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## Introduction

Water is the liquid of life; it makes up two-thirds of our bodies, yet most of us take the safety of our drinking water for granted. The U.S. has one of the safest public drinking water supplies in the world, and the quality of our drinking water has improved over the last 25 years. However, challenges exist now and for the future which require the participation of all consumers if we are to maintain high quality water supplies.

As a global society, we have learned a great deal about drinking water quality throughout history. However, there is still much to learn about the health effects of drinking water contaminants, the monitoring and treatment technologies required to detect and remove contaminants, and ways to protect our water sources. The ability to improve drinking water quality and human health through research, technology, and protection programs is dependent on our commitment as a society to invest in drinking water. To plan for the future, we must first evaluate our progress thus far in providing and protecting this vital resource. That is the intent of this report.

## Drinking Water Prior to 1974

Ancient civilizations established themselves around water sources. While the importance of ample water *quantity* for drinking and other purposes was apparent to our ancestors, an understanding of drinking water *quality* was not well known or documented. Although historical records have long mentioned aesthetic problems (an unpleasant appearance, taste or smell) with regard to drinking water, it wasn't until the early 1900s that standards for water quality, other than for general clarity, existed.<sup>1</sup> However, prior to that time, people had observed that some waters seemed to produce disease, while others did not. Gradually, people recognized that their senses alone were not accurate judges of water quality.<sup>2</sup>

During the 1800s, scientists began to gain a greater understanding of the sources and effects of drinking water contaminants, especially those that were not visible to the naked eye. In 1855, epidemiologist Dr. John Snow proved that cholera was a waterborne disease by linking an outbreak of illness in London to a

public well that was contaminated by sewage. In the late 1880s, Louis Pasteur demonstrated the “germ theory” of disease, which explained how microscopic organisms (microbes) could transmit disease through media like water.<sup>2</sup> This explained the cause-effect relationship between many contaminated drinking water sources and nearby epidemics.

During the late nineteenth and early twentieth centuries, concerns regarding drinking water quality continued to focus mostly on disease-causing microbes (pathogens) in public water supplies. Scientists and engineers studied these waterborne pathogens, tried to determine their sources, and began to develop techniques to remove them from, or render them harmless in, water supplies.

Federal regulation of drinking water quality began in 1914, when the U.S. Public Health Service set standards for the bacteriological quality of drinking water. The standards applied only to water systems which provided drinking water to interstate carriers like ships, trains, and buses, and only applied to contaminants capable of causing contagious disease.<sup>2</sup> The Public Health Service revised and expanded these standards in 1925, 1946 and 1962. The 1962 standards, regulating 28 substances, were the most comprehensive federal drinking water standards in existence before the Safe Drinking Water Act of 1974 (*see Appendix B*).<sup>3</sup> With minor modifications, all 50 states adopted the Public Health Service standards either as regulations or as guidelines for all of their public water systems, even though they were not federally mandated.<sup>4</sup>

By the late 1960s it became apparent that the aesthetic problems, pathogens and chemicals identified by the Public Health Service were not the only drinking water quality concerns. Industrial and agricultural advances and the creation of new man-made chemicals also had negative impacts on the environment and public health. Many of these new chemicals were finding their way into water supplies through factory discharges, street and farm field runoff, and leaking underground waste disposal areas. Many of these chemicals were also suspected of causing health problems.

These health concerns spurred the federal government to conduct several studies on the nation’s drinking water supply. One of the most telling was a water system survey conducted by the Public Health Service in 1969 which showed that only 60 percent of the systems surveyed delivered water that met all the Public Health Service standards. Over half of the treatment facilities surveyed had major deficiencies involving disinfection, clarification, or pressure in the distribution system (the pipes that carry water from the treatment plant to buildings), or combinations of these deficiencies. Small systems, especially those with fewer than 500 customers, had the most deficiencies.<sup>5</sup>

A study in 1972 found that 36 chemicals were detected in treated water taken from treatment plants that drew water from the Mississippi River in Louisiana.<sup>6</sup> As a result of this and other similar studies, new legislative proposals for a federal safe drinking water law were introduced and debated in Congress in 1973.

Chemical contamination of water supplies was only one of many environmental and health issues that gained the attention of Congress and the public in the early 1970s. This increased awareness eventually led to the passage of several federal environmental and health laws dealing with polluted water, hazardous waste, pesticides, etc. (*see Appendix D*). One of these laws was the Safe Drinking Water Act (SDWA) of 1974. That law, with significant amendments in 1986 and 1996, is administered today by the U.S. Environmental Protection Agency’s Office of Ground Water and Drinking Water (EPA) and its partners.

## Overview of SDWA and the National Drinking Water Program

SDWA aims to ensure that public water supplies meet national standards that protect consumers from harmful contaminants in drinking water. EPA regulations under SDWA apply to public water systems (*see Public Water Systems on next page*). Public water systems can be publicly or privately owned. People who are not served by a public water system use private wells.

## Public Water Systems

Public water systems provide drinking water to at least 25 people or 15 service connections for at least 60 days per year. Today, there are approximately 170,000 public water systems in the U.S. providing water to more than 250 million people.

**Table 1. Size Categories of Public Water Systems**

System Size (Population Served)	Percent of Community Water Systems			
	1980	1985	1990	1995
Very Small (25–500)	67	63	63	61
Small (501–3,300)	22	24	24	25
Medium (3,001–10,000)	6	7	7	8
Large (10,001–100,000)	4	5	5	6
Very Large (over 100,000)	1	1	1	1

There are two main types of public water systems:

**Community Water Systems** provide drinking water to the same people year-round. Today, there are approximately 54,000 community water systems serving more than 250 million Americans in their homes. All federal drinking water regulations apply to these systems.

**Non-Community Water Systems** serve customers on less than a year-round basis. Non-community systems are, in turn, divided into two categories:

- 1) Those that serve at least 25 of the same people for more than six months in a year but not year-round (e.g., schools or factories that have their own water source); most drinking water regulations apply to the 20,000 systems in this category.
- 2) Those that provide water to places like gas stations and campgrounds where people do not remain for long periods of time; only regulations of contaminants posing immediate health risks apply to the 96,000 systems in this category.

EPA divides public water systems into categories based on characteristics such as where they serve customers and how often they serve the same people. Water systems with different characteristics are then subject to different regulations. This report focuses on community water systems, because they are subject to all SDWA regulations and serve the greatest number of people on a continual basis.

## Trends in the Number of Water Systems

The first public water system in the U.S. to pump its water from a surface source and distribute it through a system of pipes was built in Philadelphia in 1799. By 1860, more than 400 water systems had been developed to serve the nation's major cities and towns. By 1900, this number had increased to more than 3,000 systems.<sup>7</sup>

This growth, however, was not necessarily an indication that more people had gained access to safer drinking water. Some of these systems, ironically, contributed to major outbreaks of disease in the early 1900s because, when contaminated, the pumped and piped supplies provided a means for spreading bacterial disease throughout communities.<sup>2</sup>

By the early 1960s, there were more than 19,000 public water systems in the U.S.<sup>2</sup> In the late 1970s, EPA began tracking the number of community and non-community water systems in the nation through periodic surveys. In 1980, there were about 62,000 community water systems serving approximately 200 million people in the U.S.<sup>8</sup> Since then, the number of public water systems in the U.S. has decreased. As the cost of providing safe drinking water has increased, consolidation (joining larger systems) has proven to be a cost-effective solution for some very small systems.

While the percentage of very large water systems has remained constant since 1980, there are fewer very small water systems and slightly more small, medium, and large water systems, demonstrating this consolidation trend.

In 1980, 18 percent of the community water systems in the U.S. drew their supply primarily from surface water sources, and 82 percent of community water systems drew primarily from ground water.<sup>8</sup> These percentages

have also remained relatively stable over the years (*see Figure 1*).

### Establishing National Standards for Drinking Water Quality

SDWA requires EPA to regulate contaminants which present health risks and are known, or are likely, to occur in public drinking water supplies. For each contaminant requiring federal regulation, EPA sets a non-enforceable health goal, or maximum contaminant level goal (MCLG). This is the level of a contaminant in drinking water below which there is no known or expected risk to health. EPA is then required to establish an enforceable limit, or maximum contami-

nant level (MCL), which is as close to the MCLG as is technologically feasible, taking cost into consideration. Where analytical methods are not sufficiently developed to measure the concentrations of certain contaminants in drinking water, EPA specifies a treatment technique, instead of an MCL, to protect against these contaminants.

There has been a three-fold increase in the number of contaminants regulated under SDWA since the passage of the Act in 1974. Most of these standards were set in the early 1990s (*see Figure 2*).

### Implementing and Enforcing Drinking Water Regulations

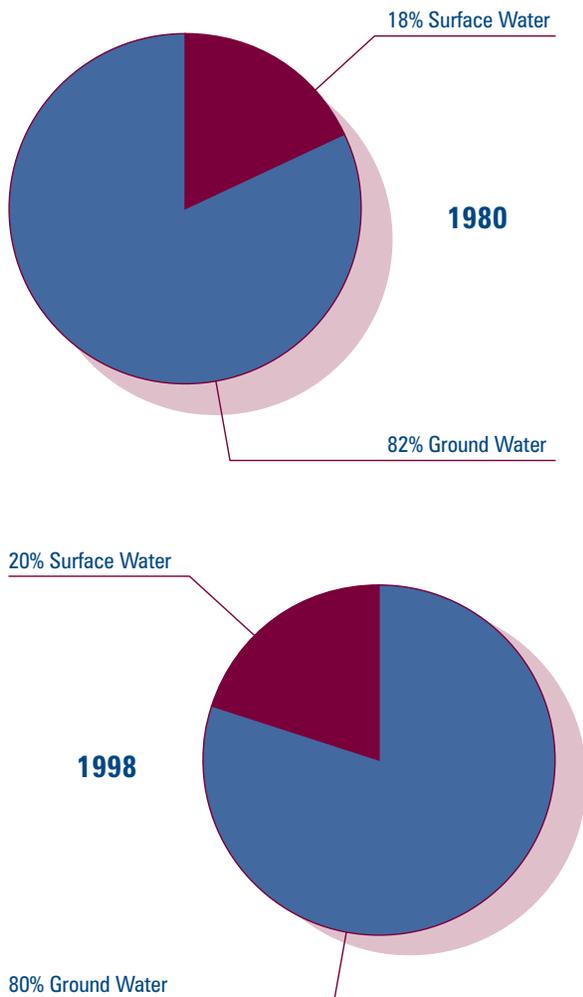
Beginning in 1974, SDWA gave EPA the authority to delegate the primary responsibility for enforcing drinking water regulations to states, territories or tribes, provided that they meet specific requirements. States with this responsibility are commonly referred to as having “primacy.” To assist states in developing and implementing their own drinking water programs, SDWA authorized EPA to provide grants to the states and directed the agency to help states administer their programs. All states but Wyoming have assumed primacy and receive grants from EPA to help pay for the oversight of water systems and other program responsibilities. No tribal governments have yet been granted primacy.

With EPA’s oversight, states with primacy adopt, implement, and enforce the standards established by the federal drinking water program to ensure that the public water systems in their jurisdictions provide consumers with safe water.

