treatment consisted of fluoridation only before 1982. Due to problems of trichloroethylene concentrations in one well, a packed column air stripping tower was constructed and placed in operation in early 1984. In addition, water from this well is now being chlorinated. In 1985, treatment costs accounted for 6 percent of total operating costs. The low costs resulted from fluoridation being the only treatment for all water and air stripping plus chlorination for the water supplied by one well. Treatment costs accounted for 16 percent of total capital costs. Before the change in treatment processes, treatment costs accounted for 5 percent of totaloperating costs and for less than 1 percent of total capital costs.

The first complete year of operation of the new treatment facility was 1984. However, a pilot study using a portable air stripping tower began in early 1982. Therefore, the base year for calculating incremental operating costs is 1981. Capital costs (depreciation plus interest) of the new treatment facilities were first incurred in 1984.

The EPA report concluded that the total annual compliance cost for VH was $324 per treated million gallons in 1985. The EPA figure was based on water subject to air stripping, which was only 20 percent of total treated water. The reanalyzed data are reported in table 3-3. Annual capital compliance costs for VH are calculated as $72/RPMG (a two-year average) and annual operating compliance costs are calculated as $64/RPMG (a four-year average). Therefore, in the case of VH, the annual cost of meeting water quality standards was $136/RPMG, or approximately fourteen cents per 1,000 gallons billed. The increase in system costs due to new treatment facilities was relatively modest. Given total system costs of $1,288/RPMG for VH in 1981, average annual compliance costs of $136/RPMG represent an increase of 11 percent over this base level. This compares to an increase in total system

TABLE 3-3

WATER PRODUCTION AND SDWA COMPLIANCE COSTS FOR HARTLAND, WISCONSIN

	Production	Compliance Costs			Cost Ratios		
Year	Revenue Producing Million Gallons (RPMG)	Capital (TKC)	Operating (TOC)	Total (TC)[1]	TKC / RPMG	TOC / RPMG	TC[2] / RPMG
1982	171	n.a.	$20,807	n.a.	n.a.	$122	n.a.
1983	176	n.a.	9,183	n.a.	n.a.	52	n.a.
1984	184	$11,052	11,204	$22,256	$60	61	$121
1985	200	16,658	4,104	20,762	83	21	104
Average	183	$13,855	$11,325	$25,180	$72	$ 64	$136

[1] Calculated as TKC + TOC

[2] Calculated as (TKC/RPMG) + (TOC/RPMG)

Source: Bruce E. Burris and Robert C. Gumerman, Safe Drinking Water Act Cost Impacts on Selected Water Systems (Cincinnati: Water Engineering Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, September 1987), and calculations by authors.

TABLE 3-4

REVENUE-COST RATIOS FOR HARTLAND, WISCONSIN

Year	Dollars of Revenue Per Million Gallons (R/RPMG)	Cost in Dollars Per Million Gallons (C/RPMG)	Ratio of Revenues (R/RPMG) To Costs (C/RPMG) (R/C)
1976	$1,167	$1,272	0.92
1977	1,295	1,139	1.14
1978	1,293	1,059	1.22
1979	1,261	1,134	1.11
1980	1,325	1,153	1.15
1981	1,339	1,288	1.04
1982	1,333	1,326	1.01
1983	1,332	1,403	0.95
1984	1,972	1,466	1.35
1985	1,923	1,481	1.30

Source: John Lindsay, Secretary-Treasurer, Hartland Utility Commission, and calculations by authors.

costs that also amounted to $136/RPMG, or 11 percent, between 1981 and 1985. In other words, virtually all of the increase in system costs for VH is attributable to the cost of SDWA compliance.

The ten largest consumers served by VH account for 13 percent of total billed usage in 1985. The VH rate structure involves a declining block rate. The block rates were increased 40 percent in 1984 and approximately 20 percent in 1986. Table 3-4 shows the revenue-cost ratios (R/C) for VH. The ratios vary from 0.92 to 1.35 and exceed 1.0 in eight of ten years. Thus, there is evidence that the added treatment costs have been passed on to VH consumers.

LeRoy, New York

LeRoy Village (LV) is located in northwestern New York. LV has a designed capacity of 1.7 MGD, a water service area of three square miles, service connections of nearly 1,800, and a population served of 5,000. In addition, LV serves an additional 1,000 population in two adjacent water districts. The system produced .9 MGD in 1985. A substantial portion of water production is unaccounted for; in 1985, 33 percent of treated water output was non-revenue producing.

Prior to 1983, the water treatment facilities consisted of rapid sand (pressure) filters and chlorination contained in a plant built in 1915. Due to problems of turbidity, a package plant consisting of flocculation, sedimentation, and filtration was constructed and placed in operation in late 1983. In 1985, treatment costs accounted for 46 percent of total operating costs and 88 percent of total capital costs. In 1981, prior to the change in treatment processes, treatment costs accounted for 55 percent of total operating costs and 17 percent of total capital costs. The first complete year of operation of the new treatment facility was 1984, making 1983 the base year for calculating incremental operating costs. The first capital costs of the new treatment facility (depreciation plus interest) were incurred by LV in 1982.

The EPA report concluded that the total annual compliance cost for LV was $942 per treated million gallons. The reanalyzed data, reported in table 3-5, reveal annual capital compliance costs of $1,462/RPMG (a four-year average) and annual operating compliance costs of $80/RPMG (a two-year average). Therefore, in the case of LV, the annual cost of meeting water quality

TABLE 3-5

WATER PRODUCTION AND SDWA COMPLIANCE COSTS FOR LEROY, NEW YORK

	Production	Compliance Costs			Cost Ratios		
Year	Revenue Producing Million Gallons (RPMG)	Capital (TKC)	Operating (TOC)	Total (TC)[1]	TKC / RPMG	TOC / RPMG	TC[2] / RPMG
1982	243	$287,488	n.a.	n.a.	$1,183	n.a.	n.a.
1983	231	459,830	n.a.	n.a.	1,991	n.a.	n.a.
1984	208	287,155	$ 9,043	$296,198	1,381	$ 43	$1,424
1985	210	271,360	24,436	295,796	1,292	116	1,408
Average	223	$326,458	$16,740	$343,198	$1,462	$ 80	$1,542

[1] Calculated as TKC + TOC
[2] Calculated as (TKC/RPMG) + (TOC/RPMG)

Source: Bruce E. Burris and Robert C. Gumerman, Safe Drinking Water Act Cost Impacts on Selected Water Systems (Cincinnati: Water Engineering Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, September 1987), and calculations by authors.

TABLE 3-6

REVENUE-COST RATIOS FOR LEROY, NEW YORK

Year	Dollars of Revenue Per Million Gallons (R/RPMG)	Cost in Dollars Per Million Gallons (C/RPMG)	Ratio of Revenues (R/RPMG) To Costs (C/RPMG) (R/C)
1976	$ 848	$ 501	1.69
1977	757	532	1.42
1978	1,034	566	1.83
1979	1,019	529	1.93
1980	1,065	626	1.70
1981	1,058	586	1.81
1982	2,681	1,877	1.43
1983	1,530	2,775	0.55
1984	2,466	2,254	1.09
1985	1,571	2,356	0.67

Source: Jeff R. Smith, Village Administrator, Village of LeRoy, and calculations by authors.

standards was $1,542/RPMG, or approximately $1.54 per 1,000 gallons billed. For LV, the construction of a treatment plant to comply with the SDWA resulted in substantial costs in both absolute and relative terms. Given total system costs of $586/RPMG for LV in 1981, average annual compliance costs of $1,542/RPMG represent an increase of 263 percent over this base level. This compares to an increase in total system costs of $1,770/RPMG, or 302 percent, between 1981 and 1985. The LV case lends support to the hypothesis that the cost impact of the SDWA on small commission-regulated utilities will be substantially greater than the cost impact on larger water utilities.

The ten largest consumers served by LV accounted for 45 percent of total billed usage in 1985. The LV rate structure involves a uniform commodity rate for residential customers (differing inside and outside the village) and customers in the two water districts, and a declining block rate for commercial customers. Table 3-6 shows the revenue-cost ratios (R/C) for LV. The R/C for LV varies from .55 to 1.93 and in eight of ten years exceeds 1.0. The evidence suggests that the added treatment costs have been passed on to LV consumers.

Potsdam, New York

Potsdam Village (PV) is located in northern New York. PV has a designed capacity of 2.6 MGD, a water service area of twelve square miles, service connections of nearly 1,700, and a service population of 10,600. The system produced 1.1 MGD in 1985, although 33 percent of the treated water output was unaccounted-for, or non-revenue producing, water. Prior to 1983, the water treatment plant was a conventional facility built in 1920. Due to problems of trihalomethane concentrations, a plant consisting of flocculation, sedimentation, filtration, and ozonation was constructed and placed in operation in late 1983. In 1985, treatment costs accounted for 67 percent of total operating costs and 80 percent of total capital costs. In 1982, prior to the change in treatment processes, treatment costs accounted for 36 percent of total operating costs and 65 percent of total capital costs. The first complete year of operation of the new treatment facility was 1984, making 1983 the base year for calculating incremental operating costs. Capital costs for the new facility were first incurred by PV in 1983.

Based on 1985 treated water, the EPA report concluded that the total annual compliance cost for PV was $1,575 per treated million gallons. Table 3-7 reports the reanalyzed data. Annual capital compliance costs are calculated as $1,647/RPMG (a three-year average) and annual operating compliance costs are calculated as $415/RPMG (a two-year average). Thus, the annual cost of meeting water quality standards with the construction of a new plant was $2,062/RPMG, or approximately $2.06 per 1,000 gallons billed. For PV, this was clearly more than a modest cost increase. Given total system costs of $1,447/RPMG for PV in 1982, average annual compliance costs of $2,062/RPMG represent an increase of 143 percent over this base level. This compares to an increase in total system costs of $2,243/RPMG, or 155 percent, between 1982 and 1985. The PV case also lends support to the hypothesis that the cost impact of the SDWA on small water utilities will be substantially greater than the cost impact on larger water utilities.

The ten largest consumers served by PV accounted for 52 percent of total billed usage in 1984. The PV rate structure involves a uniform commodity rate differing for customers inside and outside the village. In 1982, water rates rose by 200 percent, followed by rate decreases of 14 percent, 3 percent, and 10 percent in 1983, 1984, and 1985. Water rates have remained unchanged since 1985. Table 3-8 shows the revenue-cost ratios (R/C) for PV. The R/C for PV varies from .86 to 1.82, and in eight of ten years exceeds 1.0. There is evidence that the added treatment costs have been passed on to PV consumers.

Scottsdale, Arizona

The City of Scottsdale (CS) is located in southern Arizona, has a designed capacity of 30 MGD, a water service area of eighty-nine square miles, in excess of 24,200 service connections, and serves a retail population of 53,400. The retail population is only 46 percent of the system's total population. The residual was served by the City of Phoenix's distribution system which CS bought in 1987. Twenty-nine wells provide 100 percent of CS supplies. Of the supply, only a small proportion of water production is unaccounted for; in 1986, for example, only 3 percent of treated water output was non-revenue producing.

Prior to 1985, water treatment consisted of chlorination only. Due to problems of trichloroethylene and various inorganic chemical concentrations in

TABLE 3-7

WATER PRODUCTION AND SDWA COMPLIANCE COSTS FOR POTSDAM, NEW YORK

	Production	Compliance Costs			Cost Ratios		
Year	Revenue Producing Million Gallons (RPMG)	Capital (TKC)	Operating (TOC)	Total (TC)[1]	TKC / RPMG	TOC / RPMG	TC[2] / RPMG
1983	278	$439,782	n.a.	n.a.	$1,582	n.a.	n.a.
1984	278	434,869	$ 83,877	$518,746	1,564	$302	$1,866
1985	270	485,016	142,554	627,570	1,796	528	2,324
Average	275	$453,222	$113,216	$566,438	$1,647	$415	$2,062

[1] Calculated as TKC + TOC

[2] Calculated as (TKC/RPMG) + (TOC/RPMG)

Source: Bruce E. Burris and Robert C. Gumerman, Safe Drinking Water Act Cost Impacts on Selected Water Systems (Cincinnati: Water Engineering Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, September 1987), and calculations by authors.

TABLE 3-8

REVENUE-COST RATIOS FOR POTSDAM, NEW YORK

Year	Dollars of Revenue Per Million Gallons (R/RPMG)	Cost in Dollars Per Million Gallons (C/RPMG)	Ratio of Revenues (R/RPMG) To Costs (C/RPMG) (R/C)
1977	$1,177	$ 645	1.82
1978	1,220	790	1.54
1979	1,185	851	1.39
1980	1,169	804	1.45
1981	1,190	1,182	1.01
1982	1,249	1,447	0.86
1983	3,790	3,651	1.04
1984	4,031	3,053	1.32
1985	3,654	3,691	0.99

Source: Beverly Brownell, Treasurer, Village of Potsdam, and calculations by authors.

several wells, an air stripping (packed column) tower was constructed and placed in operation in 1985. In 1986, treatment costs accounted for 1 percent of total operating costs. Chlorination kept treatment costs low. In addition, air stripping was applied to supplies from only one well, also helping to keep costs low. Treatment costs accounted for less than 1 percent of total capital costs. In 1984, prior to the change in treatment processes, treatment costs were of an even lesser relative magnitude. The first complete year of operation of the new treatment facility was 1986, making 1984 the base year for calculating incremental operating costs. Capital costs (depreciation plus interest) of the new treatment facilities were first incurred in 1986.

The EPA, using air-stripped treated water to measure per-unit costs, concluded that the total annual compliance cost for CS was $142 per treated million gallons. However, in 1986, the proportion of the utility's treated water subject to air stripping was only 2 percent. Table 3-9 shows the SDWA compliance cost calculations for CS using revenue-producing water as the denominator. Annual capital compliance costs are calculated as $1.88/RPMG and annual operating compliance costs are calculated as $1.11/RPMG. Therefore, in the case of CS, the annual cost of meeting water quality standards was $2.99/RPMG, or less than one cent per 1,000 gallons billed. This is clearly a negligible addition to system costs. Given total system costs of $546/RPMG for CS in 1984, average annual compliance costs of $2.99/RPMG represent an increase of less than 1 percent over this base level. This compares to an increase in total system costs of $224/RPMG, or 41 percent, between 1984 and 1986.

The CS rate structure involves a declining block rate; prior to 1983, CS had a uniform commodity rate. The two block rates were increased in 1984 (12 and 41 percent, respectively), in 1987 (27 and 10 percent), and again in 1988 (10 percent each). Table 3-10 shows the revenue-cost ratios (R/C) for CS. The R/C for CS varies from 1.20 to 2.78 and in all ten years exceeds 1.0. Thus, there is evidence that the added treatment costs have been passed onto CS consumers.

Everett, Washington

The City of Everett (CE) located in northwestern Washington has a designed capacity of 50 MGD, a water service area of forty-six square miles,

TABLE 3-9

WATER PRODUCTION AND SDWA COMPLIANCE COSTS FOR SCOTTSDALE, ARIZONA

	Production	Compliance Costs			Cost Ratios		
Year	Revenue Producing Million Gallons (RPMG)	Capital (TKC)	Operating (TOC)	Total (TC)[1]	TKC / RPMG	TOC / RPMG	TC[2] / RPMG
1986	7,497	$14,058	$8,318	$22,376	$1.88	$1.11	$2.99
Average	7,497	$14,058	$8,318	$22,376	$1.88	$1.11	$2.99

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[1] Calculated as TKC + TOC

[2] Calculated as (TKC/RPMG) + (TOC/RPMG)

Source: Bruce E. Burris and Robert C. Gumerman, Safe Drinking Water Act Cost Impacts on Selected Water Systems (Cincinnati: Water Engineering Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, September 1987), and calculations by authors.

TABLE 3-10

REVENUE-COST RATIOS FOR SCOTTSDALE, ARIZONA

Year	Dollars of Revenue Per Million Gallons (R/RPMG)	Cost in Dollars Per Million Gallons (C/RPMG)	Ratio of Revenues (R/RPMG) To Costs (C/RPMG) (R/C)
1977	$ 617	$ 222	2.78
1978	726	306	2.37
1979	751	628	1.20
1980	707	576	1.23
1981	759	573	1.32
1982	970	720	1.35
1983	966	716	1.35
1984	1,026	546	1.88
1985	1,301	817	1.59
1986	1,237	772	1.60

Source: James Turnbull, Resource Analyst, City of Scottsdale, and calculations by authors.

service connections in excess of 18,300 (only 27 percent metered), and a retail population served of 57,000. The service connections include wholesale customers, including forty water districts and sixty-five other water distributors serving 53,500 retail customers. CE supplies substantial untreated water (9,454 MG in 1984) to a paper mill.

Only 3 percent of water production was unaccounted for in 1984. Prior to 1983, water treatment consisted of chlorination only, but because of problems of turbidity and trihalomethane concentrations, a filtration plant consisting of chemical coagulation, direct filtration, disinfection, and flocculation was built and placed in operation in late 1983. The next year, treatment costs accounted for 25 percent of total operating costs and for 44 percent of total capital costs. In 1981, by contrast, treatment costs accounted for 6 percent of total operating costs and 2 percent of total capital costs. The first complete year of operation of the new treatment facility was 1984; therefore, the base year for calculating incremental operating costs is 1983. The capital costs (depreciation plus interest) of the new treatment facility were first incurred in 1982.

For 1984, the EPA found that the total annual compliance cost for CE was $216 per treated million gallons. Table 3-11 reports the reanalyzed data. The annual capital compliance costs over three years are calculated as $80/RPMG. Forty-three percent of the capital costs were borne by the state of Washington and a wholesale customer (a public utility district). The compliance cost calculations in this study include these funded costs. However, due to the nature of the funding, interest charges in the calculations are substantially less than normal. Annual operating compliance costs are calculated as $29/RPMG (one year only). Therefore, in the case of CE, the annual cost of meeting water quality standards was $109/RPMG, or approximately eleven cents per 1,000 gallons billed.

The revised calculation presented here presumes that in the regulatory process, compliance costs will be spread over all revenue-producing water. However, in this case, one can clearly argue that the denominator should exclude the substantial amount of untreated water supplied by CE to the paper mill. This approach is consistent with cost-based pricing theory. The total cost of SDWA compliance for treated water customers exclusively amounts to about twenty-two cents per 1,000 gallons billed, or about twice as much as when the untreated water is considered.

TABLE 3-11

WATER PRODUCTION AND SDWA COMPLIANCE COSTS FOR EVERETT, WASHINGTON

	Production	Compliance Costs			Cost Ratios		
Year	Revenue Producing Million Gallons (RPMG)	Capital (TKC)	Operating (TOC)	Total (TC)[1]	TKC / RPMG	TOC / RPMG	TC[2] / RPMG
1982	21,140	$1,500,850	n.a.	n.a.	$71	n.a.	n.a.
1983	21,100	1,591,043	n.a.	n.a.	75	n.a.	n.a.
1984	19,980	1,866,502	$577,124	$2,443,626	93	$29	$122
Average	20,740	$1,652,798	$577,124	$2,229,922	$80	$29	$109

[1] Calculated as TKC + TOC

[2] Calculated as (TKC/RPMG) + (TOC/RPMG)

Source: Bruce E. Burris and Robert C. Gumerman, Safe Drinking Water Act Cost Impacts on Selected Water Systems (Cincinnati: Water Engineering Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, September 1987), and calculations by authors.

TABLE 3-12

REVENUE-COST RATIOS FOR EVERETT, WASHINGTON

Year	Dollars of Revenue Per Million Gallons (R/RPMG)	Cost in Dollars Per Million Gallons (C/RPMG)	Ratio of Revenues (R/RPMG) To Costs (C/RPMG) (R/C)
1976	$ 98	$ 83	1.18
1977	102	94	1.09
1978	115	93	1.24
1979	127	111	1.14
1980	129	119	1.08
1981	182	199	0.91
1982	324	266	1.26
1983	330	284	1.16
1984	390	354	1.10

Source: Clair H. Olivers, City of Everett Public Works Department, and calculations by authors.

Nevertheless, using either calculation for CE, the SDWA is associated with a modest absolute increase in system costs (including the capital costs that were not passed on to CE consumers). Given total system costs of $199/RPMG for CE in 1981, average annual compliance costs of $109/RPMG represent an increase of 55 percent over this base level. This compares to an increase in total system costs of only $111/RPMG, or 56 percent, between 1981 and 1984. Although the absolute magnitude of the compliance costs is very modest, it represents a substantial relative increase and accounts for virtually the entire increase in system costs, due to relatively low system costs prior to the construction of the filtration plant.

The eight largest users served by CE accounted for 82 percent of total billed usage in 1984. The CE rate structure involves a flat charge for unmetered customers and a declining block rate for metered customers. Water rates increased 25 percent as a result of the new filtration plant. Table 3-12 shows the revenue-cost ratios (R/C) for CE. The R/C varies from 0.91 to 1.26, and in nine of ten years exceeds 1.0. As in the other cases, there is evidence that the added treatment costs have been passed on to CE consumers.

San Juan, California

San Juan Suburban Water District (SJ) is located in central California. SJ has a designed capacity of 120.0 MGD, a water service area of sixteen square miles, service connections in excess of 4,600 (less than 1 percent metered), and serves a retail population of 14,000. The service connections include wholesale customers such as water districts, which accounted for 81 percent of SJ water sales in 1985. Wholesale customers serve an additional retail population of 136,000. The American River provides 100 percent of SJ supplies, and only a minute proportion of water production is unaccounted for; less than 1 percent of treated water output was non-revenue producing in 1985.

Prior to 1979, water treatment consisted of alum coagulation and chlorination. Due to problems of turbidity, a new treatment plant (100 MGD) consisting of flocculation and sedimentation was constructed and placed in operation in late 1979. A new filtration plant (120 MGD) was completed in late 1983. Two years later, treatment costs accounted for 27 percent of total operating costs and 52 percent of total capital costs. In 1978, by contrast, treatment costs accounted for 24 percent of total operating costs and 45 percent of total capital costs. Because the first complete year of operation of the new treatment facility was 1980, the base year for calculating incremental operating costs is 1979. The capital costs of the new facilities (depreciation plus interest) essentially were first incurred in 1980.

Using 1985 treated water, the EPA report concluded that the total annual compliance cost for SJ was $73 per treated million gallons. The reanalyzed data appear in table 3-13. Annual capital compliance costs for six years averaged $55/RPMG and annual operating compliance costs for two years averaged $24/RPMG. Therefore, in the case of SJ, the annual cost of meeting water quality standards was $79/RPMG, or approximately eight cents per 1,000 gallons billed. In absolute terms, this was a modest increase. Given total system costs of $132/RPMG for SJ in 1979, average annual compliance costs of $79/RPMG represent an increase of 60 percent over this base level. This compares to an increase in total system costs of $92/RPMG, or 70 percent, between 1979 and 1985. The somewhat large increase in relative terms is due to the fairly low system costs prior to the construction of new treatment facilities.

The five largest consumers served by SJ accounted for 82 percent of total billed usage in 1985. The SJ rate structure includes a flat charge for unmetered (residential) customers and a uniform commodity rate for metered commercial and wholesale customers. Since 1977, water rates have increased five times. The average rate hike was 10 percent. Table 3-14 shows the revenue-cost ratios (R/C) for SJ. The R/C varies from 0.52 to 0.56 and in all ten years is less than 1.0. There is little evidence of full-cost pricing. Part of the deficiency may be attributed to SJ charging rates sufficient to retire debt but insufficient to cover depreciation charges.

Tacoma, Washington

The City of Tacoma (CT) is located in northwestern Washington, and has a gravity flow system with a designed capacity of 72 MGD. The gravity flow system can be augmented by wells to generate a maximum flow rate of 116 MGD. CT has a water service area of ninety square miles, service connections of nearly 74,000, and a population served of 213,000. CT is under the jurisdiction of the Tacoma Public Utility Board. A surface source (Green River) provides 75 percent of CT supplies; wells provide the rest. Only 9 percent of water production was unaccounted for in 1984.

TABLE 3-13

WATER PRODUCTION AND SDWA COMPLIANCE COSTS FOR SAN JUAN, CALIFORNIA

	Production	Compliance Costs			Cost Ratios		
Year	Revenue Producing Million Gallons (RPMG)	Capital (TKC)	Operating (TOC)	Total (TC)[1]	TKC / RPMG	TOC / RPMG	TC[2] / RPMG
1980	12,032	$646,046	n.a.	n.a.	$54	n.a.	n.a.
1981	13,902	730,005	n.a.	n.a.	53	n.a.	n.a.
1982	13,689	714,902	n.a.	n.a.	52	n.a.	n.a.
1983	12,993	820,845	n.a.	n.a.	63	n.a.	n.a.
1984	15,661	876,715	$394,794	$1,271,509	56	$25	$81
1985	17,161	864,170	393,589	1,257,759	50	23	73
Average	14,240	$775,447	$394,192	$1,169,639	$55	$24	$79

[1] Calculated as TKC + TOC

[2] Calculated as (TKC/RPMG) + (TOC/RPMG)

Source: Bruce E. Burris and Robert C. Gumerman, Safe Drinking Water Act Cost Impacts on Selected Water Systems (Cincinnati: Water Engineering Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, September 1987), and calculations by authors.

TABLE 3-14

REVENUE-COST RATIOS FOR SAN JUAN, CALIFORNIA

Year	Dollars of Revenue Per Million Gallons (R/RPMG)	Cost in Dollars Per Million Gallons (C/RPMG)	Ratio of Revenues (R/RPMG) To Costs (C/RPMG) (R/C)
1978	$ 114	$ 141	0.81
1979	113	132	0.86
1980	116	173	0.67
1981	110	190	0.58
1982	127	214	0.59
1983	136	249	0.55
1984	119	228	0.52
1985	118	225	0.52

Source: Von Carter, Controller, San Juan Suburban Water District, and calculations by authors.

Prior to 1983, water treatment for CT was minimal and involved only chlorination. Due to problems of tetrachloroethylene and trichloroethylene concentrations in ground water, five air stripping towers (designed capacity of 7 MGD) were constructed and placed in operation in 1983. In 1984, treatment costs accounted for only 3 percent of total operating costs; this low proportion was because most of the raw water was chlorinated only. Similarly, treatment costs accounted for only 3 percent of total capital costs. In 1982, prior to the additional treatment process, treatment costs accounted for 4 percent of total operating costs and 3 percent of total capital costs. The base year for calculating incremental operating costs is 1982, the year before the new treatment facility's first year of operation. The capital costs (depreciation plus interest) of the new treatment facility were first incurred in 1983.

Based on 1984 air-stripped treated water, the EPA report concluded that the total annual compliance cost for CT was $133 per treated million gallons. However, for CT, the proportion of treated water subject to air stripping in 1983-1984 was only 2 percent. Table 3-15 shows the reanalyzed data for CT using revenue-producing water as the denominator. Annual capital compliance costs averaged $1.35/RPMG over three years. Although the capital costs were borne by the EPA and the state of Washington, the compliance cost calculations include these funded costs. Because of this funding arrangement, however, the calculations do not reflect interest charges that would normally be applicable. Annual operating compliance costs are calculated as $1.73/RPMG (a three-year average). Therefore, in the case of CT, the annual cost of meeting water quality standards was $3.08/RPMG, or less than one cent per 1,000 gallons billed. This represents an inconsequential increase in system costs, even including the capital costs that were not passed on to CT consumers. Given total system costs of $402/RPMG for CT in 1982, average annual compliance costs of $3.08/RPMG represent an increase of less than 1 percent over this base level. This compares to an increase in total system costs of $64/RPMG, or 16 percent, between 1982 and 1985. The CT case supports the hypothesis that the SDWA will have a lesser impact on larger water utilities.