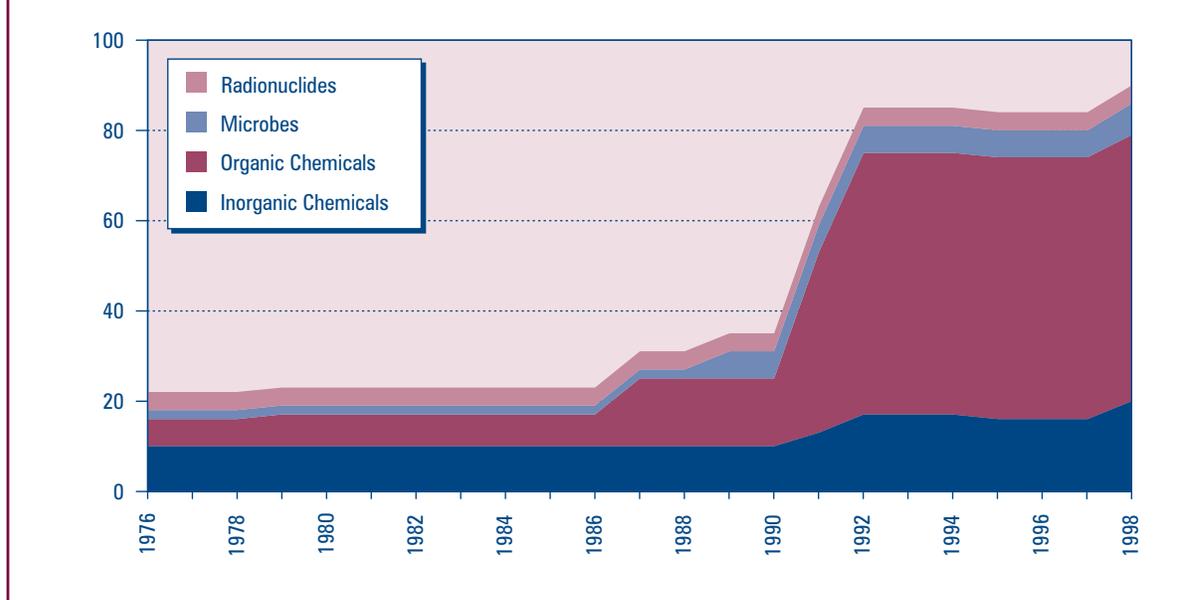
Water systems are required to collect water samples at designated intervals and locations. The samples must be tested in state approved laboratories. The test results are then reported to the state, which determines whether the water system is in compliance or violation with the regulations. There are three main types of violations:

- (1) *MCL violation* — occurs when tests indicate that the level of a contaminant in treated water is above EPA or the state’s legal limit (states may set standards equal to, or more protective than, EPA’s). These violations indicate a potential

**Figure 1. Percentage of Community Water Systems Using Ground Water vs. Surface Water**



**Figure 2. Number of Contaminants Regulated Under the Safe Drinking Water Act, by Contaminant Type**



health risk, which may be immediate or long-term.

- (2) *Treatment technique violation* — occurs when a water system fails to treat its water in the way prescribed by EPA (for example, by not disinfecting). Similar to MCL violations, treatment technique violations indicate a potential health risk to consumers.
- (3) *Monitoring and reporting violation* — occurs when a system fails to test its water for certain contaminants, or fails to report test results in a timely fashion. If a water system does not monitor its water properly, no one can know whether or not its water poses a health risk to consumers.

If a system violates EPA/state rules, it is required to notify the public. States are primarily responsible for taking appropriate enforcement actions if systems with violations do not return to compliance. States are also responsible for reporting violation and enforcement information to EPA quarterly. The information is stored in a federal database called the Safe Drinking Water Information System (SDWIS) and is used to:

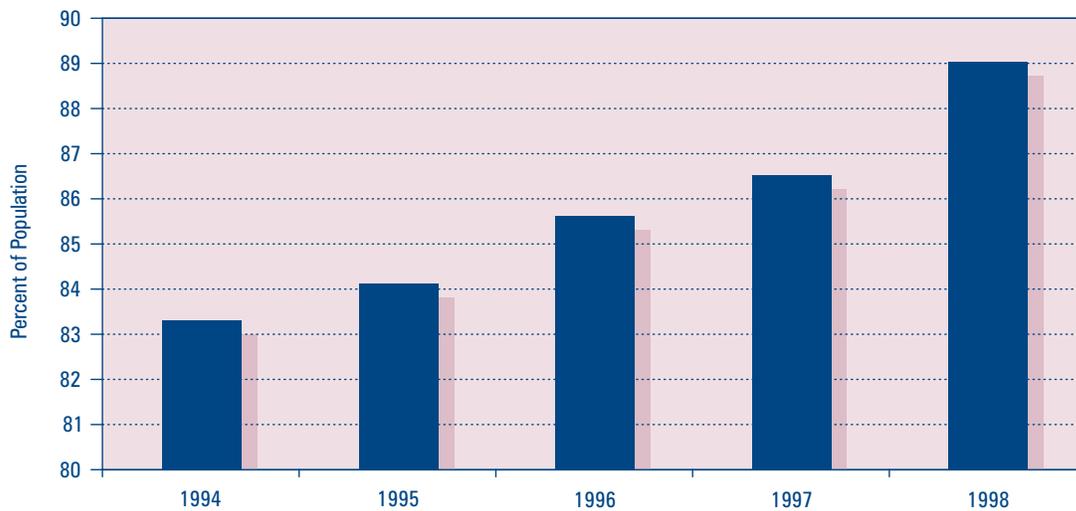
- Help EPA monitor the safety of the nation's public drinking water supply and track the status of drinking water rule implementation;
- Help EPA determine when new regulations are necessary to protect drinking water; and
- Share information with the public and Congress, such as this report, on the status of public drinking water.

### **Tracking Progress Toward Achieving Drinking Water Goals**

As required by the Government Performance and Results Act, EPA has developed long-term goals and objectives that ensure accountability for improving various aspects of the drinking water program. In addition to helping EPA measure its progress in improving drinking water quality and implementing regulations, the goals and objectives also serve as the framework for the Agency's planning and resource allocation decisions.

As part of its overall goal to maintain clean and safe water, EPA's primary drinking water objective is to protect human health so that, by 2005, 95 percent of the population served by community water systems will receive water that meets health-based drinking

**Figure 3. Percent of Population Served by Community Water Systems With No Violations of Health-Based Standards**



water standards in place as of 1994. For any new regulations, the objective is 95 percent compliance within five years. Starting from a baseline of 83 percent in 1994, the population being served by community water systems with no violations of health-based standards has increased steadily to 89 percent in 1998 (*see Figure 3*).

## The Original Safe Drinking Water Act

The 1974 SDWA called for EPA to regulate drinking water in two steps. The first step involved the creation of national interim primary drinking water regulations which, under Congressional direction, were based largely on the 28 1962 Public Health Service standards. These not only included MCLs, but also established requirements for monitoring and analyzing regulated contaminants in drinking water, reporting analytical results, record keeping, and notifying the public when a water system fails to meet federal standards for any of the contaminants. These interim MCLs were designed to be enforceable until revised.

The second step involved the revision of these standards, as necessary, following a comprehensive review

by the National Academy of Sciences of the health risks posed to consumers.

The first 18 interim standards were set in 1975 for:

- six synthetic organic chemicals (man-made chemicals which contain carbon, such as pesticides)
- ten inorganic chemicals (substances of mineral origin that do not contain carbon)
- turbidity (the cloudiness of water)
- total coliform bacteria (bacteria that are used as indicators of fecal contamination in water)<sup>9</sup>

(Levels were set for coliform bacteria and turbidity because, while not in and of themselves a health concern, high levels of both may indicate the presence of pathogens.)

Interim standards for radionuclides (combined radium-226 and radium-228 and two other classes of radionuclides) were promulgated in 1976. An interim standard for total trihalomethanes (TTHMs), a group of four volatile organic chemicals which form when disinfectants react with natural organic matter in the water, was set in 1979.

In 1979, EPA also set non-enforceable guidelines (called national secondary drinking water regulations) for contaminants that may cause aesthetic problems in drinking water. These contaminants include chlorides, color, copper, corrosivity, foaming agents, iron, manganese, odor, pH, sulfate, total dissolved solids and zinc.<sup>10</sup>

## The 1986 SDWA Amendments

Although SDWA was amended slightly in 1977, 1979, and 1980, the most significant changes to the 1974 law occurred when SDWA was reauthorized in 1986.

During the mid-1980s, Congress was frustrated by the slow pace at which EPA was developing new regulations; only 23 contaminants had been regulated between 1975 and 1985. Fluoride, one of the 18 contaminants for which an interim standard was promulgated in 1975, was the only one of the 18 standards revised before the 1986 Amendments.

Congress also wanted to rectify major deficiencies in the implementation of programs established by SDWA. Of particular concern was the fact that disease-causing microbial contamination had not been sufficiently controlled under the original Act. Also, during the early 1980s, synthetic chemicals of industrial and agricultural origin were being detected with increasing frequency, especially in ground water sources.<sup>2</sup> Some surface water sources were also being contaminated with industrial and municipal wastes, but many were showing improvements in water quality due to the increased application of pollution controls, such as waste water treatment plants.

To safeguard the public's health, the 1986 Amendments required EPA to set MCLGs and MCLs for 83 named contaminants (this list included the interim standards, except for TTHMs). The amendments declared that the interim standards promulgated in 1975 were final primary drinking water standards, included provisions for periodic review of the data and studies upon which MCLGs and MCLs were based, and allowed variances for systems that could not meet certain requirements. The 1986 Amendments

also augmented the federal drinking water role by requiring EPA to:

- establish regulations, beyond the 83 specified contaminants, within certain time frames (e.g., regulate 25 additional contaminants every three years starting in 1991)
- require disinfection of all public water supplies
- specify filtration requirements for nearly all water systems that draw their water from surface sources
- develop additional programs to protect ground water supplies (e.g. a new Wellhead Protection program and an enhanced Sole Source Aquifer program)
- establish monitoring requirements for unregulated contaminants which states were required to report on every five years so that EPA could decide whether or not to regulate those contaminants
- implement a new ban on lead-based solder, pipe and flux materials in distribution systems
- specify the “best available technology” for treating each contaminant for which EPA sets an MCL. EPA specifies a “best” technology for all of the major drinking water contaminant groups: pathogens, organic and inorganic chemicals, and disinfectant byproducts.

In 1988, SDWA was amended again by the Lead Contamination Control Act, which established a program to eliminate lead-containing drinking water coolers in schools.

Although Congress' 1986 SDWA revisions required EPA to regulate or revise the standard for the 83 specified contaminants by 1989, time constraints and limited resources at the state and federal levels prevented this from occurring. By 1992, EPA had issued regulations for 76 of the 83 mandated contaminants (those remaining were arsenic, radium, radon, two other classes of radionuclides, and sulfate, most of which had interim standards). These 76 contaminants fall into four basic rule categories, as described below:

## The Total Coliform Rule

Coliforms are a group of bacteria that are common in both the environment and the digestive tracts of humans and animals. Most of these bacteria are harmless; however, their presence in water at levels which are above EPA's standard indicates that pathogens may also be in the water. Among the health problems that pathogens can cause are diarrhea, cramps, nausea and vomiting. Together these symptoms comprise a general illness category known as gastroenteritis. While gastroenteritis is not usually dangerous for healthy adults, it can lead to more serious health problems or even death for people with undeveloped or weakened immune systems, such as the very young, elderly, people with HIV/AIDS or those who have undergone chemotherapy or organ transplants.