The largest user served by CT in 1984 accounted for 43 percent of total billed usage. Until 1988, the CT rate structure involved a declining block rate differing for consumers inside and outside the city. In 1988, the CT rate structure was changed to a uniform commodity rate for residential

TABLE 3-15

WATER PRODUCTION AND SDWA COMPLIANCE COSTS FOR TACOMA, WASHINGTON

	Production	Compliance Costs			Cost Ratios		
Year	Revenue Producing Million Gallons (RPMG)	Capital (TKC)	Operating (TOC)	Total (TC)[1]	TKC / RPMG	TOC / RPMG	TC[2] / RPMG
1983	24,277	$34,000	$45,298	$79,298	$1.40	$1.87	$3.27
1984	25,183	34,000	46,952	80,952	1.35	1.86	3.21
1985	26,000	34,000	37,900	71,900	1.31	1.46	2.77
Average	25,153	$34,000	$43,383	$77,383	$1.35	$1.73	$3.08

[1] Calculated as TKC + TOC

[2] Calculated as (TKC/RPMG) + (TOC/RPMG)

Source: Bruce E. Burris and Robert C. Gumerman, Safe Drinking Water Act Cost Impacts on Selected Water Systems (Cincinnati: Water Engineering Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, September 1987), and calculations by authors.

TABLE 3-16

REVENUE-COST RATIOS FOR TACOMA, WASHINGTON

Year	Dollars of Revenue Per Million Gallons (R/RPMG)	Cost in Dollars Per Million Gallons (C/RPMG)	Ratio of Revenues (R/RPMG) To Costs (C/RPMG) (R/C)
1975	$ 202	$ 194	1.04
1976	234	216	1.08
1977	271	233	1.16
1978	290	285	1.02
1979	343	273	1.26
1980	417	332	1.26
1981	476	378	1.26
1982	596	402	1.48
1983	578	442	1.31
1984	587	466	1.26

Source: Jane Evancho, Civil Engineer, Tacoma Department of Utilities, and calculations by authors.

customers while retaining the declining block rate for commercial and industrial customers. Table 3-16 shows the revenue-cost ratios (R/C) for CT. The R/C for CT varies from 1.02 to 1.48 and in all ten years exceeds 1.0. There is evidence, therefore, that the added treatment costs have been passed on to CT consumers.

CHAPTER 4

COMPARATIVE ANALYSIS OF EIGHT WATER SYSTEMS

Chapter 3 provided case studies of eight water utility systems using data from EPA sources. This chapter compares the data across the eight systems and makes some general observations about the cost impact of SDWA compliance on small systems. While the sample is neither large nor random, it is sufficient for purposes of illustration and exploratory analysis.

The Eight Cases Compared

Table 4-1 provides an overview of the general system characteristics for the eight water systems. For this and subsequent tables, the year for which the data apply (data year) is indicated. The cases are arranged in ascending order according to size, based on production output measured in millions of gallons daily (MGD). The first four systems can be considered small, although they are not representative of the many "very small" systems serving fewer than 500 connections. (They are more accurately termed small-medium systems.) The second four systems can be considered medium in size. (A few of these are actually medium-large.) The smallest system in the group is Idyllwild, California (IW) and the largest is City of Tacoma, Washington (CT), although in terms of capacity, the San Juan (SJ) system is the largest. The only system in the sample regulated by a state public utility commission is the Hartland, Wisconsin (VH), system.

Service connections for the eight systems range from 1,400 to 74,000. For six of the eight, service is 100 percent metered. Not surprisingly, the population served by each system corresponds roughly with the output of the systems. San Juan (SJ) provides service in the most densely populated area. The sample represents a good mix of utilities with different water sources. Four systems use surface water exclusively, two use well water exclusively, and the remaining two rely on wells for 75 percent and surface sources for 25 percent of their water.

TABLE 4-1

SUMMARY OF GENERAL SYSTEM CHARACTERISTICS FOR EIGHT WATER SYSTEMS

System, State	Data Year	Output in Million Gallons Daily	Capacity in Million Gallons Daily	Service Connections (000)	Percent Metered	Population Served (000)	Service Area in Square Miles	Water Sources[1]
IW, CA	1984	0.3	0.8	1.4	100%	2.8-20.0[2]	3	75% W 25% S
VH, WI[3]	1985	0.9	1.4	1.5	100	6.2	3	100% W
LV, NY	1985	0.9	1.7	1.8	100	5.0-6.0[4]	3	100% S
PV, NY	1985	1.1	2.6	1.7	100	10.6	12	100% S
CS, AZ	1986	21.1	30.0	24.2	100	53.4[5]	89	100% W
CE, WA	1984	30.5	50.0	18.3	27	57.0[6]	46	100% S
SJ, CA	1985	47.4	120.0	4.6	1	150.0[7]	16	100% S
CT, WA	1984	75.9	72.0-116.0[8]	74.0	100	213.0	90	75% W 25% S

Source: Bruce E. Burris and Robert C. Gumerman, Safe Drinking Water Act Cost Impacts on Selected Water Systems (Cincinnati: Water Engineering Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, September 1987).

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[1] W = wells; S = surface.

[2] Population served is 2,800 plus 20,000 during peak vacation periods.

[3] This is the only system regulated by a state public utility commission.

[4] Population served is 5,000 plus 1,000 in adjacent water districts.

[5] Prior to 1987, more than half of Scottsdale's population was served by Phoenix. In 1987, Scottsdale bought the distribution system from Phoenix.

[6] Includes wholesale customers, 40 water districts, and 65 distributors serving 53,500 retail customers. A paper mill received 9,454 MG in 1984.

[7] Includes 136,000 customers (81 percent of total population served) for whom service is provided by wholesale distributors.

[8] A gravity flow system of 72 MGD is augmented by wells for a maximum flow rate of 116 MGD.

Table 4-2 indicates that the eight water systems vary significantly according to the amount of water that actually generates revenues. The annual output data correspond to the daily output data, with the exception of San Juan (SJ) which is surpassed in revenue-producing water by Everett (CE) as well as Tacoma (CT). Differences in output levels essentially bisect the sample. The first four systems produce fewer than 500 million gallons per year and fewer than 300 million gallons generate revenues for them. The other four systems produce somewhere between 7.7 and 28.6 billion gallons of water annually. For these systems, at least 90 percent of water output produces revenues, compared with 63 to 67 percent for the smaller systems. The last column in table 4-2 is the converse of revenue-producing water, that is, unaccounted-for water. These differences are particularly relevant to this study for several reasons. One is that utilities of different sizes, and with different capacities for generating revenue, vary in terms of their ability to implement SDWA measures and take advantage of scale economies in the process. Second, revenue recovery should be less of a burden on larger firms because they are able to spread costs over a larger customer base. For these reasons, price or rate shock (discussed in detail in chapter 5) should not be a big problem for large systems. Third, some utilities produce large quantities of water that do not generate revenue, that is, unaccounted-for water. Based on our sample, this problem may be more likely for smaller systems. When it occurs, treatment costs must be recovered from fewer units of output, thereby increasing per-unit costs. In sum, a small water utility may be disadvantaged by limited scale economies, a smaller customer base, and suboptimal production levels. These factors may hamper efforts to comply with the SDWA.

A comparison of systems in terms of revenue-producing water is also important because the EPA has based its calculations of the cost impact of SDWA compliance on treated water for a recent year. Our case studies examine average per-unit costs using all revenue-producing water. For some utilities, the EPA cost calculation considers only a relatively small amount of treated water, even though the revenue base from which the cost of treatment can be recovered is actually much larger. If only some of a utility's water requires special treatment to be in compliance, that portion cannot be segregated and sold at a higher rate. It is reasonable to spread the cost of treatment over all revenue-producing water. This can result in a lower per-unit cost measurement. Some utilities, however, have large amounts of unaccounted-for

TABLE 4-2

WATER OUTPUT, REVENUE PRODUCTION, AND UNACCOUNTED-FOR WATER FOR EIGHT WATER SYSTEMS

System	Data Year	Total Water Output in Million Gallons (TMG)	Revenue-Producing Output in Million Gallons (RPMG)	Percentage of Water Output Producing Revenue (RPMG)/(TMG)	Percentage of Unaccounted-for Water 100-[(RPMG)/(TMG)]
IW	1984	122	77	63%	37%
VH	1985	317	200	63	37
LV	1985	313	210	67	33
PV	1985	403	270	67	33
CS	1986	7,729	7,497	97	3
CE	1984	20,598	19,980	97	3
SJ	1985	17,334	17,161	99	1
CT	1985	28,571	26,000	91	9

Source: Bruce E. Burris and Robert C. Gumerman, Safe Drinking Water Act Cost Impacts on Selected Water Systems (Cincinnati: Water Engineering Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, September 1987), and calculations by authors.

water from which revenues are not generated. Obviously, unsold water does not generate revenue. This can result in a higher per-unit cost measurement.

In the long term, regulators may need to differentiate between treated and untreated water as well as between water that produces revenue and water that does not. They may want to devise rate structures that assign treatment costs only to drinking water and not to water sold for other purposes, such as industrial applications, a policy consistent with a strictly cost-based pricing perspective and the principle of "the burdens following the benefits." Regulators may also question management prudence in instances where large quantities of unaccounted-for water have been treated with costly technologies. For this study, however, the focus is simply on revenue-producing water without regard to these distinctions. Table 4-3 provides a summary of the treatment issues dealt with by each of the eight water systems. Each had decades of experience with conventional filter technologies and chlorination. The SDWA has identified several contaminants for which new treatment methods are required. For each contaminant, specific methods are appropriate. For example, air stripping is used in cases of tetrachloroethylene and/or trichloroethylene, and flocculation and/or sedimentation in cases of turbidity. The information in table 4-3 gives a rough idea about the range of treatment technologies that water utilities may need to implement.

Before and After the SDWA: Cost and Revenue Comparisons

As treatment problems were identified, each of the eight water systems invested in capital improvements and incurred additional operating expenses to remedy the problems and comply with current or impending SDWA regulations. The ideal research design for assessing the impact of the SDWA on the costs of small water systems is an interrupted time series approach that compares costs, revenues, and their relationship before and after implementing compliance measures. Given the many different financial circumstances of individual utilities, it is appropriate to calculate treatment costs as a percentage of capital costs or operating costs (depending on the type of expenditure) for appropriate years.

Table 4-4 compares capital and operating costs before and after SDWA compliance. For six of the eight cases, treatment costs as a percentage of capital costs increase. Only for Scottsdale (CS) and Tacoma (CT), both relatively larger systems, do these costs appear stable. Cost increases are particularly dramatic for LeRoy (LV) and Everett (CE). The findings are somewhat different in the realm of operating costs. In two cases the percentage of operating costs devoted to SDWA treatment actually declined. The largest increase was for Potsdam (PV), whose treatment costs relative to total operating costs increased from 36 to 67 percent. While there is little doubt that the SDWA contributes to increased capital and operating costs, the data provide somewhat more evidence of this effect in the area of capital expenditures.

TABLE 4-3

TREATMENT ISSUES FOR EIGHT WATER SYSTEMS

System	Previous Treatment	Treatment Problem	New Treatment (Year Implemented)
IW	Rapid sand filters and chlorination	Bacteria and giardia	Package filtration (1980)
VH	Fluoridation	Trichloroethylene	Air stripping and chlorination (1984)
LV	Rapid sand filters and chlorination	Turbidity	Package plant for flocculation, sedimentation, and filtration (1983)
PV	Conventional	Trihalomethane concentrations	Flocculation, sedimentation, filtration, and ozonation (1983)
CS	Chlorination	Trichloroethylene and inorganic chemical concentrations	Air stripping (1985)
CE	Chlorination	Turbidity and trihalomethane concentrations	Chemical coagulation, direct filtration, disinfection, and flocculation (1983)
SJ	Alum coagulation and chlorination	Turbidity	Flocculation and sedimentation (1979); filtration (1983)
CT	Chlorination	Tetrachloroethylene and trichloroethylene	Air stripping (1983)

Source: Derived from Bruce E. Burris and Robert C. Gumerman, Safe Drinking Water Act Cost Impacts on Selected Water Systems (Cincinnati: Water Engineering Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, September 1987).

Table 4-5 examines both revenues and costs for each water system before and after SDWA compliance on a per-million-gallons (MG) basis. The purpose of this analysis is to assess the degree to which the costs of SDWA compliance are passed along to consumers. Also compared are the revenue-cost ratios

TABLE 4-4

TREATMENT COSTS BEFORE AND AFTER SDWA COMPLIANCE FOR EIGHT WATER SYSTEMS

	Before SDWA Compliance			After SDWA Compliance		
		Treatment Costs as a Percent of:			Treatment Costs as a Percent of:	
System	Data Year	Capital Costs	Operating Costs	Data Year	Capital Costs	Operating Costs
IW	1979	4%	4%	1984	14%	6%
VH	1981	1	5	1985	16	6
LV	1981	17	55	1985	88	46
PV	1982	65	36	1985	80	67
CS	1984	1	1	1986	1	1
CE	1981	2	6	1984	44	25
SJ	1978	45	24	1985	52	27
CT	1982	3	4	1984	3	3

Source: Bruce E. Burris and Robert C. Gumerman, Safe Drinking Water Act Cost Impacts on Selected Water Systems (Cincinnati: Water Engineering Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, September 1987), and calculations by authors.

TABLE 4-5

REVENUES AND COSTS BEFORE AND AFTER SDWA COMPLIANCE FOR EIGHT WATER SYSTEMS

	Before SDWA Compliance				After SDWA Compliance			
System	Data Year	Revenue RPMG	Cost RPMG	Revenue Cost	Data Year	Revenue RPMG	Cost RPMG	Revenue Cost
IW	1975	$2,858	$2,113	1.35	1984	$3,044	$1,943	1.30
VH	1976	1,167	1,272	.92	1985	1,923	1,481	1.30
LV	1976	848	501	1.69	1985	1,571	2,356	.67
PV	1977	1,177	645	1.82	1985	3,654	3,691	.99
CS	1977	617	222	2.78	1986	1,237	772	1.60
CE	1976	98	83	1.18	1984	390	354	1.10
SJ	1978	114	141	.81	1985	118	225	.52
CT	1975	202	194	1.04	1984	587	466	1.26

Source: Bruce E. Burris and Robert C. Gumerman, Safe Drinking Water Act Cost Impacts on Selected Water Systems (Cincinnati, Ohio: Water Engineering Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, September 1987), and calculations by authors.

for each system. In each case, the amount of revenue received for every million gallons produced increases, but to varying degrees. The cost per million gallons increased in every case with the exception of Idyllwild (IW), the smallest system in the sample.