Testing water for each of a variety of microbes would be difficult and expensive, but coliform can be easily detected in water. Therefore, coliform levels are used to indicate whether a water system may be vulnerable to pathogens in the water.

In the Total Coliform Rule, EPA set a health goal (MCLG) of zero for total coliforms. EPA also set an MCL for total coliforms. Systems may not find coliforms in more than 5.0 percent of the samples they take each month. If more than 5.0 percent of the samples contain coliforms, water system operators must report this violation to the state and the public.

Most water systems test for coliforms throughout the distribution system on a monthly basis. Some test many times per day, depending on the system size (larger systems test the most). The presence of coliforms in drinking water may indicate that the system's treatment system is not performing properly or that there is a problem with the distribution system. To prevent or eliminate microbial contamination, systems may need to take a number of actions, including repairing the disinfection/filtration equipment, flushing or upgrading the pipes that carry water to customers, and better protecting source water from contamination.

## The Surface Water Treatment Rule

EPA issued the Surface Water Treatment Rule in response to Congress' mandate to require systems that draw their water from surface sources (rivers, lakes and reservoirs) to disinfect their water before distribution and filter, where appropriate. The rule seeks to reduce the occurrence of unsafe levels of disease-causing microbes, including viruses, *Legionella* bacteria, and the protozoan *Giardia lamblia*. These pathogens are present at varying concentrations in most surface waters.

Most of the country's large water systems use surface water as their source. Surface water is particularly susceptible to microbial contamination from sewage treatment plant discharges and farm field runoff. These sources often contain high levels of fecal microbes that originate in septic systems or livestock waste.

Ingestion of *Giardia* and viruses can cause problems in the human digestive system, generally in the form of diarrhea, cramps, and nausea. *Legionella* in water are a health risk if the bacteria are aerosolized (e.g. in an air conditioning system or a shower) and then inhaled. Inhalation can result in a type of pneumonia known as Legionnaires' Disease.

The rule sets MCLGs for *Legionella*, *Giardia*, and viruses at zero because any exposure to these contaminants represents some health risk. Because it is not feasible to accurately measure the level of pathogens in drinking water, EPA requires surface water systems to use certain treatment techniques to minimize the risk from these contaminants.

Specifically, all surface water systems must filter and disinfect their water to provide a minimum of 99.9 percent combined removal and inactivation of *Giardia*, and 99.99 percent removal and inactivation of viruses. The adequacy of the filtration process is determined by measuring the turbidity of the treated water; higher levels of turbidity are often an indicator that the filtration process is not working as it should.

Some public water supplies that have pristine and protected sources may be granted a waiver from the filtration requirement. These supplies must provide

the same level of protection as those that filter; however, their protection is provided through disinfection alone. The vast majority of water supplies in the U.S. that use a surface water source filter their water.

Because it is possible for microbes to enter the distribution system (through cracks or joints in pipes), water systems are also required to provide continuous disinfection of the drinking water entering the distribution system and maintain a detectable disinfectant level within the distribution system.

### The Chemical Rules

The chemical contaminants that EPA regulated in these rules generally pose long-term (i.e., chronic) health risks if ingested over a lifetime at levels consistently above the MCL. These chemicals can cause a wide variety of health effects. For example, some can accumulate in the liver or kidneys and interfere with the functions of these organs. Others can affect the nervous system or cause cancer.

Along with their long-term effects, some of these contaminants can also cause immediate (i.e., acute) health risks. Nitrate and nitrite can cause acute health effects in infants by limiting the blood's ability to carry oxygen from the lungs to the rest of the body. Therefore, EPA's MCL for nitrate and nitrite was set specifically at a level to protect infants.

The chemical contaminants enter the environment through a wide variety of pathways. Some are used in dry cleaners and automotive service stations. Others come from frequently-applied fertilizers (e.g., nitrate) or pesticides (e.g., alachlor). Still others are used in industrial processes to produce other chemicals or as solvents (e.g., trans-1,2-Dichloroethylene). A number of contaminants may be naturally occurring, including inorganic elements such as arsenic.

EPA also limits the amount of some chemicals that water systems may add to water during the treatment process (e.g., acrylamide and epichlorohydrin).

EPA set different monitoring schedules for different chemicals, depending on the routes by which each enters the water supply. In general, surface water systems must take samples more frequently than ground water systems because their water is subject to

more external influences and the water quality changes more frequently due to seasonal and agricultural cycles. Systems which prove that they are not susceptible to contamination can often get state permission to reduce the frequency of monitoring. However, if such systems detect contamination, they must begin monitoring more frequently.

### The Lead and Copper Rule

Lead and copper are both naturally-occurring metals. Both were used to make household plumbing fixtures and pipes for many years, although Congress banned the installation of lead solder, pipes, and fittings in 1986. Water flowing through, or sitting in, pipes containing lead or copper can pick up these metals.

Lead and copper have different health effects. Lead is particularly dangerous to fetuses and young children because it can slow their neurological and physical development. Anemia (a condition in which the blood is deficient in red blood cells, hemoglobin or total volume) may be one sign of a child's exposure to high lead levels. Lead may also affect the kidneys, brain, nervous system, and red blood cells, and is considered a possible cause of cancer.

Copper is a health concern for several reasons. While it is essential to the body at very low levels, short-term consumption of water containing copper at concentrations well above EPA's legal limit could cause nausea, vomiting, and diarrhea. It can also lead to serious health problems in people with Wilson's disease. Exposure to drinking water containing copper above the action level over many years could increase the risk of liver and kidney damage.

To prevent these effects, EPA set health goals and action levels for lead and copper. An action level differs from an MCL in that an MCL is a legal limit on the amount of a contaminant that is allowed in drinking water, whereas an action level is a trigger for requiring additional prevention or removal steps.

EPA requires water systems to not only evaluate the pipes in their distribution systems, but also the age and types of housing that they serve. Based upon this information, the systems must collect water samples at points throughout the distribution system where

lead contamination is more likely to occur, including regularly-used bathroom or kitchen taps.

When the concentration of lead or copper reaches the action level in ten percent of the tap water samples, the water system must begin certain water treatment steps. For example, water systems can reduce the amount of lead or copper that leaches out of pipes by taking measures to make the water less acidic (i.e., less corrosive).

When a water system exceeds the action level for either metal, it must also assess its source water. In most cases, there will be little or none of either contaminant in the source water and no treatment will be necessary. If there are high levels in the source water, treatment, in addition to corrosion control, further lessens the chance that consumers will have elevated levels of lead and copper at their taps.

The rule requires systems that exceed the lead action level to educate the affected public about how to reduce lead intake. Consumers can further reduce the potential for elevated lead levels at their taps by ensuring that all plumbing and fixtures meet local plumbing codes. A system which continues to exceed the lead action level after completing corrosion control and treatment of source water must replace some of its lead distribution pipes.

## The 1996 SDWA Amendments

In the late 1980s and early 1990s, several reports were released about the national drinking water program which drew attention to the need for amending SDWA. The reports raised issues such as whether implementation schedules for new SDWA regulations were realistic; whether public health was being threatened by many water systems' non-compliance with EPA regulations; whether funding for regulation development, implementation and compliance was adequate; and whether EPA and states' enforcement of regulations was lacking.<sup>11</sup> There was also a general recognition that the numerous contaminant-specific standard setting requirements of the 1986 amendments resulted in a "regulatory treadmill [which] dilutes limited resources on lower priority contami-

nants and as a consequence may hinder more rapid progress on high-priority contaminants," according to Mr. Robert Perciasepe, former Assistant Administrator of EPA's Office of Water in Congressional testimony on January 31, 1996.<sup>12</sup>

After much discussion, SDWA was amended in 1996, emphasizing comprehensive public health protection through risk-based standard setting, increased funding, reliance on best available science, prevention tools and programs, strengthened enforcement authority for EPA, and public participation in drinking water issues.

The Amendments improved upon the existing regulatory framework in two important ways. First, they created a new focus on setting contaminant regulation priorities based on data about the adverse health effects of the contaminant, the occurrence of the contaminant in public water systems, and the estimated reduction in health risk that would result from regulation. The Act also increased requirements for research to give EPA more sound scientific data on which to base regulatory decisions. For each proposed regulation, EPA must also conduct a thorough analysis of the costs to water suppliers and benefits to public health, including people with weakened immune systems. Public health protection remains the primary basis for deciding the levels at which drinking water standards are set.

Second, states were given greater flexibility to implement SDWA to meet their specific needs while arriving at the same level of public health protection. The 1996 Amendments seek to prevent drinking water contamination by increasing states' and water systems' capacity to provide safe water.

For example, funding for infrastructure and other water system improvements, especially for small water systems, has significantly increased through the establishment of a new multi-year, multi-billion dollar drinking water state revolving loan fund. New prevention programs, such as source water assessments, will give states and water suppliers information they need to prevent contamination of drinking water sources, thereby providing another barrier of defense against contamination, in addition to treatment. The Amendments also require national minimum guidelines for states to certify operators of drinking water systems, and a water system capacity development

## The 1996 Amendments: Improving Public Access to Information and Increasing Opportunities for Public Participation

### Consumer Confidence Reports

Every community water system must provide its customers with an annual water quality report starting in 1999. The reports tell customers about the source of their water supply, the level of any regulated contaminants detected in their water, and the health effects of contaminants detected above the safety limit.

### Source Water Assessments

No later than 2003, states will be examining each of the nation's drinking water sources to identify contaminant threats and determine how susceptible drinking water sources are to contamination. Communities may assist their state and water system in conducting the assessments, and the states must make the results of the assessments available to the public.

### Drinking Water State Revolving Fund (DWSRF)

This federal grant program provides money for states, who, in turn, provide loans to water systems to upgrade their facilities and ensure compliance with drinking water standards. A portion of each state's federal grant money can be set aside for several specific purposes, including acquiring land to buffer drinking water sources from contamination and funding other local protection activities. Each year, every state develops an intended use plan for how it intends to use all funds, including a list of water systems that will be receiving loan assistance to upgrade their treatment facilities. This list is available to the public, and states are required to seek public input into the development of their intended use plan.

### State Capacity Development Strategies

By October 2000, states must develop strategies to ensure that all public water systems have the technical, financial and managerial capability to ensure that safe drinking water is provided to their customers. States are required to involve the public in the development of these strategies, and to make the final strategy available to the public.

### Operator Certification Revisions

States that need to revise their existing programs to certify operators of public water systems, in order to

meet new requirements, must submit their program changes to EPA by February 2001. These states must obtain public input while revising their programs, and are encouraged to use citizen advisory committees to help implement these programs.

### Public Notification Improvements

Public water systems must notify their customers when they violate a drinking water standard. EPA is revising the existing Public Notification rule to better tailor the form, manner, and timing of the notices to the relative risk to health. The proposed rule will make notification easier and more effective for both water systems and the public.

### New Publicly-Accessible Drinking Water Contaminant Databases

EPA has collected information from water systems on the occurrence of contaminants in drinking water to assist in its decision-making about which contaminants to regulate in the future and which standards for regulated contaminants to reexamine. The data is accessible to the public via the Internet at [www.epa.gov/enviro/](http://www.epa.gov/enviro/) under "Drinking Water Occurrence" and "Drinking Water Microbial and Disinfection Byproduct Information."