If revenues keep pace with costs (such as those associated with SDWA compliance) the ratio of revenues to costs will remain relatively stable. If revenues lag behind costs, this ratio will have a lesser value over time, suggesting that the burden of SDWA compliance costs, along with other increasing costs, are not necessarily passed along to consumers. It also suggests the possibility that a water system's revenue stream is impaired by the additional cost of SDWA compliance.

The data in table 4-5 suggest that during the time the eight water systems were implementing SDWA compliance measures, the ratio of revenues to costs declined in all but two cases, Hartland (VH) and Tacoma (CT). For three systems--LeRoy (LV), Potsdam (PV), and Scottsdale (CS)--the drop was substantial. During the post-SDWA period, there appears to be a much closer correspondence between revenues and costs. An exception may be in the case of San Juan (SJ), where revenues lagged behind costs during both of the years we examined (as well as every year in between).

While it is difficult to generalize from these findings, it is reasonable to suggest that implementing SDWA compliance measures does affect small water utilities' costs and revenues. Evidence also suggests that for the most part compliance costs are being passed along to water customers under full-cost pricing. Regulated utilities experiencing deficits or declines in revenue-cost ratios due to SDWA compliance efforts are likely to bring the problem to the attention of state utility regulators. The impact of the SDWA will be seen not only in terms of implementation costs for treatment methods, but also in terms of effects on the overall financial condition of individual water utilities.

Average Cost Impact of SDWA Compliance

For each of the cases in the sample, the available data were used to calculate average compliance costs for the period in which SDWA treatment methods were implemented. Table 4-6 reports average production in revenue-producing million gallons (RPMG), average capital costs per million gallons

(TKC/RPMG), and average operating costs per million gallons (TOC/RPMG). Average capital and operating costs are added to find average total costs for treatment (TC/RPMG). In addition to presenting this figure on a per-unit basis, table 4-6 displays average compliance cost per 1,000 gallons billed. This figure provides a measurement that can be more easily translated to customer bills.

As table 4-6 indicates, the per-unit costs of SDWA compliance vary dramatically. Capital costs range from $1/RPMG to $1,647/RPMG, and operating costs range from $1/RPMG to $415/RPMG. Total SDWA compliance costs range from $3/RPMG to $2,062/RPMG. This amounts to between $0.01 and $2.06 per 1,000 gallons billed. Obviously, some customers would hardly detect the effect of compliance on their water bills while others would witness a highly noticeable increase. The table also demonstrates the probable effect of scale economies. Treatment costs for the four largest utilities would appear to add no more than eleven cents for every 1,000 gallons billed. Two of the smaller utilities, LeRoy (LV) and Potsdam (PV), experience the greatest cost impact of the eight cases in the sample.

Table 4-7 presents average treatment costs in comparison to a base year for each water system, making it possible to assess the impact of SDWA compliance relative to changes in system costs as a whole. As a percentage of base year system costs, treatment costs range from 1 percent to 263 percent. The two systems that experienced the highest relative cost impact are in the smaller system category. By contrast, total costs for all of the systems increased from roughly 10 percent to 300 percent over their base levels during the comparable time period for each case. The last column compares treatment costs to increases in total system costs. Compliance costs account for the vast majority of cost increases in five cases. For the other three cases, increases in total system costs cannot be so closely linked to the SDWA.

When SDWA compliance accounts for a substantial share of increased costs, it is reasonable to assume that requests for rate relief will be attributed, and attributable, to the SDWA. In some cases, however, the evidence is not entirely clear. The data suggest that increases in costs associated with the SDWA are not always linked in a generalizable way to increases in total system costs. For this reason, among others, utility regulators will find it useful to segregate SDWA compliance costs from other system costs to fully understand the factors driving each request for rate recovery.

TABLE 4-6

AVERAGE COST IMPACT OF SDWA COMPLIANCE FOR EIGHT WATER SYSTEMS

System	Data Years	Average Capital Cost (TKC/RPMG)	Average Operating Cost (TOC/RPMG)	Average Total Cost (TC/RPMG)	Average Total Cost Per 1,000 Gallons Billed
IW	1980 - 1984	$125	$133	$258	$0.26
VH	1982 - 1985	72	64	136	0.14
LV	1982 - 1985	1,462	80	1,542	1.54
PV	1983 - 1985	1,647	415	2,062	2.06
CS	1986	2	1	3	0.01
CE	1982 - 1984	80	29	109	0.11
SJ	1980 - 1985	55	24	79	0.08
CT	1983 - 1985	1	2	3	0.01

Sources: Individual contacts at each water system and calculations by authors. (See tables, chapter 3.)

TABLE 4-7

COMPARISON OF SDWA COMPLIANCE COSTS AND TOTAL SYSTEM COSTS FOR EIGHT WATER SYSTEMS

System	Base Year	Base Year System Costs/ RPMG	Treatment Costs/ RPMG	Treatment Costs Per Base Year Costs	Increase in Total System Costs/ RPMG	Increase in Total System Costs Per Base Year Costs	Treatment Costs Per Increase in Total System Costs
IW	1979	$2,370	$258	11%	$1,398	59%	18%
VH	1981	1,288	136	11	136	11	100
LV	1981	586	1,542	263	1,770	302	87
PV	1982	1,447	2,062	143	2,243	155	92
CS	1984	546	3	1	224	41	1
CE	1981	199	109	55	111	56	98
SJ	1979	132	79	60	92	70	86
CT	1982	402	3	1	64	16	5

Source: Bruce E. Burris and Robert C. Gumerman, Safe Drinking Water Act Cost Impacts on Selected Water Systems (Cincinnati: Water Engineering Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, September 1987), and calculations by authors.

Cost Effects of Different SDWA Treatment Measures

As a whole, the case studies of water utilities complying with SDWA standards provide evidence that compliance costs vary substantially across water systems, apparently as a function of site-specific factors. The data also provide insight into the cost impact of certain treatment processes. Table 4-8 combines data from three earlier tables (4-1, 4-6, and 4-7) to provide an overview of the cost impacts of different SDWA treatment measures according to system size as measured by output, cost per 1,000 gallons billed, and the percentage increase in system costs.

Three of the systems, Hartland (VH), Scottsdale (CS), and Tacoma (CT), added air stripping to their treatment inventory. In the case of Hartland, which is significantly smaller than the other two systems, chlorination was added during the same time period. The result for all three cases was only a modest increase in absolute costs, ranging between one cent and thirteen cents per 1,000 gallons billed. In relative terms, this treatment technology appeared to add only between 1 and 11 percent to total system costs. Idyllwild (IW), the smallest system in the sample, also experienced modest increases in absolute costs (twenty-six cents per 1,000 gallons billed) and relative costs (11 percent of total system costs) upon the addition of a package filtration plant.

Everett (CE) and San Juan (SJ) are systems of medium size that implemented comparable treatment technologies. In the case of Everett (CE), the addition of treatment plant using coagulation, filtration, disinfection, and flocculation added only a modest increase in absolute costs (twenty-two cents per 1,000 gallons billed). However, these treatment measures increased total system costs by more than 50 percent. For San Juan (SJ), absolute costs increased only eight cents per 1,000 gallons, representing an increase in system costs of 86 percent.

The results were much different for two smaller water systems, LeRoy (LV) and Potsdam (PV), that installed similar treatment facilities using flocculation, sedimentation, and filtration technologies. LeRoy (LV) experienced a substantial increase in absolute costs ($1.54 per 1,000 gallons billed) accompanied by a substantial increase in relative costs (263 percent). The increase in absolute costs for Potsdam (PV) was even greater ($2.06 per

TABLE 4-8

COST EFFECTS OF DIFFERENT SDWA TREATMENT MEASURES FOR EIGHT WATER SYSTEMS

System	Treatment Measure (Year Implemented)	Output in Million Gallons Daily	Cost Per 1,000 Gallons Billed	Percentage Increase in System Costs
IW	Package filtration (1980)	.3	$0.26	11%
VH	Air stripping and chlorination (1984)	.9	0.14	11
LV	Package plant for flocculation, sedimentation, and filtration (1983)	.9	1.54	263
PV	Flocculation, sedimentation, filtration, and ozonation (1983)	1.1	2.06	143
CS	Air stripping (1985)	21.1	0.01	1
CE	Chemical coagulation, direct filtration, disinfection, and flocculation (1983)	30.5	0.11	55
SJ	Flocculation and sedimentation (1979); filtration (1983)	47.4	0.08	86
CT	Air stripping (1983)	75.9	0.01	1

Source: Bruce E. Burris and Robert C. Gumerman, Safe Drinking Water Act Cost Impacts on Selected Water Systems (Cincinnati: Water Engineering Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, September 1987), and calculations by authors.

1,000 gallons billed), although the cost increase relative to total system costs was slightly less (143 percent).

In general, the findings reinforce the view that the cost impact of the SDWA varies widely across utility systems. They also indicate that differences in system size and treatment technologies will play a role in determining this impact. From these data, it appears that the addition of air stripping towers involves lower costs than the construction of new filtration or treatment plants. Moreover, the cost impact of either technological choice will be less for larger water systems than for smaller systems. Of course, the type of technology called for--and the costs that go along with it--will depend on the type of contaminant problem in a particular water system. In complying with the provisions of the SDWA, the choice of technology will be driven by the contaminant issue, not the cost issue. Water systems and rate regulators will be constrained by this reality.

Comparison of EPA and Case Study Calculations of SDWA Compliance Costs

The method used by the EPA for determining the cost and rate impacts of SDWA compliance varies significantly from the method used in this study. In concluding this analysis, therefore, the EPA calculations are compared with the revised cost calculations derived from the case studies. Table 4-9 provides a comparison of total cost data for each water system.

The problem of using treated water as compared with revenue-producing water when calculating the per-unit cost of SDWA treatment was noted earlier. The case studies use revenue-producing water as the denominator. In some cases, this amount will be much less than the amount of treated water due to unaccounted-for water. The result of using a smaller denominator in the case studies is a higher measurement of compliance costs than that of the EPA. However, the EPA calculated costs using only the amount of water treated by a newly installed method, and in some cases this amount is small in comparison to total revenue-producing water. The result of using a higher denominator in the case studies is a lower measurement of compliance costs than that of the EPA.

As table 4-9 indicates, the recalculated costs correspond to the EPA cost calculations in only a few cases. For two cases, Scottsdale (CS) and Tacoma (CT), the calculation of SDWA compliance costs in this study was only a fraction of the EPA cost calculation. Both of these systems had installed air stripping towers to treat a small amount of water, about 2 percent of all treated water in their systems. According to this study, treatment costs are more appropriately spread over a larger revenue base (all revenue-producing

TABLE 4-9

COMPARISON OF EPA AND CASE STUDY CALCULATIONS OF SDWA COMPLIANCE COSTS

System	Case Study Data Years	EPA Data Year	Case Study Cost Per Revenue-Producing Million Gallons	EPA Cost Per Treated Million Gallons	Case Study Cost Per RPMG/ EPA Cost Per MG
IW	1980 - 1984	1984	$258	$536	48%
VH	1982 - 1985	1985	136	324	42
LV	1982 - 1985	1985	1,542	942	164
PV	1983 - 1985	1985	2,062	1,575	131
CS	1986	1986	3	142	2
CE	1982 - 1984	1984	109	216	50
SJ	1980 - 1985	1985	79	73	108
CT	1983 - 1985	1984	3	133	2

Source: Bruce E. Burris and Robert C. Gumerman, Safe Drinking Water Act Cost Impacts on Selected Water Systems (Cincinnati: Water Engineering Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, September 1987), and calculations by authors.

water), thereby reducing per-unit costs. Scottsdale and Tacoma also fall into the group of medium-sized water systems in the sample. For three other cases, Idyllwild (IW), Hartland (VH), and Everett (CE), the recalculated compliance cost is less than half of the EPA cost calculation. In the case of San Juan, the EPA calculation of SDWA compliance costs corresponds closely to the findings here. Finally, in the cases of LeRoy (LR) and Potsdam (PV), the EPA figure is far less than this study's calculation of costs incurred by water systems in the course of implementing the SDWA.

In sum, the results are mixed. It is not easy to predict the impact of the SDWA on the basis of general water system characteristics. The data are sufficient, however, to speculate that somewhat larger systems may experience a lesser impact than the EPA report seems to suggest. For the smaller systems, the recalculated costs are reasonably close to the original EPA cost calculations. Differences between the EPA analysis and the reanalyzed data are largely attributable to the use of revenue-producing water in this study for calculating per-unit costs. Ratemakers should be cautious, however, in generalizing the results of this analysis or applying any cost analysis to specific cases. The characteristics and circumstances of each water system are likely to weigh heavily on the actual costs necessary to implement the SWDA. Important cost determinants appear to be system size, the type of treatment technology warranted, and the extent of contamination in a system's water supplies. Because of the potential for substantial cost impacts on water systems and their customers, it may be useful for regulators to segregate SDWA compliance costs from other investments and expenses in the course of reviewing a utility's revenue requirements.

Finally, at least in the long term, the distinction between treated water (for drinking) and untreated water (for other uses) could prove to be an important element of water utility rate design decisions. Also, the distinction between water that generates revenue and water that does not has proven to be highly significant to the evaluation of per-unit costs of SDWA compliance. Large quantities of water that do not generate revenue may raise questions about management prudence, especially when unaccounted-for water has been treated with a costly technology. As always, the challenge for public utility commissions will be to assess many different factors as they make cost recovery determinations for individual water utilities.

CHAPTER 5

THE CONVERSION OF SDWA COSTS INTO RATES

The case studies indicate that implementation of the SDWA will have a substantial but uneven impact on water companies. Some experiencing the greatest effects will be commission-regulated utilities. Thus, state utility regulators are concerned with the effect of SDWA compliance on water consumers. The chief concerns of many commissions may be whether compliance costs have been prudently incurred and how water utilities are to recover prudently incurred costs through rates. Abrupt large rate hikes may be necessary as water systems either construct new facilities or upgrade existing ones. Commissions may feel the need to address the issue of rate shock for water consumers and ways to mitigate it.