### Annual Compliance Report

Every year states must publish a report listing systems in their jurisdiction with violations of federal drinking water standards. EPA must summarize this information in a national report and make it available to the public.

### Health Care Provider Outreach and Education

EPA and the U.S. Centers for Disease Control and Prevention (CDC) must jointly establish a national health care provider training and public education campaign to inform both the professional health care provider community and the general public about waterborne disease and the symptoms that may be caused by infectious agents, including microbial contaminants.

program to ensure that water systems have the managerial, technical, and financial capacity to effectively protect drinking water supplies.

Finally, the Amendments reflect the fact that effective drinking water protection must be founded on government and water system accountability, and on public awareness and involvement. “Right-to-know” provisions in the Amendments will give consumers the information they need to make their own health decisions, allow increased participation in drinking water decision-making, and promote accountability at the water system, state and federal levels.<sup>13</sup>

## The History of Drinking Water Treatment

People first treated water to improve its aesthetic qualities. Methods to improve the taste and odor of drinking water were recorded as early as 4000 B.C. Ancient Sanskrit, and Greek writings recommended water treatment methods such as filtering through charcoal, exposing to sunlight, boiling, and straining.<sup>14</sup>

Visible cloudiness (turbidity) was the driving force behind early water treatments, as many source waters contained particles that had an objectionable taste and appearance. To clarify water, the Egyptians reportedly used the coagulant alum (a chemical that causes suspended particles to settle out of water) as early as 1500 B.C.<sup>15</sup> During the 1700s, filtration was established as an effective means of removing particles from water, although the degree of clarity was not measurable at that time.<sup>1</sup> By the early 1800s, slow sand filtration was beginning to be used regularly in Europe, mainly to improve water’s aesthetic qualities. By the late 1800s and early 1900s, slow sand filtration was used by water systems in some U.S. cities such as Philadelphia.<sup>15</sup>

Soon after, scientists learned that turbidity was not only an aesthetic problem; particles in source water such as fecal matter could harbor disease-causing microbes. The design of most drinking water treatment systems built in the U.S. during the early 1900s was driven by the need to reduce turbidity, thereby removing microbial contaminants which were causing typhoid, dysentery and cholera epidemics.

While filtration was a fairly effective treatment method for reducing turbidity, it was disinfectants like chlorine that played the largest role in reducing the number of waterborne disease outbreaks in the early 1900s. In 1908, chlorine was used for the first time as a primary disinfectant of drinking water in Jersey City, New Jersey. The use of other disinfectants such as ozone also began in Europe around this time, but were not employed in the U.S. until several decades later.<sup>15</sup>

Today, filtration and chlorination remain effective treatment techniques for protecting U.S. water supplies from harmful microbes, although additional advances in disinfection have been made since the early 1900s.

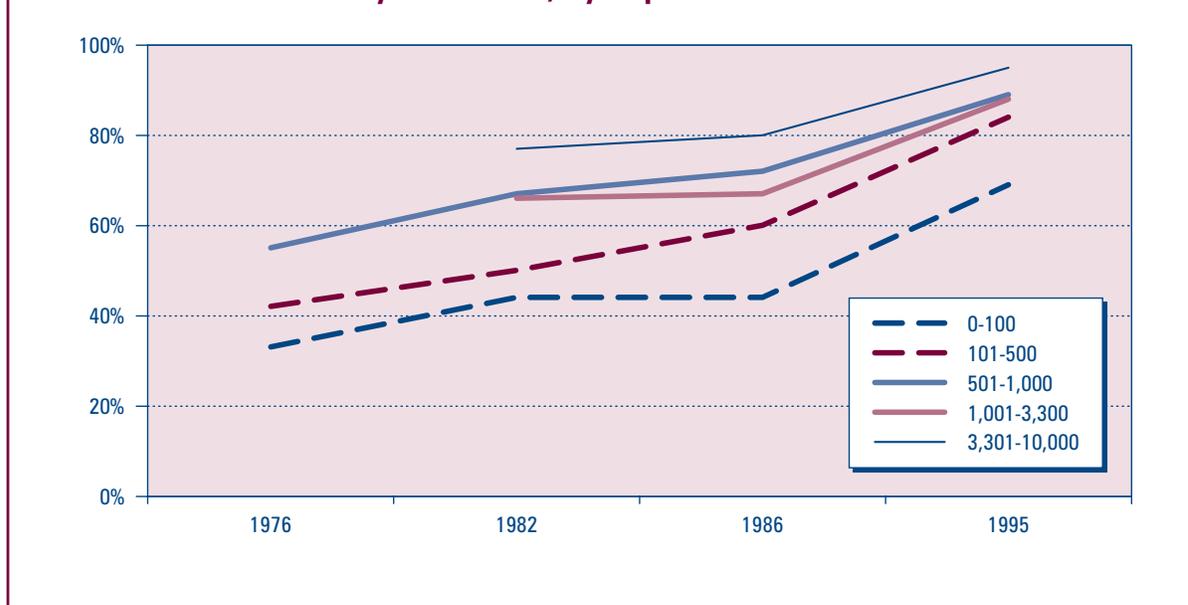
By the 1960s, standard drinking water treatment techniques in the U.S. also included aeration, flocculation, and granular activated carbon adsorption (for removal of organic contaminants). In the 1970s and 1980s, advancements were made in membrane filtration development for reverse osmosis and other new treatment techniques such as ozonation (*see Appendix C*).<sup>15</sup>

According to a 1995 EPA survey, approximately 64 percent of community ground water and surface water systems disinfect their water with chlorine. Almost all of the remaining surface water systems, and some of the remaining ground water systems, use another type of disinfectant, such as ozone or chloramine.<sup>18</sup>

Some treatment advancements have been driven by the discovery of chlorine-resistant pathogens in drinking water that can cause illnesses like hepatitis, gastroenteritis, Legionnaire’s Disease, and cryptosporidiosis. Other advancements resulted from the need to remove more and more chemicals found in sources of drinking water.

Over the years, the number of water systems applying some type of treatment has increased. According to several EPA surveys, from 1976 to 1995, the percentage of small and medium community water systems that treat their water has steadily increased. For example, as figure 4 shows, in 1976 only 33 percent of systems serving fewer than 100 people provided treatment. By 1995, that number had risen to 69 percent.<sup>16-18</sup>

**Figure 4. Percentage of Community Water Systems Providing Any Treatment, by Population Served**



Most large systems have provided some treatment from the beginning, as they draw their water from surface sources which are more susceptible to pollution. These systems also have the customer base to provide the funds needed to install and improve treatment equipment. Because distribution systems have extended to serve a growing population (as people have moved from concentrated urban areas to more suburban areas), additional treatment has been required to keep water safe until it is delivered to all customers.

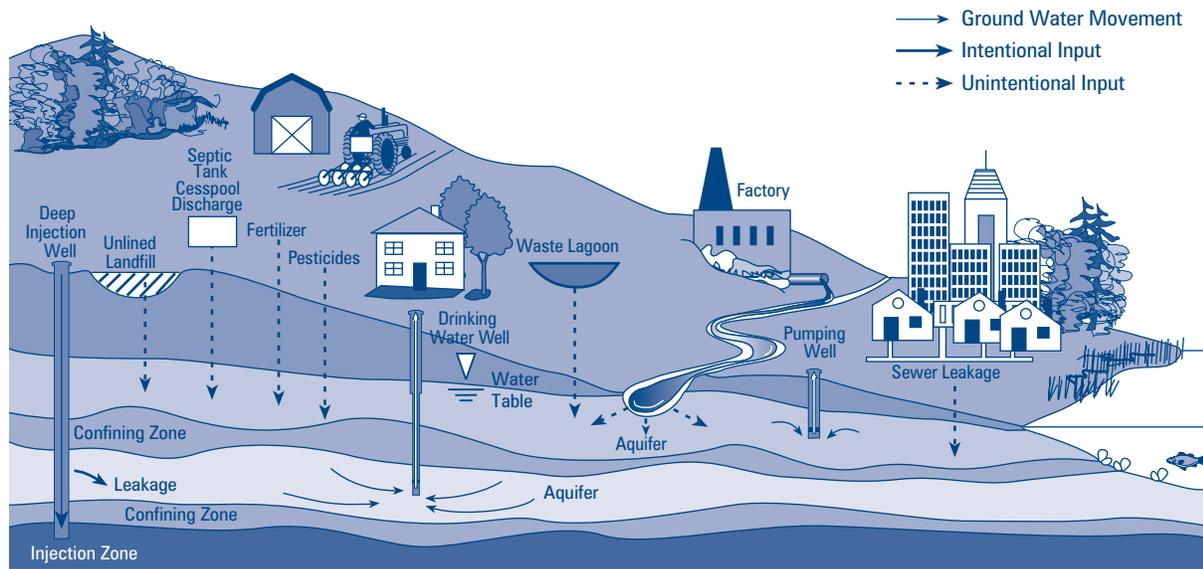
### Protecting Drinking Water Sources

Although treatment techniques can be very effective at removing contaminants from drinking water, they can sometimes be expensive to employ. Also, removing contaminants from drinking water does not necessarily remove them from the environment (e.g., contaminants removed from water are often disposed of on land or released into the air). A more environmentally-sustainable solution to drinking water contamination is to prevent pollutants from reaching drinking water sources in the first place.

Until the 1970s, ground water was thought by many to be naturally protected from dangerous contaminants. Since then, scientists have learned that contaminants from various commercial, industrial, residential and agricultural activities have reached some ground water sources (*see Figure 5*).<sup>17</sup>

The nature of ground water makes it especially difficult to clean up once contamination occurs, and clean-up can cost millions of dollars and take many years to complete. Therefore, pollution prevention is a more prudent and, in many cases, more cost-effective approach to protecting ground water used for drinking water.

Approximately 80 percent of the community water systems in the U.S. draw their water from underground sources, so it is crucial to public health that these sources be protected from contamination. Since the early 1970s, Congress has enacted a range of laws, including provisions in SDWA, to regulate waste disposal wells and underground storage tanks, and remediate and regulate hazardous waste disposal sites (*see Appendix D*).

**Figure 5. Sources of Ground Water Contamination**

### Underground Injection Control

The Underground Injection Control Program, mandated by the 1974 SDWA, was one of the first SDWA provisions created specifically to protect underground sources of drinking water. This program regulates wells that are used by various municipal, agricultural, commercial and industrial entities to inject fluids underground for the purpose of disposal, hydrocarbon production and storage, or mineral recovery. Fluids may also be injected into underground wells to replenish depleted aquifers (natural underground layers of sand or gravel that contain water) with surface water for later retrieval, and to prevent salt water intrusion into underground sources of drinking water.

Shallow drainage systems which discharge contaminants above or directly into underground sources of drinking water are additional examples of waste injection practices regulated under this program. Injection practices not regulated by the Underground Injection Control program include small drainage systems (serving fewer than 20 persons) which inject *only* sanitary waste.

For regulatory purposes, EPA groups injection practices which have similar functions and/or construction and operating features into one of five classes of injection wells (*see Appendix E*). EPA also establishes minimum requirements for states and

territories with primacy for Underground Injection Control programs. These requirements are designed to ensure that injected fluids stay within the wells and the intended injection zones and do not endanger underground sources of drinking water.