Compliance Costs and the Regulatory Process

The SDWA can affect many different elements of the regulatory process, as well as the resources of the state public utility commissions. Plant additions may require certification proceedings. Financing arrangements for capital improvements, and associated cost-recovery plans, may require regulatory approval as well. Monitoring, reporting, and even accounting procedures at both the utility and the commission may be affected by SDWA compliance activities. There may be a need for coordination with the state primacy agencies responsible for SDWA compliance.[1] Rate regulators may want to facilitate compliance by encouraging technology transfer from larger to smaller jurisdictional utilities. One way for very small water companies to meet SDWA standards is to form or join regional companies that are more capable of covering increased costs. Transferring utility assets and/or

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[1] See, for example, California Department of Health Services and California Public Utilities Commission, Memorandum of Understanding: On Maintaining Safe and Reliable Water Supply for Regulated Water Companies in California, 1987.

forming a new utility may require the approval of state regulators who will want to be assured that the transaction is in the public interest. State commissions may also want to exercise regulatory oversight of the regional utility. Finally, although highly unlikely given the exemption provisions, there is a chance that SDWA could contribute to service abandonment. This too would require regulatory review and possibly intervention.

The focal point of most rate regulators' concerns about SDWA compliance, of course, is rates. Through rate base regulation, state commissions must examine the capital costs associated with SDWA compliance to ascertain if the costs satisfy the prudent investment standard. State commissions must also examine the operating costs associated with SDWA compliance to ascertain if the costs satisfy the reasonableness standard. They will also want assurances that proposed rates for water service are just and reasonable.

The traditional rate base regulation formula is:

$$R = O + D + T + rB.$$

where: R = revenue requirements,
O = operating expenses,
D = depreciation charges,
T = taxes,
r = permitted rate of return, and
B = rate base.

Compliance with the SDWA (meaning implementation of new treatment processes, monitoring, reporting, and educational requirements) affects three components of revenue requirements (R): operating expenses (O), depreciation charges (D), and asset book value or rate base (B). The increase in (O) from SDWA compliance will be included in (R) and thus will be treated as an above-the-line expense paid by consumers. The new capital investment required by SDWA compliance, once accepted by commissions as a prudent investment, will be included in rate base (B) and subsequently amortized or depreciated (D).

Compliance costs associated with the SDWA may vary with the type of utility ownership.[2] For example, to the extent that investor-owned firms pay state and federal taxes and typically have higher costs of capital than

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[2] Dreese and Davis, Briefing Paper on the Economic Impact of the Safe Drinking Water Act Amendments of 1986.

publicly-owned systems, the revenue requirements of investor-owned utilities will tend to exceed those of publicly-owned utilities, given equal SDWA compliance costs.

For investor-owned water utilities, the cost of SDWA compliance must be recovered through a formal rate process. In this context, capital investment costs must satisfy the standard of prudence and operating costs must satisfy the standard of reasonableness. By contrast, many publicly-owned water utilities (generally outside public utility commission jurisdiction) can usually recover compliance costs without being subject to a comprehensive rate case incorporating evidence of this nature.

Public utility commissions are mandated by state statutes to identify costs, such as SDWA compliance costs, and allocate them to a jurisdictional utility's ratepayers according to regulatory standards. Commissions have the responsibility to ensure that any prudently incurred and reasonable expenses are recovered through just and reasonable rates and other user charges.

Early Evidence of Rate Shock

The available evidence regarding very small water systems indicates that the cost burden imposed by the SDWA and related state legislation will not be minimal. Chapters 2, 3, and 4 of this report suggest such a conclusion even though these analyses do not directly link changes in rates or customer bills to the cost of SDWA compliance. Based on a 1986 survey by the Association of State Drinking Water Administrators (ASDWA), filtration standards alone were estimated to increase water rates 600 percent for very small systems (less than 100 population served), as compared to 160 percent for systems serving populations between 3,300 and 10,000.[3]

Utilities, Inc. projects that monitoring costs for each of its various water systems, which range from 100 to 3,000 customers, will be approximately

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[3] Barry R. Sagraves, John H. Peterson, and Paul C. Williams, "Financing Strategies for Small Systems," American Water Works Association Journal 80 (August 1988): 40-43.

$6,000 between 1987-1989.[4] Assuming that each service connection consumes 80,000 gallons each year, the annual monitoring cost ranges from one cent per 1,000 gallons billed for the largest system (3,000 customers) to twenty-five cents per 1,000 gallons billed for the smallest system (100 customers). The monitoring cost projections provide more evidence that the cost burden of the SDWA is sharply reduced as one moves from very small to larger water systems.

Rate shock is experienced when a customer's bill for a utility service is sharply increased relative to its previous level. An increase from $40 to $50 monthly is less shocking than an increase from $15 to $50 per month, even though the resulting bill is the same. Although rate shock can be an issue for utilities of different size, it is expected that the smaller the company the bigger the shock.

Some early cases of rate shock associated with SDWA compliance costs can be identified. In South Carolina, a water utility made several improvements to comply with state drinking water standards, including construction of a new well to replace an abandoned one that had high radionuclide levels. The result was an increase in average water bills of approximately 75 percent, or $1.28 per 1,000 gallons billed.

In Pennsylvania, an engineering consulting firm commissioned by the Department of Environmental Resources recently recommended a three-phase water quality capital improvement program for a system serving a mobile home park. At present, the water system has thirteen service connections and has plans for an additional twenty-one. Mobile home park residents pay a flat monthly charge. The capital improvements would add $23 to this bill. The annual capital costs of the improvements are estimated to be approximately $8,300, or $3.43 per 1,000 gallons consumed.

Of course, rate recovery for public utilities is never automatic. In Massachusetts, a water system with ninety-five residential customers recently incurred expenses to decontaminate and upgrade its reservoir and install chlorination facilities. The utility requested a temporary surcharge that

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[4] Material provided by David Demeree, Vice-President of Operations, Utilities, Inc. His company recently installed a softening process in a water system serving 150 customers. With a capital cost of $50,000 and an estimated annual operating cost of $3,000, the new treatment process costs fifty cents per 1,000 gallons billed.

would more than double its present fixed charges. The Massachusetts Department of Public Utilities, citing inadequate accounting records, a lack of cost increase documentation, and questionable affiliate transactions, found a revenue deficiency that would justify only a 30 percent increase in charges.

In sum, the somewhat limited evidence available on small water systems indicates that cost burden associated with water quality improvements may be substantial and that translating SDWA compliance costs into rates may result in rate shock for many water consumers.

Phase-in Issues, Alternatives, and Implications

In the context of high-cost increments of capacity (primarily nuclear), rate phase-in plans recently have been discussed, and in some cases actually implemented, for the electric utility industry.[5] The objective of these plans is to avoid rate shock caused by large front-end charges by realigning prices and revenue requirements over time. In theory, at least, customers benefit from phase-in plans because a sharp price increase for a vital utility service is avoided. Utilities benefit, too, because revenue and earnings levels are maintained. Without phase-in, and depending on price elasticities, higher prices may dampen the demand for a utility's service, making it necessary to recover costs over fewer units of production. This adverse effect is compounded if a utility must seek additional rate increases to cover a revenue shortfall.

Given the potential for relatively large capital investments associated with SDWA compliance, particularly for small water utilities, a relevant issue is whether phase-in plans can be applied to water rate regulation. As in the case of electricity, the purpose a phase-in plan is to minimize rate shock and possibly avoid a substantial short-term decrease in water usage. Perhaps the most serious problems ensuing from substantial rate increases due to SDWA compliance are the inducement for consumers to withdraw from small systems and

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[5] William M. Gallavan and Bruce T. Smith, "The Regulatory Challenges of Major Plant Additions, Rate Shock, and Other Regulatory Headaches," in _Changing Patterns in Regulation, Markets, and Technology: The Effects on Public Utility Pricing_, edited by Patrick C. Mann and Harry M. Trebing (East Lansing, Michigan: The Institute of Public Utilities, Michigan State University, 1984), 441-450.

the potential for new customers to be discouraged from connecting to existing systems, further reinforcing the scale economy problems already confronting small water systems.[6] In addition, existing consumers can dampen the impact on their bills by reducing water consumption. Even though the rate increases may be modest or manageable for most larger water utilities and the households they serve, smaller water utilities may face financing problems and rate shock.[7] For example, a small financially troubled water utility may have difficulty financing a modest capital investment of $50,000 when its annual operating expenses are only $5,000.

Each phase-in method generates a different distribution of costs and benefits between investors and ratepayers as well as between present and future generations of consumers. The effects of each method on both investors and consumers are largely a function of the length and nature of the phase-in period. Phase-in methods tend to shift risk to utility investors by deferring cost recovery. In other words, nearly all phase-in plans create a deferred asset that must be paid for in the future. In the short term, water utilities are confronted with reduced income and cash flows. This may be particularly harmful to a small water utility that is financially troubled and has difficulty obtaining financing for the new treatment technology. The longer the phase-in period, the longer is the deferral of recovery, and the greater is the investor risk. Longer phase-in periods also shift more costs to future ratepayers.

It follows that a key regulatory issue surrounding phase-in plans is that of intergenerational equity, which involves the transfer of income between present and future ratepayers. The issue is whether customers pay only for the cost of facilities from which they derive discernible benefit. Phase-in schemes cause income transfers between present and future consumers by incorporating amortization periods of different lengths. The determination of an amortization period is not arbitrary, but linked in some fashion to an assumption about an asset's useful life. Longer amortization periods produce

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[6] Frank C. Brimelow and Sneh B. Vein, Effect of Fees on Water Service Cutoffs and Payment Delinquencies (Cincinnati: Water Engineering Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, August 1986).

[7] David Berry, "The Impact of Water Quality Improvements on Household Water Bills," Water International 10 (1985): 146-150.

an increasing cost burden on future ratepayers relative to present ratepayers. Shorter amortization periods produce an opposite effect. Similarly, an amortization period longer than the useful life of an asset has the effect, all other things being equal, of shifting costs from present to future ratepayers. An amortization period shorter than an asset's useful life tends to shift costs from future to present ratepayers.

Phasing-in rate increases does not, in the long term, eliminate extensive rate hikes, but merely spreads them out over a longer period of time, thus cushioning the impact of increasing costs on utility ratepayers. While there are many options for phasing-in compliance costs in the water utility sector, they can be placed in two basic categories.[8] Some levelize rates by altering the timing of the inclusion of capital costs into rates. Others either adjust the method of depreciation or defer the recovery of operating costs.

The levelizing plans can assume one of two forms. First, the capital costs from SDWA compliance can be gradually included in a water utility's rate base before the actual implementation of the treatment technology, with final inclusion occurring sometime afterwards. In essence, the capital compliance costs would be eased into rates by recovering some costs before compliance. Any levelizing plan which involves revenue recovery prior to technology implementation creates, in an accounting context, a deferred liability (or payment owed to ratepayers) that must be repaid to ratepayers sometime after actual implementation. Second, the capital costs from SDWA compliance can be included in the rate base in several stages but only after actual implementation of the treatment technology. Any levelizing plan that involves cost deferral creates, in an accounting context, a deferred asset which must be amortized (added to revenue requirements) during the service life of the treatment technology. In brief, rates must be adjusted upward at some point.

Rate base phase-in plans tend to benefit present consumers over future consumers and ratepayers over investors. (An exception is a pre-operational rate base phase-in.) Again, the distributional effects on different generations of consumers and on investors versus consumers depend upon the nature and length of the phase-in period. As a class, consumers may pay more

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[8] David K. Owens, "The Impact of New High Cost Plant on Established Ratemaking Practices," in Changing Patterns in Regulation, Markets, and Technology: The Effects on Public Utility Pricing, edited by Mann and Trebing, 508-517.

for water service over the long term under rate base phase-in than they would under traditional ratemaking methods. Investors tend to bear the risk of under-recovering costs.

The allowance of construction work in progress (CWIP) in a utility's rate base is viewed by some as a method of reducing rate shock. A related phase-in method is "mirror" or "negative" CWIP. In this particular method, CWIP is permitted in the rate base. After the plant is placed in operation, the CWIP component is amortized, resulting in an increase in operating expenses over time. At the end of the amortization period, the rate base is restored to the level before CWIP. The use of "mirror" CWIP avoids the problem of intergenerational inequity. That is, by compressing the CWIP benefit into the early years of plant operation, the benefit is not extended to future ratepayers over the life of the facility, but essentially is returned to the present generation of ratepayers who funded the benefit. Inclusion of any CWIP in rate base, however, runs the risk of a form of inequity that discriminates against those customers who leave the system before a new plant is placed into service.

A variation is a trended rate plan. One example is the use of trended original cost (TOC) in which the asset increment (the capital cost of new treatment technology) is increased over time to reflect an increase in replacement value of assets resulting from inflation. The increase in rate base value is coupled with a decrease in the rate of return on rate base, thus generating an effect of lower rates in the earlier years of the capital investment with subsequent rate increases over time. With the trended rate base approach, cost underrecovery occurs in the earlier years and cost overrecovery occurs in the later years. This deferred cost recovery approach generates an increase in cash flow over time causing a positive effect on the utility's financial stability. TOC plans tend to benefit present rather than future consumers and thereby worsen the problem of intergenerational inequity, particularly in the case of SDWA compliance costs since both present and future generations of consumers are presumed to benefit equally.

Phase-in options other than levelizing are also available. The recovery of operating costs resulting from SDWA compliance can be deferred or altered as to the timing of their inclusion in revenue requirements. The depreciation or service life of the treatment technology can be lengthened. Decelerated depreciation or inverted depreciation charges can be employed. An amortization approach can be used that permits a return on the entire capital investment associated with SDWA compliance coupled with delayed recovery of capital investment. Finally, an amortization approach can be employed that incorporates normal recovery of capital investment coupled with deferral of a return on capital.

The factors to be considered in the selection or approval of a phase-in plan include the effects on consumers (the intergenerational income transfer issue), the effects on investors, the effects on taxes, the effects on cash flow and the financial viability of the water utility, and the effects on water demand caused either by an unwillingness or an inability of a utility and its regulators to minimize rate shock.[9]

To assess the consumer, investor, cash flow, and other financial effects of alternative phase-in plans, it would be possible to develop a hypothetical water system having certain operating and financial properties. For this exercise, it would be necessary to make assumptions about annual revenue-producing water output, capital investment, permitted rate of return, operating expenses, depreciation, average asset service life, taxes, and average price, among other things. Given these data assumptions, as well as assuming a level of capital investment (and associated operating costs), then the cost impact of SDWA compliance could be estimated over a time horizon of five to ten years under different ratemaking options.

The ratemaking options for dealing with rate shock include traditional ratemaking treatment, "mirror" CWIP, pre-operational rate base phase-in (allowance of CWIP), post-operational rate base phase-in, trended original cost, deferral of operating expenses, deferral of rate of return, and depreciation rate adjustments. For each of these options, the average water rate could be estimated over a specified future time horizon. These estimated water rate patterns, under the different ratemaking options, would assist regulators in their consideration of minimizing rate shock associated with SDWA compliance.

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[9] A. Lawrence Kolbe and James A. Read, Jr., "Utility Rate Shocks: The Problem and Possible Solutions," Proceedings of the 1986 Rate Symposium on Pricing Electric, Gas and Telecommunications Services (Columbia, Missouri: University of Missouri, 1986), 29-44.

In sum, proponents of phase-in schemes argue that under traditional ratemaking, present consumers would bear a disproportionate share of the costs of treatment technologies that benefit both present and future consumers. Some would also argue that traditional ratemaking favors future ratepayers over present ratepayers in the first place because it does not take into account inflation or the declining value of each asset in a utility's rate base, upon which the rate of return is earned. Thus, phase-in can be viewed as a way to rectify these forms of intergenerational inequity. The key benefit of phase-in for present consumers, of course, is that increases in water rates in the short term will tend to be substantially lower than without phase-in. A key benefit for water utilities is the avoidance of a short-term drop in demand due to rate shock.

The primary criticisms of phase-in levied in the electricity industry do not appear to have much validity when applied to SDWA compliance costs. One early argument against phase-in was that postponement of price increases in the short term provides little assurance that the high-cost plant will be needed in the long term. The justification for SDWA compliance costs is more certain and immediate. Once a treatment technology is operational, both current and future consumers will benefit from cleaner water. The risks associated with phase-in that may have some relevance are the risk of perpetuating an intergenerational inequity favoring present ratepayers over future ratepayers and the risk that the delay in cost recovery will be detrimental to the financial health of the utility.

An alternate and simple means of mitigating some rate shock is to substitute monthly for quarterly billing. This sometimes overlooked method reduces the magnitude of consumer water bills but does not actually reduce water rates. The advantages of monthly billing are simplicity and the absence of distributive effects on present and future consumers. The key disadvantage is tripling the printing, postage, processing, accounting, and other administrative costs associated with customer billing. These additional expenses can be a significant burden on small water utilities and, apart from other cost increases, could trigger requests for rate relief.

In addition to examining measures for mitigating rate shock, commissions in cooperation with state legislatures and other state agencies could be developing measures to furnish needed capital to those water utilities under commission jurisdiction that have difficulty complying with the SDWA. These measures could include credit support and direct subsidies.[10] For example, drinking water regulators (state primacy agencies) can provide technical and financial assistance to small water utilities, cooperate with commissions on SDWA implementation matters, and reinforce financial assistance programs.[11] Commission staff can also facilitate the provision of technical assistance to small jurisdictional utilities by large jurisdictional utilities that, because of scale economies, are in a better position to meet SDWA requirements.

Although some water systems may have multiple contamination problems (each mandating an expensive increment of treatment), many systems are expected to have only one or two contamination problems, at the most. For example, microbiological contamination is anticipated to affect many systems. However, for ground water systems (which comprise the majority of systems under commission jurisdiction) the cost of compliance appears to be minimal. Similarly, the potentially high costs of complying with new standards on disinfection will not affect many water systems under commission jurisdiction since these standards apply primarily to surface water systems. In addition, many of the contaminants now covered by the SDWA are not anticipated to be found in many systems, with the exception of radon and lead.

In the short term, the water systems most likely to be making capital improvements to comply with the SDWA that result in substantial rate increases are the medium-sized utilities. Medium-sized utilities comprise less than 20 percent of the approximately 6,000 water utilities under commission jurisdiction. Large systems will tend to benefit from economies of scale, making compliance more manageable. For very small systems that cannot afford the capital and operating costs associated with SDWA compliance in the first place, phase-in may be inappropriate.

Many of the very small (and often financially troubled) water utilities regulated by state commissions probably will apply for and receive exemptions from the SDWA as long as they meet the EPA's financial and health criteria. Alternatively, they may seek to join or form regional water companies that are in a better position to meet the provisions of the SDWA. Of course, no

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[10] Sagraves, et al., "Financing Strategies for Small Systems."

[11] G. Wade Miller, John E. Cromwell III, and Frederick A. Marrocco, "The Role of the States in Solving the Small Systems Dilemma," American Water Works Association Journal 80 (August 1988): 32-37.

utility with water contaminants that pose an unreasonable health risk can expect to be exempt from safe drinking water regulations.

Finally, it is important to note that much of the SDWA cost and rate impact is still part of an uncertain future. The SDWA was initially enacted in 1974, but has had little or no impact until recently. Current slippage in the deadlines for the promulgation of standards appears to be a continuation of an historical pattern. On the one hand, state public utility commissions need to keep informed of EPA standards to fulfill their responsibility in assuring the provision of cost-effective and good quality water service by jurisdictional utilities. On the other hand, some of the potential issues for commissions associated with SDWA compliance may ultimately be less problematic than previously anticipated.

CHAPTER 6

SUMMARY AND CONCLUSIONS

The Safe Drinking Water Act (SDWA) will affect water utilities under the jurisdiction of state public utility commissions. The costs of compliance with the SDWA will have an impact on the rates charged for water service. In some cases, this impact will cause rate shock for consumers accustomed to much smaller water service bills.

This study consisted of four principal components. The first was a sensitivity analysis for a hypothetical water company that provided evidence of the different costs associated with alternative treatment processes. The analysis employed alternative interest rates and amortization periods to provide an understanding of the financing and payback implications of the investment in treatment technologies. Regulators and their staffs will be concerned about this issue as they consider SDWA compliance costs as part of a water utility's overall revenue requirements.

The second component consisted of the development of eight case studies of small and medium-sized water systems, using information originally prepared for the Environmental Protection Agency (EPA). Time-series data provided insight about a number of variables related to SDWA compliance. The analysis emphasized the use of revenue-producing water as the denominator in calculating the per-unit cost of SDWA compliance. The annual cost of compliance ranges from \$1/RPMG to \$1,647/RPMG for capital costs, from \$1/RPMG to \$415/RPMG for operating costs, and from \$3/RPMG to \$2,062/RPMG for total costs. Total compliance costs amount to between \$.01 and \$2.06 per 1,000 gallons billed. For five of the eight systems in the sample, SDWA compliance also accounts for a large share of increases in total system costs over base levels. Based on data comparing costs to revenues, it appears that ratepayers are picking up the tab for SDWA compliance under full-cost pricing by the water systems in the sample.

The third component was a comparative analysis of the eight cases. It was found that, in general, site-specific factors may be significant determinants of compliance costs. In particular, system size and type of treatment technology implemented appear to be important. Another cost determinant is whether all or part of a system's water supplies require treatment. It is reasonable to expect the SDWA to have a more substantial impact on smaller than larger systems, even when comparable water treatment technologies are installed. While some technologies are generally less expensive than others, some utilities will have limited discretion about which technology to implement because of the type of contaminant in the water source. Clearly, compliance with water quality standards will be more of a burden for some water utilities, and their ratepayers, than others.

In some instances, the cost calculations in this study differ significantly from those of the EPA. The use of revenue-producing water in this study for calculating per-unit costs is the primary reason for the difference. Regulators should be cautious about applying any cost analysis to a particular water system given the difficulty of generalizing results. The potentially dramatic cost impact of the SDWA suggests that regulators might consider segregating SDWA compliance costs from other utility investments and expenses when contemplating their recovery through rates. In the long term, distinctions between treated and untreated water, and between water that produces revenue and water that does not, may prove to be important to regulatory decisionmaking about SDWA cost recovery and associated issues of rate design and management prudence.

The fourth component of the study concerned the effects of SDWA compliance costs on rates for water service. Compliance costs affect a water utility's operating expenses, depreciation charges, and rate base. The prudence standard must be met for investments and the reasonableness standard must be met for operating costs. Resultant rates must meet the just and reasonable standard. Rate shock may lead some water utilities and their regulators to consider phase-in plans for water rates. In evaluating these plans, effects on both consumers and investors should be considered.

For consumers, phase-in plans can create intergenerational income transfers and inequities among customer classes. In most phase-in plans, present consumers benefit at the expense of future consumers. Investors will be concerned with the effects of phase-in on a utility's cash flow, taxes, and financial viability. Most phase-in plans create a deferred asset, the cost of which must be recovered from future ratepayers. Small utilities experiencing financial distress may find it difficult to finance treatment technologies. However, the possibility of exemption for very small water systems and the advantage of scale economies for large systems mean that medium-sized utilities may be most affected by the SDWA, at least in the short term.

The analysis of the impact of the SDWA continues to center on the issue of water utility size. Economies of scale are fully expected to apply to water utilities as they implement treatment technologies. The more water a utility produces, the less its per-unit costs of treatment. Moreover, a larger utility has the advantage of scale economies in other aspects of production that also help keep costs down. Not only will a larger utility be less affected by the SDWA, but its customers are less likely to experience rate shock.

The very small water utilities, with service connections of less than 500, are at the other extreme. They do not enjoy economies of scale, but suffer from them. All other things being equal, the per-unit costs of SDWA compliance for very small water companies may be substantial. Their customers may experience rate shock of a significant magnitude. All other things, however, are not necessarily equal. For example, very small water systems may be granted an exemption from the provisions of the SDWA. In fact, the problem of affordability--a key concern for many small water utilities--is grounds for exemption by the EPA if certain criteria are met, and only if the exemption does not pose an unreasonable health risk.

The bad news is that customers of the very small water utilities may not receive water that meets current federal standards; the good news is, they may not have to pay for the technologies needed to meet those standards. Rate regulators, too, may be able to avoid the rate shock issue if exemptions are granted. However, if exemptions are not granted, some small utilities may have to consider forming or joining a regional water system to comply with the SDWA, a process that may require the approval of state regulators. Some public utility commissions may also be able to facilitate SDWA compliance by encouraging technology transfer from the larger to the smaller water utilities in their states.

Assuming that large water systems will not be greatly affected by the SDWA and that small systems will be able, at least, to postpone compliance and its costs, the issue of the medium-sized utilities remains. In the short term, medium-sized utilities will neither be exempted from the SDWA nor able to avoid rate shock from the cost of compliance. These utilities will make substantial capital improvements, incur additional operating expenses to comply with the SDWA, and seek rate recovery for these costs. Prudent and reasonable expenses will be passed along to ratepayers who, absent a phase-in plan, will experience rate shock.

The sample of cases used in this study consisted of utilities of small to medium size. The smallest system had an average output of 0.3 MGD and served 1,400 connections (a population ranging from 2,800 to 20,000). Unless much smaller systems are examined, one can only speculate about the cost impact of new treatment processes on commission-regulated water utilities, the majority of which serve populations less than 1,000. Clearly a need exists for further research into the cost and rate impacts of the SDWA with an emphasis on collecting and analyzing empirical data.

Water of bad quality is not necessarily the result of imprudent management, but may be the product of natural circumstances beyond the control of the average utility. From the perspective of federal regulators, however, noncompliance is seen as not only imprudent but unlawful. Compliance with the SDWA is mandated by federal law unless a water utility qualifies for and receives an exemption. Yet state regulators need to be assured that expenses incurred in the course of compliance are prudent and reasonable, within the constraints of federal standards, before passing them along to ratepayers. Regulators also need to be assured of the justness and reasonableness of proposed rates. The cost of SDWA compliance does not end with the cost of a given treatment technology. As this analysis indicates, there is also a regulatory cost as jurisdictional utilities and state commissions meet the mandate of safe drinking water.

APPENDIX

The appendix is a table entitled "Contaminants Regulated Under the Safe Drinking Water Act Amendments of 1986," prepared by Ann P. Laubach of the NRRI staff.

State public utility commissions may be called upon to consider the prudence of investments and the reasonableness of expenses associated with SDWA compliance by jurisdictional water utilities. Rate review, certification, financial oversight, and interagency coordination are some of the regulatory proceedings that may be affected by compliance issues. The purpose of this appendix is to provide state commissions with a general guide to federally-regulated water contaminants, including types of treatment methods that may be required when a contaminant is detected in a utility's water source.

The table lists the eighty-three contaminants for which drinking water quality standards will be established by the U.S. Environmental Protection Agency (EPA) during the next few years. A chart provides the location of each contaminant in the table. Both are organized according to EPA target dates and contaminant types. For each contaminant, the table provides its source and/or common use, an explanation of how it gets into drinking water supplies, a summary of potential health effects on humans, and possible treatment methods. These methods are alternative processes and none has necessarily been designated by the EPA as the best available technology. The information sources used in developing the table are provided in endnotes.

It should be emphasized that concerns about health effects are based on findings where animals or human beings have been exposed to very high contaminant levels. Drinking water normally does not contain such high levels and scientists disagree about the consequences of prolonged exposure to contaminants for humans. The EPA intends, however, to establish conservative standards in order to provide a safety margin against adverse health effects.