Today, 36 states and territories have primacy for Underground Injection Control programs and EPA directly implements 17 programs. These programs regulate more than 400,000 injection wells and up to 89 percent of all hazardous waste that is land-disposed in the U.S.

### Sole Source Aquifers

Another ground water protection effort established by SDWA is the sole source aquifer protection program. Congress included this provision in the 1974 SDWA, and has not modified it since. The program allows communities, individuals, and organizations to petition EPA for protection of an aquifer that is the “sole” or principal source of drinking water for the local population.

A region is eligible for sole source aquifer status if more than 50 percent of the population in the defined area relies on the designated aquifer as its primary source of drinking water. Once EPA designates a sole source aquifer through a public process, EPA has the authority to review and approve federal financially-assisted projects that may potentially contaminate the

aquifer. If the proposed project poses no threat, then the project continues as planned. However, if there is potential for contamination of the aquifer, EPA must work with the project leader and associated federal agency to recommend protective modifications. Examples of federally funded projects that EPA reviews because the activity may impact ground water quality include:

- transportation-related improvement and construction;
- infrastructure upgrades of public water supply systems and waste water facilities;
- agricultural projects which involve animal waste management concerns; and
- construction of multi-family housing, business centers, gasoline stations, and hospitals.

Since the first sole source aquifer designation in 1975, EPA has designated 70 aquifers in 25 states and territories (*see Figure 6*).

### Wellhead Protection

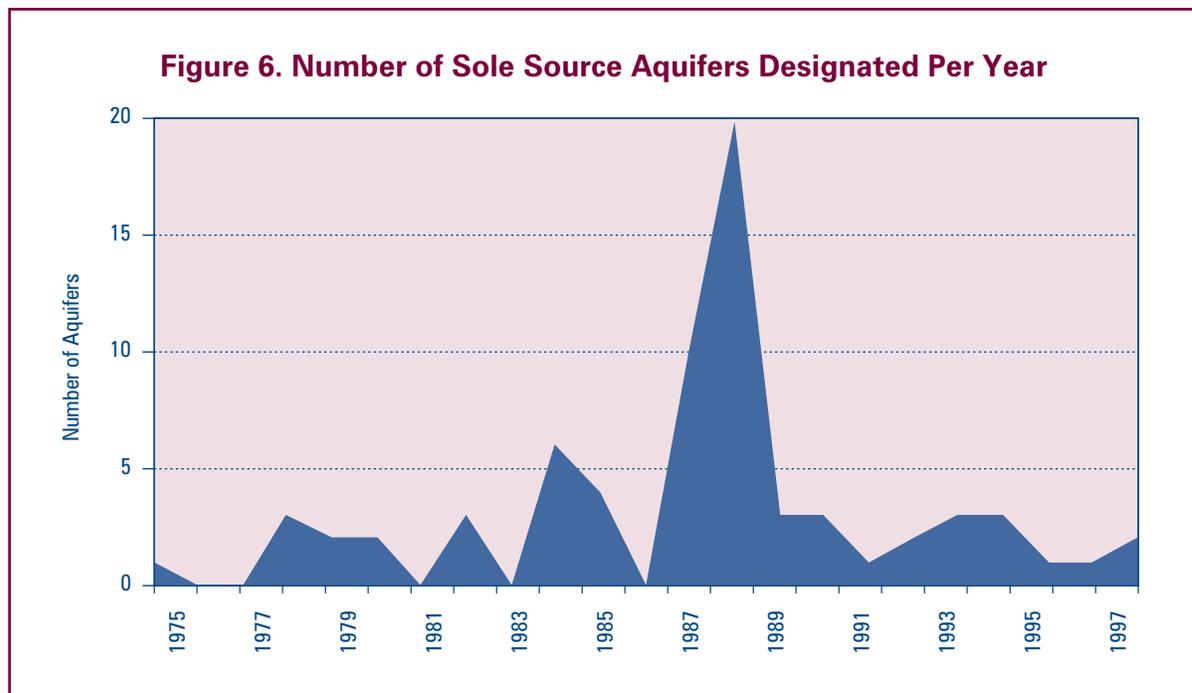
A third provision of SDWA aimed at preventing groundwater contamination is the Wellhead Protection Program. The 1986 SDWA Amendments established

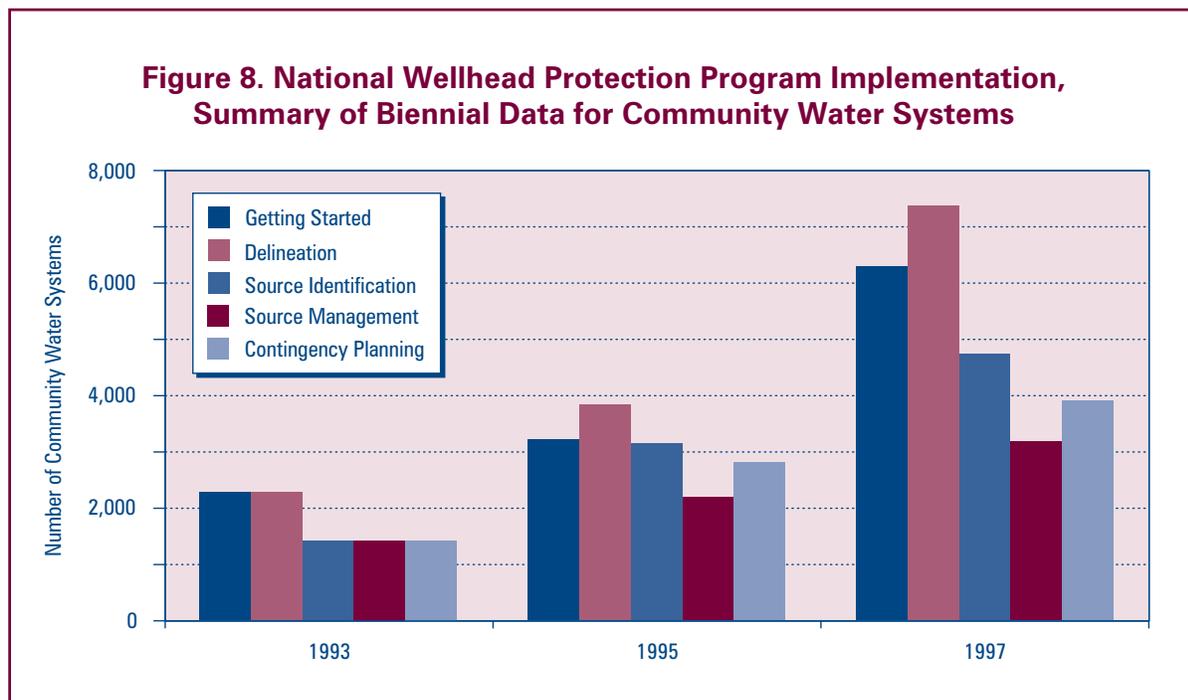
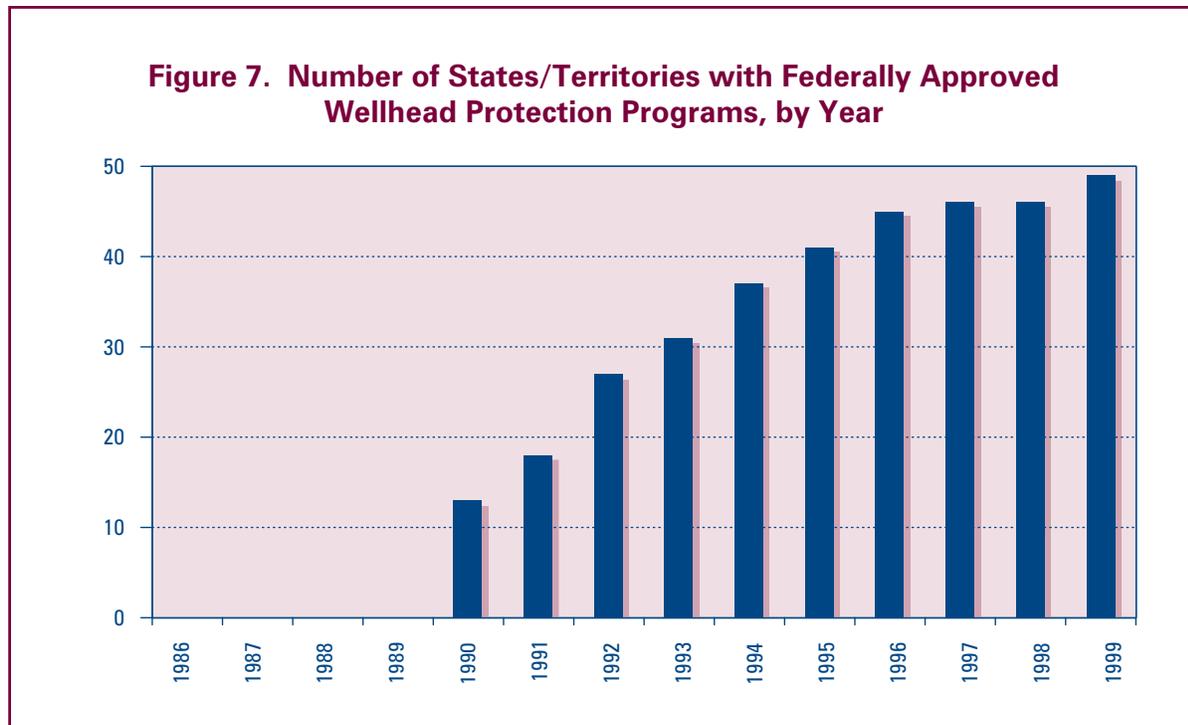
this voluntary program, under which each state is required to develop and implement a comprehensive program to protect the land areas around water supply wells from contaminants that may enter the ground water and adversely affect human health.

EPA approves state wellhead protection programs and provides technical support to state and local governments to implement the programs. Although initially hampered by lack of funding, most states persevered in developing and implementing wellhead protection programs. The states worked hard to overcome other obstacles, including a general lack of public awareness about the need to protect wellhead areas, local reluctance to require land-use controls to prevent contamination, and shortages of technical data and expertise necessary to properly delineate (determine the boundaries of) wellhead protection areas and identify contaminant sources of concern.

Working primarily with the assistance of EPA regional offices, the number of states obtaining federal approval for their wellhead protection programs has increased steadily since 1990. Today, 49 states and territories have approved wellhead protection programs in place (*see Figure 7*).

Every two years, states/territories report to EPA on their progress in implementing wellhead protection





programs for community water systems. Figure 8 shows the number of community water systems where one or more of the five steps of a local wellhead protection effort has taken place. The five steps are:

1. Getting started (usually means that a community planning or work team has been established)
2. Delineation (determination of the land area to be protected)
3. Source identification (potential sources of contamination within the delineated area have been identified)



their source water assessment reports. States will expand their wellhead protection efforts beyond the five steps discussed under State Ground Water Programs to include completion of a susceptibility determination and presentation of the final assessment report to the public.

### The Clean Water Act

Source water assessment and protection programs are not the only means by which surface water sources are protected from pollution. The Clean Water Act also seeks to protect these sources of drinking water. The 1977 Clean Water Act amended the 1972 Federal Water Pollution Control Act, which established the framework for regulating the discharge of pollutants to waters of the U.S. Aggressive use of this Clean Water Act authority can reduce the contaminant loading that might otherwise have to be removed by a drinking water treatment facility to protect public health.

The Clean Water Act requires states and authorized Native American tribes to set water quality standards which consist of two parts: 1) states and tribes assign “designated uses” to each of the waterbodies in their jurisdiction, such as serving as public drinking water sources, providing fish and shellfish for safe human consumption, and allowing recreational activities like swimming; 2) then states and tribes set water quality criteria (e.g., maximum pollutant concentrations) to support the designated uses.

If pollutant standards are not met for part or all of a waterbody, the state must establish a “total maximum daily load” (TMDL) for the pollutant. The TMDL is the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards. The TMDL is allocated among individual dischargers of the pollutant, including both point and nonpoint sources.

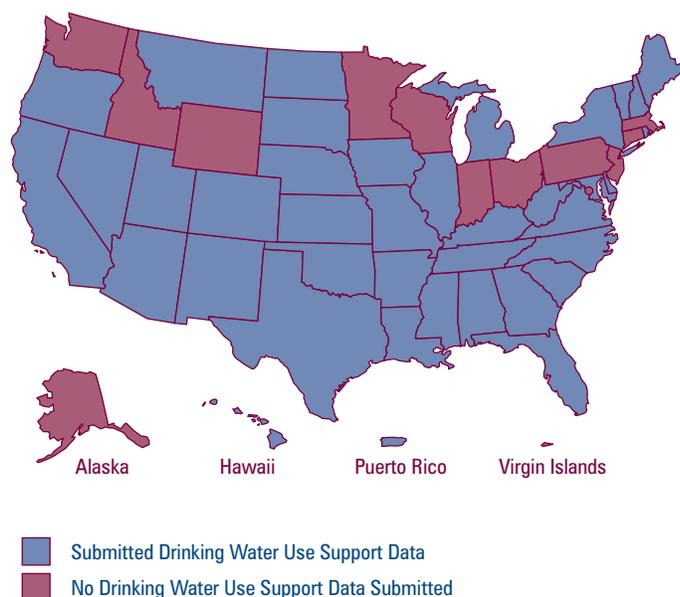
The Clean Water Act requires that states survey, assess and report on the degree to which their surface waters support designated uses. Some Native American tribes also report this information. Thirty-eight states, tribes or territories submitted data to EPA in 1998 that address the support of public drinking water use (*see Figure 10*). According to that data, the majority of waterbodies designated as public water supplies are

fully supporting that use (86 percent of assessed rivers and streams, and 85 percent of assessed lakes and reservoirs).<sup>20</sup>

In the early 1990s, only a small percentage of rivers, streams, lakes, and reservoirs were assessed for drinking water use. In 1996, EPA published state guidelines for assessing the extent to which waterbodies are of sufficient quality to support their use as drinking water supplies. EPA modified these guidelines in 1998 to provide states more flexibility. That additional flexibility has resulted in an increasing number of states performing drinking water use assessments under the Clean Water Act. The number of states that are reporting data on how they classify waterbodies for drinking water use, and on the sources of water contamination, is also increasing.

However, many challenges remain. In 1998, twelve states did not report on whether, or how, their water quality standards support drinking water use and many of the 38 states that reported water quality data did not explain how they classify waterbodies to support drinking water use, or on the sources of contamination affecting those waterbodies. The source water assessments that are required by SDWA to be com-

**Figure 10. States Submitting 1998 Drinking Water Use Support Data to EPA**



pleted no later than 2003 should help strengthen reporting from the states.

## Compliance Trends for Community Water Systems

One way to gauge whether the quality of our nation's drinking water has improved under SDWA is to examine water systems' compliance with federal regulations.

Over the past year, EPA has been evaluating the quality of the data used to assess the effectiveness of the drinking water program. The evaluation assessed quality using many different approaches. Data verification audits (performed in states by an independent EPA contractor) from the past three years were used to quantify data quality, because these audits look at data quality from the perspective of what data should have been reported by public water systems to local and state governments, as well as what data should have been transmitted from state governments to the Safe Drinking Water Information System (SDWIS), EPA's drinking water database.

This analysis concluded that about 90 percent of monitoring and reporting violations which should have been reported were reported incorrectly or not at all. About half of the MCL violations were not reported. EPA does not believe that these results are cause for immediate concern because they may be unrelated to public health. We are still investigating whether the under-reporting by states is due to poor documentation, different interpretations of regulatory requirements, inadequate staffing, or other causes. Much work remains to be done.

EPA, with its partners, is committed to correcting data deficiencies. These deficiencies make it difficult to look at historical compliance trends using SDWIS data — but this is the best source of drinking water data that exists on a nationwide basis. Therefore, EPA presents the following data on trends, realizing that the magnitude of certain trends may be inaccurate as some states have provided little or no data for certain regulations over a period of months or years. While the general trend is downward, the actual number of systems in violation may be higher than shown in the following compliance figures.

Although water systems began reporting data to states for the earliest regulations in the late 1970s, most compliance data was not entered into EPA's electronic database until around 1980. For this reason, the historical data presented here begins in 1980.

### Delays in Achieving Compliance

Under the original SDWA and its 1986 amendments, water systems were given 18 months to comply with new regulations. States used this time to obtain authority from their legislatures to adopt the new rules, promulgate their own rules (which must be at least as strict as the federal requirements), and convey to water systems the new requirements.

Over the years, many water systems have taken longer than allowed to implement new monitoring schedules, purchase and install new treatment devices, or make improvements in their existing treatment techniques. In many cases, late compliance has been due to a lack of funding and other resources at the water system level. This is especially the case when several new regulations are issued around the same time. Nevertheless, water systems that do not meet a new rule's requirements within the allotted implementation time are considered to be in violation because they may not be providing the level of public health protection that the rule intends.

When several new regulations, including the Surface Water Treatment Rule and the chemical rules, were promulgated after the 1986 Amendments and were scheduled to go into effect in the early 1990s, many water systems had difficulty meeting all the new requirements at once. The number of systems reported by states as violating these new rules generally peaked a few years after the rules were promulgated (*see Figure 19*). This was likely due to a combination of late water system compliance and a delay in the reporting of violation data by states to EPA.

To give states and water systems a more realistic amount of time to comply with new regulations, the 1996 Amendments extended the time between promulgation and implementation to three years for most new regulations.

### Total Trihalomethanes (TTHMs) and Nitrates

TTHMs form when disinfectants react with natural organic matter in water and have potential chronic health effects. TTHMs occur mostly in surface water systems because these systems are most likely to have elevated levels of organic matter in their source water, which can create these byproducts during disinfection. Nitrates have potential acute health effects and occur mostly in ground water systems (which tend to be smaller). Because trihalomethanes and nitrates are two of EPA's earliest regulated contaminants, tracking compliance with these standards provides a general sense of public drinking water quality over time.

The 1979 standard for TTHMs applies to about 3,500 community water systems (those serving at least 10,000 people). The number of community water systems with at least one violation of the TTHM MCL has been decreasing fairly steadily since the mid-1980s, going from a peak of about 70 systems (2 percent of the total that must comply) violating in 1985 to fewer than 10 systems violating in 1998 (see Figure 11). The number of community water systems with monitoring and reporting violations for TTHMs has also been decreasing fairly steadily, going from about 180 systems violating in 1985 to about 70 violating in 1998.

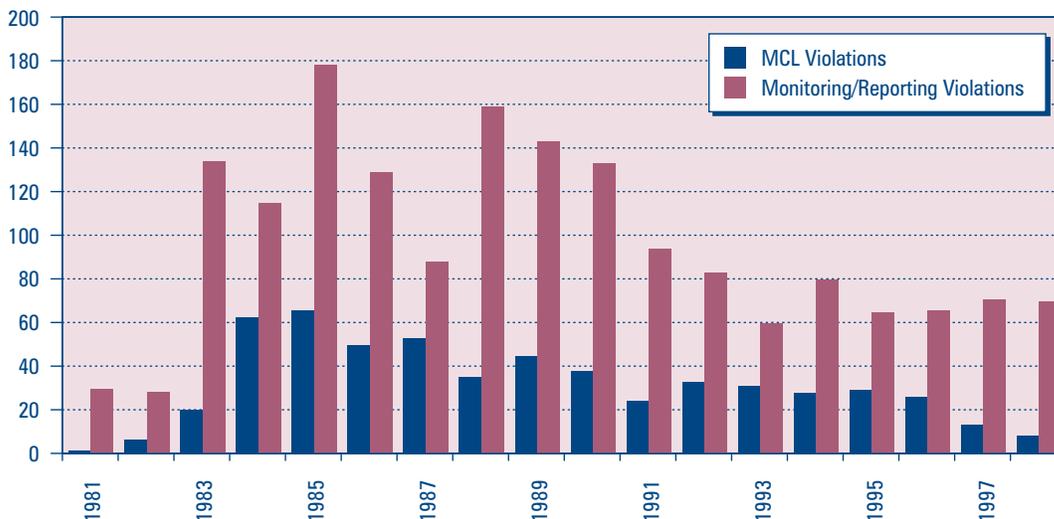
The standard for nitrate applies to all types and sizes of public water systems. The number of community water systems with MCL violations for nitrate has been decreasing slightly since the mid-1980s, going from a peak of about 340 systems violating in 1985 to approximately 190 systems in 1998 (see Figure 12). As with TTHMs, the peak number of systems with reported violations represents a small fraction — less than one percent — of the total systems which must comply with the nitrate MCL. There is no clear trend regarding the number of community water systems with monitoring and reporting violations for nitrates.

### Inorganic Chemicals

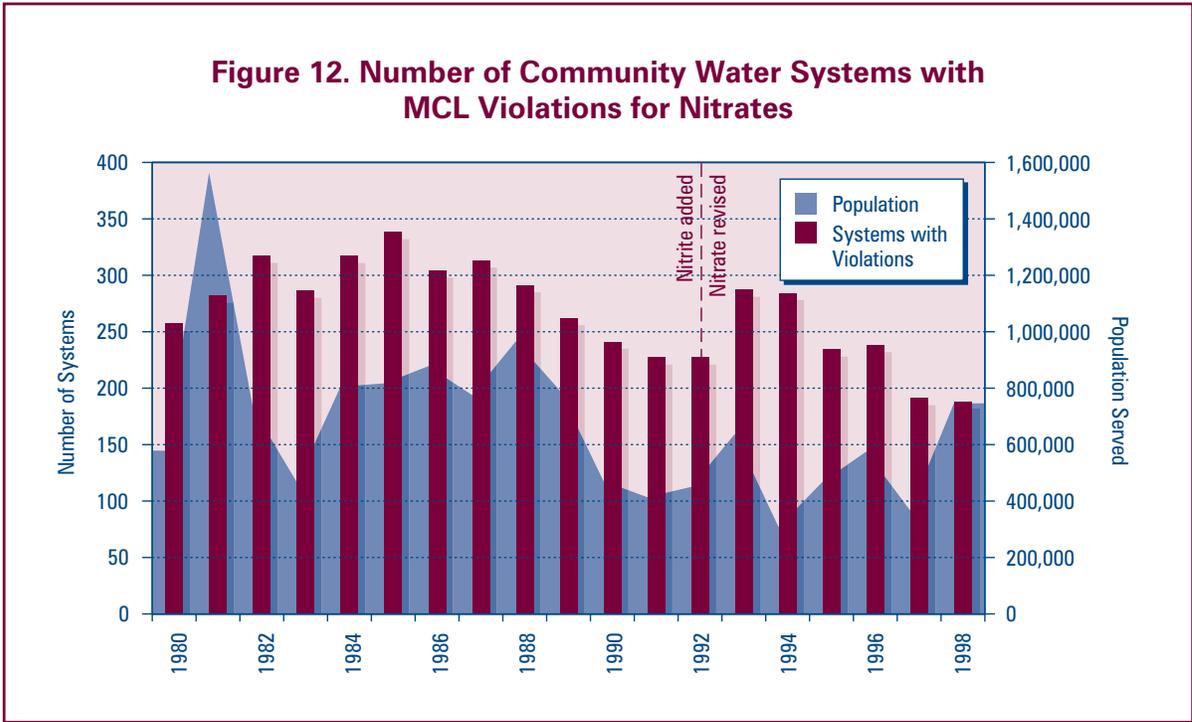
From 1976 to 1986, nine drinking water regulations existed for inorganic contaminants, including nitrate. Seven additional inorganic chemicals were assigned MCLs when the interim standards were finalized by the 1986 SDWA Amendments.