CONTAMINANTS REGULATED UNDER THE SAFE DRINKING WATER ACT AMENDMENTS OF 1986

CHART OF CONTAMINANTS BY TYPE AND TARGET DATE

Volatile Organic Chemicals (VOCs)

EPA Target Date: June 19, 1987

Benzene
Carbon tetrachloride
Dichlorobenzene (also called para-dichlorobenzene)
1,2-dichloroethane
1,1-dichloroethylene
Trichlorobenzene
1,1,1-trichloroethane
Trichloroethylene (TCE)
Vinyl chloride

Volatile Organic Chemicals (VOCs)

EPA Target Date: June 19, 1988

Chlorobenzene
Cis-1,2-dichloroethylene
Trans-1,2-dichloroethylene
Tetrachloroethylene (Perchloroethylene, or PCE)

Volatile Organic Chemicals (VOCs)

EPA Target Date: September 19, 1990

Methylene chloride

Organic Chemicals

EPA Target Date: June 19, 1988

Acrylamide
Alachlor
Aldicarb (also known as Temik)
Aldicarb sulfoxide
Aldicarb sulfone
Carbofuran
Chlordane
Dibromochloropropane (DBCP)
1,2-dichloropropane
Endrin
Epichlorohydrin
Ethylbenzene
Ethylene dibromide (EDB)
Heptachlor
Heptachlor epoxide
Lindane
Methoxychlor
Pentachlorophenol
Polychlorinated biphenols (PCBs)

CHART OF CONTAMINANTS (continued)

Styrene
Toluene
Toxaphene
2,4,5-TP (Trichlorophenoxy-propionic acid, or Silvex)
2,4-D
Xylene

Organic Chemicals

EPA Target Date: September 19, 1990

Adipates (esters of adipic acid)
Atrazine
Dalapon
Dinoseb
Dioxin (2,3,7,8-TCCD)
Diquat
Endothall
Glyphosate
Hexachlorocyclopentadiene
Phthalates (esters of phthalic acid)
Pichloram
Polynuclear aromatic hydrocarbons (PAHs)
Simazine
1,1,2-trichloroethane
Vydate (Oxamyl)

Inorganic Chemicals

EPA Target Date: June 19, 1987

Fluoride

Inorganic Chemicals

EPA Target Date: June 19, 1988

Arsenic
Asbestos
Barium
Cadmium
Chromium(+3) (trivalent form)
Chromium(+6) (hexavalent form)
Copper
Lead
Mercury - inorganic
Mercury - organic (alkyl mercury or methyl mercury)
Nitrate
Nitrite
Selenium(+4) (tetravalent form)
Selenium(+6) (hexavalent form)

CHART OF CONTAMINANTS (continued)

Inorganic Chemicals

EPA Target Date: September 19, 1990

Antimony
Beryllium
Cyanide
Nickel
Sulfate
Thallium

Microbiology and Turbidity

EPA Target Date: June 19, 1988

Giardia lamblia
Heterotrophic bacteria (standard plate count or SPC)
Legionella
Total coliforms
Turbidity
Viruses

Radionuclides

EPA Target Date: June 19, 1988

Gross alpha particle activity
Radium 226 and 228
Beta particle and photon radioactivity
Uranium
Radon (Radon-222)

CONTAMINANTS REGULATED UNDER THE SAFE DRINKING WATER ACT AMENDMENTS OF 1986[1]

TABLE OF CONTAMINANTS BY TYPE AND TARGET DATE

CONTAMINANT	SOURCE	POSSIBLE HEALTH IMPACT ON HUMANS	POSSIBLE TREATMENT
		Volatile Organic Chemicals (VOCs) EPA Target Date: June 19, 1987	
Benzene	Commercial solvent and degreaser of metals; a major component of gasoline; gets into drinking water from leaking underground storage tanks or improper waste disposal. (7)	Known human carcinogen. (19) Associated with leukemia. (7)	Air stripping (11) GAC adsorption (6) Ozone oxidation (13)
Carbon tetrachloride	Industrial solvent. (2) Once a popular household cleaning fluid; gets into drinking water by improper waste disposal. (7)	May cause cancer, central nervous system depression, liver and kidney damage. (2) Concentrates in body fat, liver and bone marrow. (12)	Air stripping (11) GAC adsorption (6) Reverse osmosis (13)
Dichlorobenzene (Also called para-Dichlorobenzene or p-Dichlorobenzene)	Industrial chemicals. (2) Gets into drinking water by improper waste disposal. (7) Infrequently detected in drinking water. (17)	1,2- and 1,3-dichlorobenzene are chemically similar to 1,4-, which causes liver and kidney damage in test animals. (7) Suspected carcinogen. (1)	GAC adsorption (6) Air stripping (11) Ozone oxidation (13)
1,2-Dichloroethane	Industrial solvent and gasoline additive. (2) Gets into drinking water from improper waste disposal. (7)	Suspected carcinogen. (2) High doses affect central nervous system, causing unconsciousness, circulatory collapse, death; lower doses can cause abnormalities of the kidneys, lungs, heart, adrenals and gastrointestinal tract. (12)	Air stripping (11) GAC adsorption (6) Reverse osmosis (13)
1,1-Dichloroethylene	Industrial solvent. (2) Found in water as a result of breakdown of related solvents, which get into water by improper waste disposal. (7)	Causes liver and kidney damage in test animals. (7)	Air stripping (11) GAC adsorption (6) Ozone oxidation (13)

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[1] Numbers in parentheses (n) following entries refer to endnotes. Asterisks (*) denote contaminants substituted by the EPA for seven listed in the congressional conference report.

TABLE OF CONTAMINANTS (continued)

CONTAMINANT	SOURCE	POSSIBLE HEALTH IMPACT ON HUMANS	POSSIBLE TREATMENT
Trichlorobenzenes	Industrial chemicals; gets into drinking water by improper waste disposal. (19)	Liver and kidney toxicity. (19)	GAC adsorption (19) Air stripping (19) Ozone oxidation (19)
1,1,1-Trichloroethane	Industrial cleaner and degreaser of metals; gets into drinking water by improper waste disposal. (7)	Depression of central nervous system. (2)	Air stripping (11) GAC adsorption (6) Reverse osmosis (13)
Trichloroethylene (TCE)	Common metal cleaning and dry cleaning fluid; gets into drinking water by improper waste disposal. (7)	Possible central nervous system depression; causes cancer in test animals. (2) Also causes liver toxicity and possible kidney damage. (12)	Air stripping (11) GAC adsorption (6) Reverse osmosis (13) Ozone oxidation (13)
Vinyl chloride	Industrial chemical used to make plastic products. (2) Found in drinking water as a result of the breakdown of related solvents, which get into water by improper waste disposal. (7)	Known human carcinogen. (19) Causes angiosarcoma to the liver. (12)	Air stripping (11) GAC adsorption (11) Ozone oxidation (13)

Volatile Organic Chemicals (VOCs)
EPA Target Date: June 19, 1988

CONTAMINANT	SOURCE	POSSIBLE HEALTH IMPACT ON HUMANS	POSSIBLE TREATMENT
Chlorobenzene (monochlorobenzene)	Industrial solvent. (2) Not common in drinking water, but has been identified at hazardous waste sites. (17)	Inadequate evidence of carcinogenicity. (17) Nervous system/liver effects. (1)	GAC adsorption (13) Aeration (19) Reverse osmosis (13) Ozone oxidation (13)
cis-1,2-Dichloroethylene	Industrial solvent. (2)	No data on long-term health effects. (2) Analogous to 1,1-Dichloroethylene (see above). (19)	Air stripping (11) GAC adsorption (11) Ozone oxidation (13)
trans-1,2-Dichloro - ethylene	Industrial solvent. (2)	No data on on long-term health effects. (2) Analogous to 1,1-Dichloroethylene (see above). (19)	Air stripping (11) GAC adsorption (13) Ozone oxidation (13)
Tetrachloroethylene (Perchloroethylene) (PCE)	Industrial and dry-cleaning solvent. (2)	Suspected carcinogen. (2) Causes depression of central nervous system. (12)	Aeration (19) GAC adsorption (13)

TABLE OF CONTAMINANTS (continued)

CONTAMINANT	SOURCE	POSSIBLE HEALTH IMPACT ON HUMANS	POSSIBLE TREATMENT
		Volatile Organic Chemicals (VOCs) EPA Target Date: June 19, 1989	
Methylene chloride	Industrial solvent. (2)	Suspected carcinogen. (2)	Aeration (19)
		Organic Chemicals EPA Target Date: June 19, 1988	
Acrylamide	The monomer of polyacrylamide, which is a frequently used polyelectrolyte in water treatment processes. (3)	A high degree of neurotoxicity. (3) Carcinogenic in animals. (19)	GAC adsorption (11) Air stripping (11) Polymer addition practices (17)
Alachlor	A registered pesticide. (3)	Probable human carcinogen. (17)	GAC adsorption (11) Air stripping (11)
Aldicarb (also known as Temik)	A registered pesticide. (3)	Cholinesterase inhibition. (5)	GAC adsorption (11)
*Aldicarb sulfoxide	A principal transformation product of aldicarb. (5)	Cholinesterase inhibition. (5)	
*Aldicarb sulfone	A principal transformation product of aldicarb. Also a commercially available pesticide. (5)	Cholinesterase inhibition. (5)	
Carbofuran	A registered pesticide. (3)	Cholinesterase inhibition. (19)	GAC adsorption (11) Reverse osmosis (13) Ozone oxidation (13)
Chlordane	A registered pesticide. (3) Sale, distribution and use of chlordane products marketed by Velsicol Chemical Co. prohibited effective 4/15/88. (18)	Liver necrosis in test animals. (17) Suspected carcinogen. (19)	GAC adsorption (11)
Dibromochloropropane (DBCP)	Soil fumigant. (2)	Sterility in males. (2) Animal carcinogen. (17)	GAC adsorption (11) Aeration (19)
1,2-Dichloropropane	Soil fumigant and industrial solvent. (2) A registered pesticide. (3) Metabolizes to 1,2-epoxypropate and chloroacetaldehyde. (17)	Probable human carcinogen. (17) Liver/kidney effects. (1)	Air stripping (11) GAC adsorption (11)

TABLE OF CONTAMINANTS (continued)

CONTAMINANT	SOURCE	POSSIBLE HEALTH IMPACT ON HUMANS	POSSIBLE TREATMENT
Endrin	A registered pesticide. (19)	Central nervous system toxicity. (19)	GAC adsorption (19)
Epichlorohydrin	Resins used as drinking water flocculant. (17)	Probable human carcinogen. (17) Reduces fertility in men. (19)	GAC adsorption (11) Polymer addition practices (17)
*Ethylbenzene	Industrial solvent. (2) Unlikely to occur at high levels in drinking water. (17)	Causes adverse kidney and liver effects on test animals. (5)	Air stripping (11) GAC adsorption (11)
Ethylene dibromide (EDB)	A registered pesticide. (3) Once used as a grain fumigant; now banned. (15)	Carcinogenic. (15) Reduces fertility in men. (19)	GAC adsorption (11) Air stripping (11)
*Heptachlor	A widely used insecticide until 1978, when all uses cancelled except subsurface control of subterranean termites. (5) Sale, distribution and use of heptachlor products marketed by Velsicol Chemical Co. prohibited effective 4/15/88. (18)	Central nervous system and hepatic effects. (5) Probable human carcinogen. (17)	GAC adsorption (11) Ozone oxidation (13)
*Heptachlor epoxide	The major metabolite of heptachlor. (5)	Central nervous system and hepatic effects. (5) Probable human carcinogen. (17)	GAC adsorption (11)
Lindane	An herbicide. (3) Limited occurrence in drinking water. (17)	Possible animal carcinogen. (19) Chronic exposure causes liver, kidney and interstitial effects. (17)	GAC adsorption (11)
Methoxychlor	An herbicide. (3) Limited occurrence in drinking water. (17)	Liver, kidney, heart toxicity with high, acute doses. (19)	GAC adsorption (11)
Pentachlorophenol	A registered pesticide. (3) Used in treatment of wood. Occurs infrequently in water as result of bio-degradation of pesticides or from hazardous waste sites. (17)	Adverse effects on fetal development in animals; liver and kidney toxicity in animals. (19)	GAC adsorption (11) Ozone oxidation (13)

TABLE OF CONTAMINANTS (continued)

CONTAMINANT	SOURCE	POSSIBLE HEALTH IMPACT ON HUMANS	POSSIBLE TREATMENT
Polychlorinated biphenols (PCBs)	A registered pesticide. (3) Limited occurrence in drinking water. (17)	Probable human carcinogen. (17)	GAC adsorption (13)
*Styrene	Used widely in manufacturing, including production of resins used to treat drinking water. (5) Metabolizes to styrene-7, 8-oxide. Occurs in both ground and surface water. (17)	Acute toxicity is relatively low. Neurologic and behavioral changes, chromosomal aberrations, skin and respiratory tract irritation. (5) Possible human carcinogen. (19)	Packed tower aeration (17) GAC adsorption (17)
Toluene	An industrial solvent (2) and registered pesticide. (3) Occurs frequently in drinking water at low levels. (17)	Central nervous system depression. (19) Irritation to eyes and respiratory system. (2)	Air stripping (11) GAC adsorption (13) Ozone oxidation (13)
Toxaphene	An herbicide. (3) Minimal occurrence in drinking water. (17)	Probable human carcinogen. (17)	GAC adsorption (11)
2,4-D	An herbicide. (3) Detected only at very low levels in drinking water. (17)	Adverse kidney and liver effects in test animals. (17)	GAC adsorption (11)
2,4,5-TP (Tricholorphenoxy-propionic acid) (also called Silvex)	An herbicide. (3) Most uses suspended in 1979; all registrations now withdrawn or cancelled. Has been found in waste water and in drinking water at hazardous waste sites. (17)	Liver and kidney toxicity in animals. (19)	GAC adsorption (11)
Xylene	A registered pesticide (3), and an industrial solvent. (2) Limited occurrence in drinking water. (17)	Inadequate evidence of carcinogenicity. (17)	Air stripping (11) GAC adsorption (13)

TABLE OF CONTAMINANTS (continued)