Despite these additions, the number of community water systems with MCL violations of inorganic contaminants other than nitrate declined steadily from its peak (about 700 systems) in 1984 by an average of 36 systems per year, to about 100 systems in 1998 (see Figure 13). This peak number of 700 violating systems represents less than two percent of the total

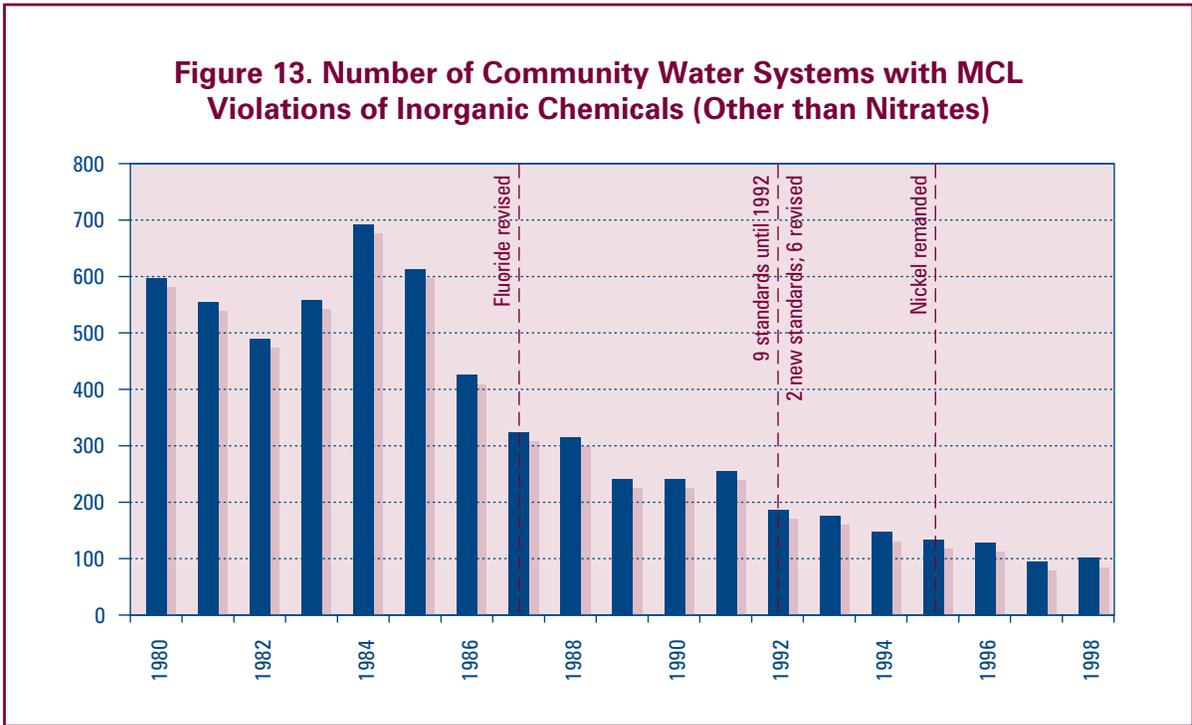
**Figure 11. Number of Community Water Systems with Violations for Total Trihalomethanes (TTHMs)**



**Figure 12. Number of Community Water Systems with MCL Violations for Nitrates**



**Figure 13. Number of Community Water Systems with MCL Violations of Inorganic Chemicals (Other than Nitrates)**



number of community water systems that must comply with MCLs for inorganic chemicals other than nitrate. No trend is decipherable in the number of community water systems violating monitoring and reporting requirements for inorganic compounds.

**Synthetic Organic Chemicals**

Synthetic organic chemicals were also some of the earliest contaminants regulated under SDWA. Six of them were assigned interim standards (mainly pesticides), and twenty-six more were regulated

beginning in 1993. The number of community water systems with MCL violations for synthetic organic chemicals generally increased from a few systems violating in the early 1980s to a peak of 60 systems violating in 1995. The number of systems violating the MCL declined since then to fewer than 20 in 1998 (see Figure 14). This peak number of violating systems represents less than one percent of the total community water systems that must comply with MCLs for synthetic organic chemicals. No trend is decipherable in the number of community water systems violating monitoring and reporting requirements for synthetic organic compounds.

### Volatile Organic Chemicals

As mentioned previously, TTHMs were the only volatile organic compounds regulated under the original SDWA. In the 1986 amendments, EPA set MCLs for 21 additional volatile organic compounds, most of which became effective in 1989. The number of community water systems with MCL violations of these volatile organic compounds peaked in 1992 at about 70 systems (representing less than one percent of the total community water systems that must comply with MCLs for volatile organic chemicals other than TTHMs). Since 1992, the number of

systems violating has declined by about eight per year to 25 systems violating in 1998 (see Figure 15).

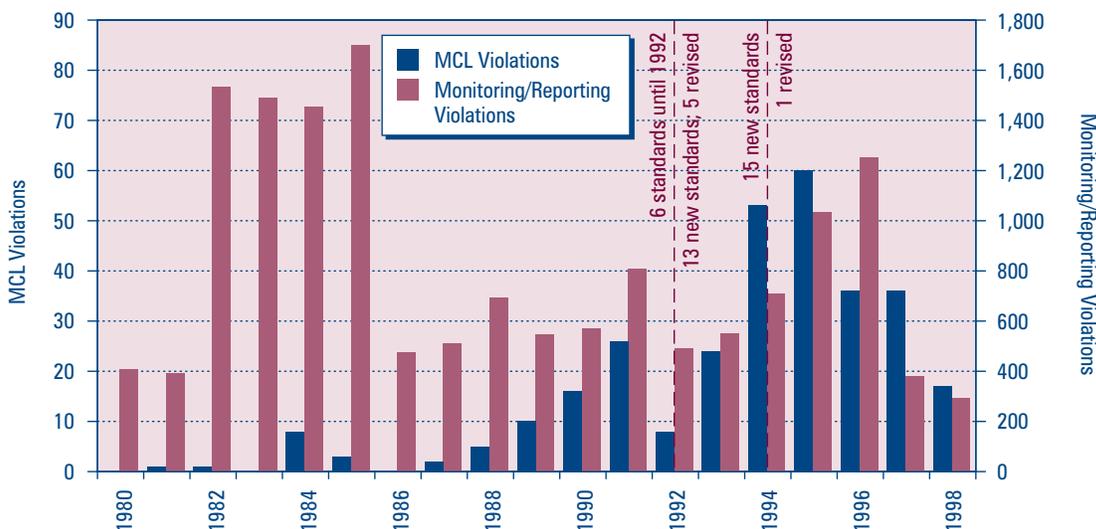
The greatest number of people were affected by these violations in the first few years of implementation. Between 1989 and 1991, the population affected by violations of volatile organic compound MCLs dropped by more than 60 percent, going from about 1.5 million people affected to less than 500,000 people affected. The population affected then increased gradually to about 600,000 in 1994 and has declined steadily since (see Figure 15).

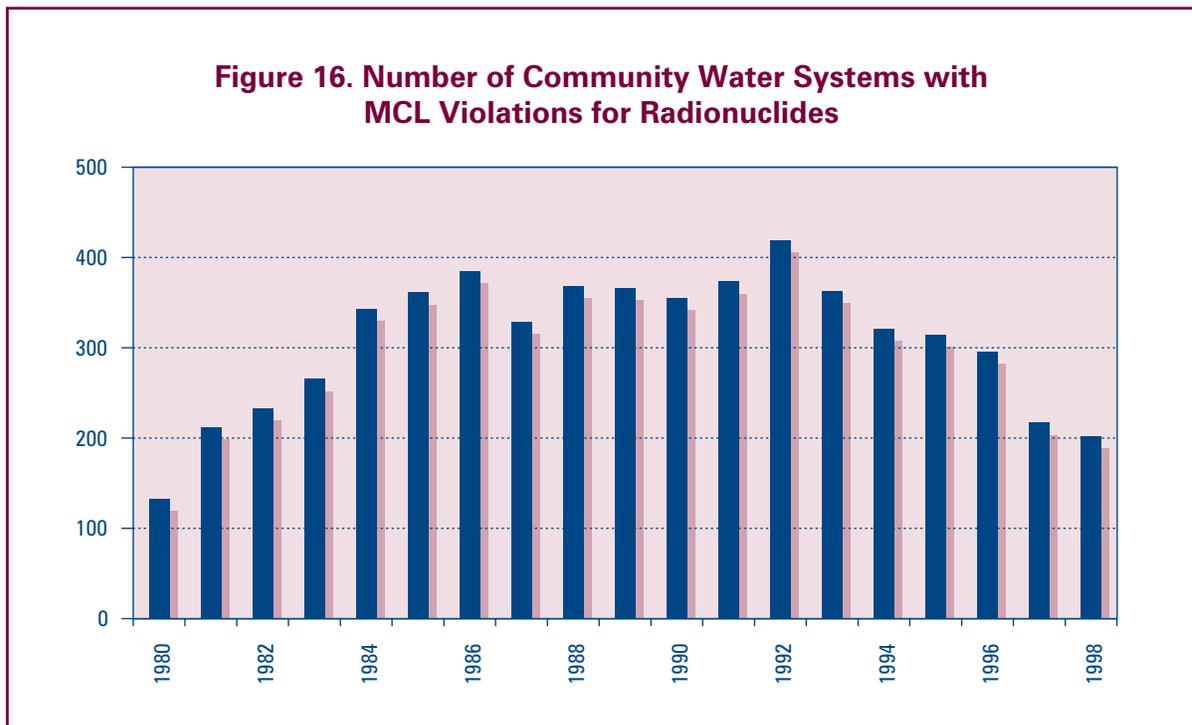
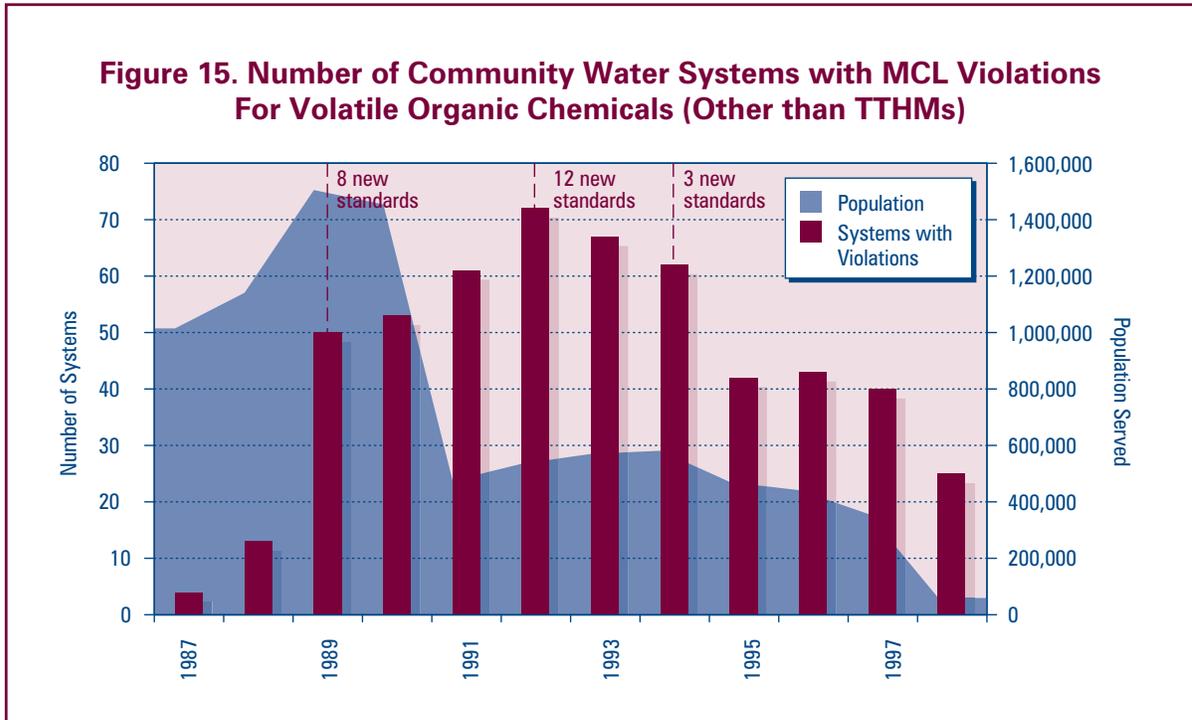
### Radionuclides