CONTAMINANT	SOURCE	POSSIBLE HEALTH IMPACT ON HUMANS	POSSIBLE TREATMENT
		Organic Chemicals EPA Target Date: September 19, 1990	
Adipates (Esters of adipic acid)	Widely used in manufacturing; very persistent and relatively insoluble in water. (3) A registered pesticide. (3)	Data is limited. Di-(2-ethylhexyl) adipate causes cancer in test animals. (19)	Activated carbon.(3)
Atrazine	Herbicide and pesticide. (3)	Possible human carcinogen. (17)	GAC adsorption (19)
Dalapon	A registered pesticide. (3)	Effect on liver and kidney weights in animals. (19)	Ion exchange (19) Conventional filtration (19)
Dinoseb	A registered pesticide. (3)	Reproductive and developmental toxicity in animals. (19)	Ion exchange (19)
Dioxin (2,3,7,8-TCDD)	A pesticide contaminant. (19)	Carcinogen; reproductive toxicity in animals. (19)	GAC adsorption (19)
Diquat	A registered pesticide. (3)	Cataracts, gastrointestinal tract and kidney toxicity in animals. (19)	Ion exchange (19) Conventional filtration (19) Clay mineral adsorption (19)
Endothall	A registered pesticide. (3)	Reproductive toxicity in animals. (19)	Ion exchange (19)
Glyphosate	A registered pesticide. (3)	No remarkable toxicity. (19)	Ion exchange (19) GAC adsorption (tentative) (19)
Hexachlorocyclopentadiene	A registered pesticide. (3)	Forestomach toxicity and nephrosis in animals. (19)	Packed tower aeration (19) GAC adsorption (19)
Phthalates (Esters of phthalic acid)	Widely used in manufacturing; very persistant and relatively insoluble in water. (3) A registered pesticide. (3) Rarely occurs in drinking water at high levels; many found at hazardous waste sites. (5)	Data is limited. (19) Di-(2-ethylhexyl) causes cancer in test animals. (3)	Activated carbon (3)

TABLE OF CONTAMINANTS (continued)

CONTAMINANT	SOURCE	POSSIBLE HEALTH IMPACT ON HUMANS	POSSIBLE TREATMENT
Pichloram	A registered pesticide. (3)	Liver and testicular toxicity; reduced fertility in animals. (19)	GAC adsorption (19)
Polynuclear aromatic hydrocarbons (PAHs)	Some occur as result of leaching of coal tar. Seldom occur at substantial levels. (3) A registered pesticide. (3)	Some are known carcinogens, some are skin irritants. (3)	Activated carbon (3) Limiting or controlling use of coal tar products for water-contact surfaces (3)
Simazine	A registered pesticide (3), herbicide, and soil sterilant. (2)	No remarkable toxicity. (19)	GAC adsorption (19) Ion exchange (19)
1,1,2-Trichloroethane	An industrial solvent (2) and registered pesticide. (3)	Suspected carcinogen. (2)	Aeration (19)
Vydate (Oxamyl)	A registered pesticide. (3)	Cholinesterase inhibition, fetal death in animals. (19)	Ion exchange (19) Conventional filtration (19) Clay mineral adsorption
<u>Inorganic Chemicals</u> EPA Target Date: June 19, 1987			
Fluoride	Naturally-occurring minerals; most common in midwest, west, and southeast. (3 and 19)	Beneficial at low levels; excess levels can cause dental flourosis (3) or crippling skeletal fluorosis. (19)	Ion exchange with activated alumina or bone charcoal (11) Reverse osmosis (19)
<u>Inorganic Chemicals</u> EPA Target Date: June 19, 1988			
Arsenic	Usually result of ground waters drawn from mineral formations containing natural arsenic ores; also can result from industrial discharges and pesticide use. (3)	Dermal and nervous system toxicity effects. (1) May either initiate or promote cancer; trace amounts may be nutritionally desirable. (3)	Ferric sulfate coagulation (11) Alum coagulation (3) Excess lime softening (3) Ion exchange (3) Reverse osmosis (3) Coagulation/filtration (17) Activated alumina (17)

TABLE OF CONTAMINANTS (continued)

CONTAMINANT	SOURCE	POSSIBLE HEALTH IMPACT ON HUMANS	POSSIBLE TREATMENT
Asbestos	Frequent occurrence in drinking water from natural mineral sources and degradation of asbestos-cement water pipe. (3)	Carcinogenic when inhaled; not considered carcinogenic when ingested. (19)	Direct filtration (11) Conventional filtration (3) Calcium carbonate saturation (3) Zinc corrosion inhibitors (3) pH adjustment (3) Lime stabilization (3) Diatomite filtration (17)
Barium	A natural mineral; deposits concentrated in Midwest; can contaminate ground water sources. (3)	Causes increased blood pressure and abnormal EKGs in rats. (3)	Lime softening (3) Ion exchange (3) Reverse osmosis (3)
Cadmium	Corrosion of galvanized pipes and fittings; also in leachates and runoff from hazardous waste sites. (3)	Kidney effects in animals (1); lung cancer in animals from inhalation. (17) Not considered carcinogenic by ingestion. (19)	Ferric sulfate coagulation (11) Lime softening (3) Excess lime softening (3) Corrosion control program (3) Ion exchange (17) Coagulation/filtration (17) Reverse osmosis (17)
Chromium(+3) (trivalent form)	Infrequent occurrence in drinking water from use of chromates as corrosion inhibitors, or leachates and runoff from hazardous waste sites. (3)	Trivalent form is relatively non-toxic, and may be essential to diet. (3)	Ferric sulfate coagulation (11) Alum coagulation (11) Excess lime softening (11) Reverse osmosis (3) Ion exchange (17) Corrosion control (17) Coagulation/filtration (17)
Chromium(+6) (hexavalent form)	+3, under oxidizing conditions such as chlorination, can convert to +6. (3)	Carcinogenic and mutagenic potential by inhalation; effects renal, hepatic, gastrointestinal systems, and skin in humans. (3 and 19)	Ferrous sulfate coagulation (11) Reverse osmosis (3) Ion exchange (17) Lime softening (17) Corrosion control (17) Coagulation/filtration (17)

TABLE OF CONTAMINANTS (continued)

CONTAMINANT	SOURCE	POSSIBLE HEALTH IMPACT ON HUMANS	POSSIBLE TREATMENT
Copper	Commonly found in drinkwater from corrosion of copper pipes. (3)	Unpleasant taste and emetic effect; affects people with Wilson's disease, an inherited autosomal recessive trait characterized by a disorder in copper metabolism; may affect persons who have a glucose phosphate dehydrogenase deficiency. (3)	Conventional treatment (11) Ion exchange (11) Corrosion control program (3)
Lead	Corrosion of lead pipe, solders, fittings; also in leachates and runoff from hazardous waste sites. (3)	Adverse affects on nervous, hematopoietic, renal, and immunological systems; carcinogenic and teratogenic effects in animals by ingestion. (3 and 19)	Corrosion control program (3)
Mercury - inorganic	Infrequent occurrence in drinking water from natural mineralization or discharges from chlorinealkali manufacture; may also contaminate wells from mercury-sealed well pumps. (3) Dental amalgams are major factor contributing to human exposure. (17)	Less toxic than organic but can be converted to organic mercury in the environment. (3)	Ferric sulfate coagulation (11) Reverse osmosis (3) Powdered activated carbon (3) GAC adsorption (3) Lime softening (17) Coagulation/filtration plus powdered activated carbon (17)
Mercury - organic (alkyl mercury) (methyl mercury)	Alkyl mercury not expected to be found in most drinking waters. (3)	Central nervous system disorders; kidney effects. (1)	GAC adsorption (3) Reverse osmosis (3) Powdered activated carbon (3)
Nitrate	Fertilizers, animal wastes, septic tanks and leach field systems; usually contaminates ground water. (3)	Causes methemoglobinemia in infants, which reduces oxygen-carrying capacity of blood. (3) Can be fatal. (19)	Anion exchange (3) Reverse osmosis (3) Modify well construction to reduce contamination from surface water run-off (3)
*Nitrite	Nitrate is converted to nitrite in gastrointestinal tract. Nitrite also occurs in drinking water as result of organic or bacterial contamination or lack of disinfection. (5)	Causes methemoglobinemia in infants, which reduces oxygen-carrying capacity of blood; can result in anoxia and death. (5)	Oxidation (17)

TABLE OF CONTAMINANTS (continued)

CONTAMINANT	SOURCE	POSSIBLE HEALTH IMPACT ON HUMANS	POSSIBLE TREATMENT
Selenium(+4) (tetravalent form)	Naturally-occurring minerals. (3)	Some evidence for carcinogenicity exists; adverse effects range from gastrointestinal problems to dental damage. (3) May be essential nutrient and anticarcinogenic. (19)	Ferric sulfate coagulation (11) Ion exchange (11) Reverse osmosis (3) Anion exchange (3) Activated alumina (3) Lime softening (17)
Selenium(+6) (hexavalent form)	Naturally-occurring minerals. (3)	Some evidence for carcinogenicity exists; adverse effects range from gastrointestinal problems to dental damage. (3)	Ion exchange (11) Reverse osmosis (3) Electrodialysis (3) Anion exchange (3) Lime softening (17) Activated alumina (17) Coagulation/filtration (17)

Inorganic Chemicals
EPA Target Date: September 19, 1990

CONTAMINANT	SOURCE	POSSIBLE HEALTH IMPACT ON HUMANS	POSSIBLE TREATMENT
Antimony	Contamination may result from mining operations and leaching from tin/antimony soldering in plumbing systems. (3)	Resembles arsenic chemically and biologically. (3) Sterility in animals. (19)	Ion exchange (tentative) (19) Reverse osmosis (tentative) (19)
Beryllium	A bivalent metallic element used chiefly as a hardening agent in alloys. (16)	Carcinogen by inhalation and injection. No evidence of carcinogenicity by ingestion. (19)	Ion exchange (tentative) (19) Reverse osmosis (tentative) (19)
Cyanide	A compound of cyanogen; used to treat iron or steel to produce a hard surface. (16)	Acutely toxic at high levels. (19)	Chlorine oxidation (19) Ozonation (19)
Nickel	Occurs naturally in small amounts from mineral salts; industrial pollution may be a source. (3)	Toxic action results in gastrointestinal irritation; dietary nickel can aggravate nickel dermatitis. (3)	Ion exchange (3) Reverse osmosis (3)
Sulfate	A bivalent anion found in nearly all natural waters. (5)	Diarrhea and dehydration. (5) Gastroenteritis. (19) May contribute to formation of various organ or duct calculi; has unpleasant taste. (3)	Membrane filtration (11) Reverse osmosis (3)

TABLE OF CONTAMINANTS (continued)

CONTAMINANT	SOURCE	POSSIBLE HEALTH IMPACT ON HUMANS	POSSIBLE TREATMENT
Thallium	A metallic element that resembles lead in physical properties; used chiefly in compound form in photoelectric cells or as a pesticide. (16)	Sterility in animals. (19)	Ion exchange (tentative) (19) Reverse osmosis (tentative) (19)
		Microbiology and Turbidity EPA Target Date: June 19, 1988	
Giardia lamblia	Protozoa found in intestines of some warm-blooded animals; contaminates surface water. (2)	Causes giardiasis, an abdominal disorder causing diarrhea, cramps, nausea, weight loss, vomiting. (2)	Filtration (11) and disinfection (8)
Heterotrophic bacteria (standard plate count (SPC))	Bacteria that require complex organic compounds of nitrogen and carbon for growth. SPC measures level of heterotrophic bacteria. (9)	Interfere with measurement of coliforms. Can also deteriorate water quality directly (slime deposits, taste, odor problems, etc.) or indirectly (pipe deterioration, etc.). (9)	Filtration and disinfection (19)
Legionella	Bacteria that are abundant in surface water; may be less prevalent or absent in ground water; may proliferate due to inadequate disinfectant residuals, warm temperatures, availability of nutrients. (8)	Causes legionellosis (Legionnaires Disease and Pontiac Fever.) (8) May be transmitted to people by aerosolization of water with subsequent inhalation. (3)	Disinfection (8)
Total coliforms	Group of bacteria usually found in intestines of warm-blooded animals. (2) Widely detected in drinking water supplies. (3)	Signal possible presence of fecal pathogens, although usually not pathogenic in themselves. (9)	Filtration (9) and disinfection (11)
Turbidity	A measurement of light scatter or absorption caused by suspended or colloidal matter (8), which may be microorganisms, heavy organic matters, mineral substances, clay, silt, wastes from industries, etc. (2) Widely detected in drinking water supplies. (3)	No direct correlation exists between low turbidity levels and health effects; however, turbidity may reduce efficiency of disinfection and interfere with total coliform analyses. (8)	Direct filtration (11) Conventional treatment (11)

TABLE OF CONTAMINANTS (continued)

CONTAMINANT	SOURCE	POSSIBLE HEALTH IMPACT ON HUMANS	POSSIBLE TREATMENT
Viruses	Generally more resistant to disinfection than coliforms, thus may be present in drinking water meeting current regulations. (3)	Several enteric viruses are causes of waterborne disease. (19)	Chlorination (11) and ozonation (19)
	Radionuclides EPA Target Date: June 19, 1988		
Beta particle and photon radioactivity	Radioactivity from man-made radionuclides, of which about 200, including strontium-90 and tritium, have half-lives long enough to be potential drinking water contaminants. (14)	Cancer. (1) Health effects vary by type and quantity of radionuclides present. (3)	Lime-soda softening (11) Ion exchange (11) Reverse osmosis (11)
Gross alpha particle activity	Radioactivity from naturally-occurring radionuclides, including thorium-232 and -230, lead-210, and polonium-210. (14)	Cancer. (1)	Depends upon ion. (19)
Radium 226 and 228	Naturally-occurring isotopes of radium, most prevalent in North-central and Appalachian states. (10) Occur mainly in ground water. (3)	Bone cancer, leukemia. (3)	Lime-soda softening (11) Reverse osmosis (11) Ion exchange (3) Lime softening (3) Selective adsorption (10)
Radon (Radon-222)	A noble, inert gas most prevalent in water in Northeast. (10) When homes are built over radon deposits, radon can seep into water; when water is aerated, radon can be released into air. (4) Surface water does not normally contain radon. (14)	Lung cancer; possibly stomach cancer. (3)	Aeration (3) GAC adsorption (3) Storage (time decay) (10)

TABLE OF CONTAMINANTS (continued)

CONTAMINANT	SOURCE	POSSIBLE HEALTH IMPACT ON HUMANS	POSSIBLE TREATMENT
Uranium	Natural uranium with 3 isotopes: uranium-234, -235, and -238. (14) Highest concentrations in Western U.S. (10) Higher concentrations in ground water than in surface water. (14)	Bone cancer, kidney damage. (10)	Coagulation and lime softening at high pH under certain conditions (3) Anion exchange (3) Reverse osmosis (3) Ion exchange (10) Lime softening (14) Conventional coagulation under certain conditions using alum or iron salts (14)

TABLE OF CONTAMINANTS (continued)

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