The interim regulations for radionuclides included standards for combined radium-226 and -228 and two other classes of radionuclide contaminants. These standards remain the same today, although revisions are under consideration at this time. A standard for radon has also been proposed.

The number of community water systems with MCL violations for radionuclides increased fairly steadily from 1980 to 1992. By 1992, EPA had proposed a less stringent standard for radium so that national resources could be focused on control of radon, which posed a higher risk and was found more frequently

**Figure 14. Number of Community Water Systems with Violations of Synthetic Organic Chemicals**





than radium. Many states may have stopped reporting water systems' radium violations in anticipation of the new standard, causing the decrease in MCL violations seen in figure 16 after 1992.

**Total Coliform**

The Total Coliform Rule became effective in December 1990, although a less stringent standard for total coliform existed (in combination with a turbidity

standard) as one of the interim regulations under the original SDWA. Community water systems with total coliform violations have accounted for the vast majority of community water systems with MCL violations each year. Monitoring is required more frequently for total coliform, thus creating more opportunities for detecting MCL violations.

The number of systems with MCL violations of total coliform has decreased fairly steadily since 1980, at a rate of about 200 systems per year (see Figure 17). Since 1980, over 80 percent of all community water systems with any MCL violation had a MCL violation for total coliform (see Figure 18). With the exception of the Surface Water Treatment Rule, no other contaminant or rule has been the cause for more than 1,000 systems having MCL/treatment technique violations. However, even the peak number of systems violating the total coliform MCL (approximately 7,000 systems in 1980) represents only about 13 percent of the total number of community water systems that must comply with the standard.

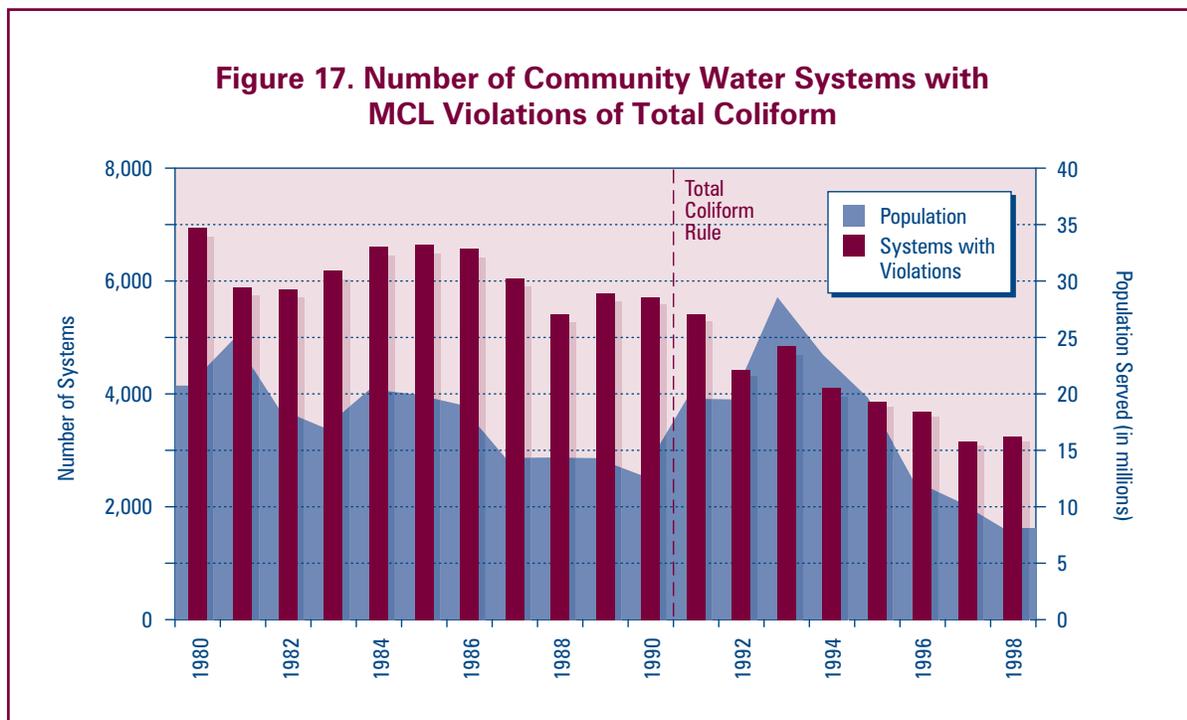
The number of systems with MCL violations of total coliform did not increase after the 1990 rule went into effect. However, the population affected by community water systems with Total Coliform Rule

MCL violations more than doubled between 1990 and 1993, going from roughly 12.5 million people affected in 1990 to 28 million in 1993. The population affected has declined steadily by about 4 million people per year since 1993 to about 8 million in 1998 (see Figure 17).

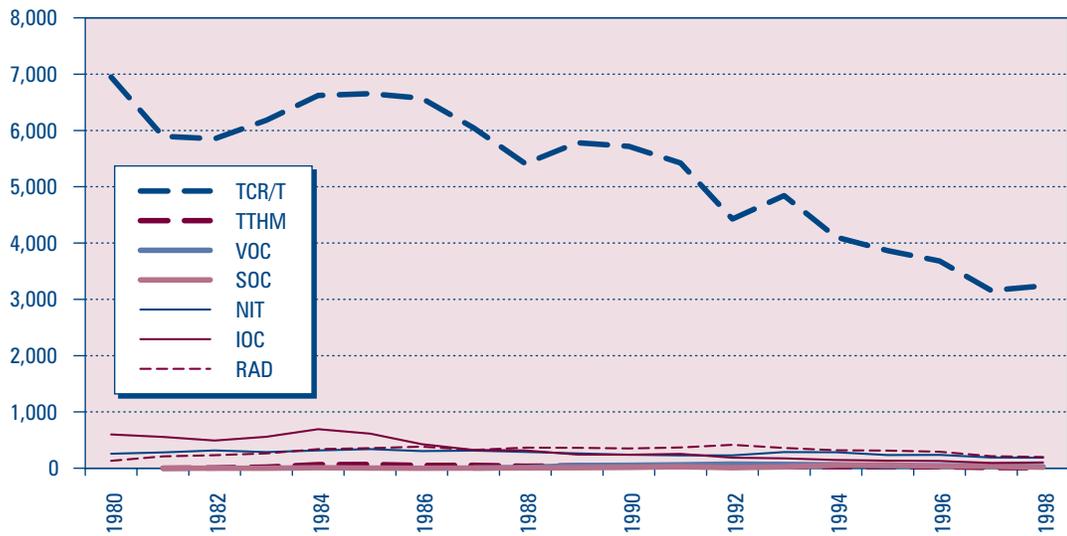
The number of systems with monitoring and reporting violations for total coliform has declined steadily since 1980 by a rate of about 600 systems per year, from approximately 20,000 systems in 1980 to about 7,000 systems violating in 1998. The population affected by these monitoring and reporting violations has also generally decreased since 1980 (see Figure 19).

### Surface Water Treatment Rule

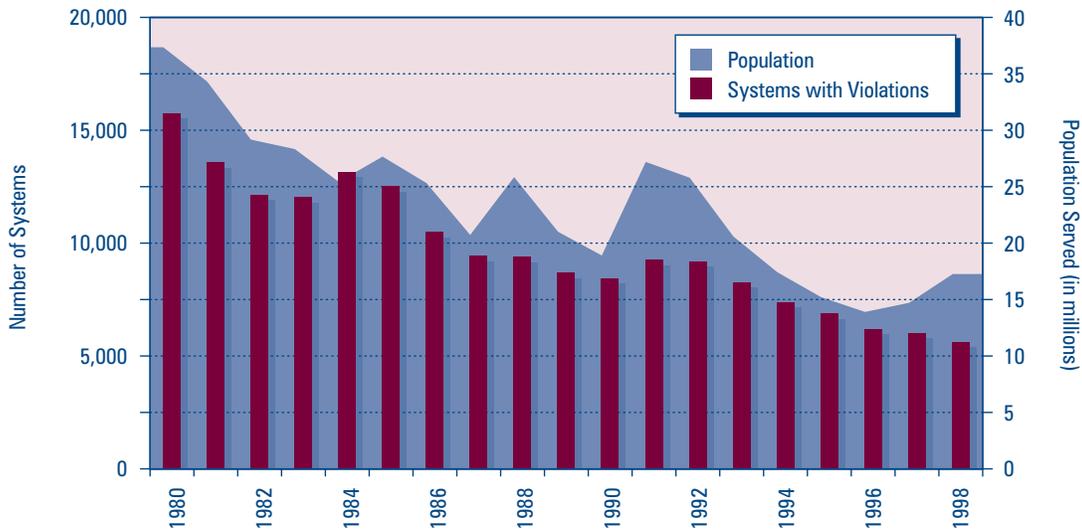
The Surface Water Treatment Rule took effect in December 1990. The number of community water systems violating the rule's treatment technique requirement increased from about 10 in 1991 to approximately 1,500 in 1994, and then dropped to just under 1,000 by 1998 (see Figure 20). When non-compliance was at its highest, the number of systems violating the surface water treatment rule represented about 14 percent of the total number of community water systems that must comply with the rule.



**Figure 18. Number of Community Water Systems with Any MCL Violations**



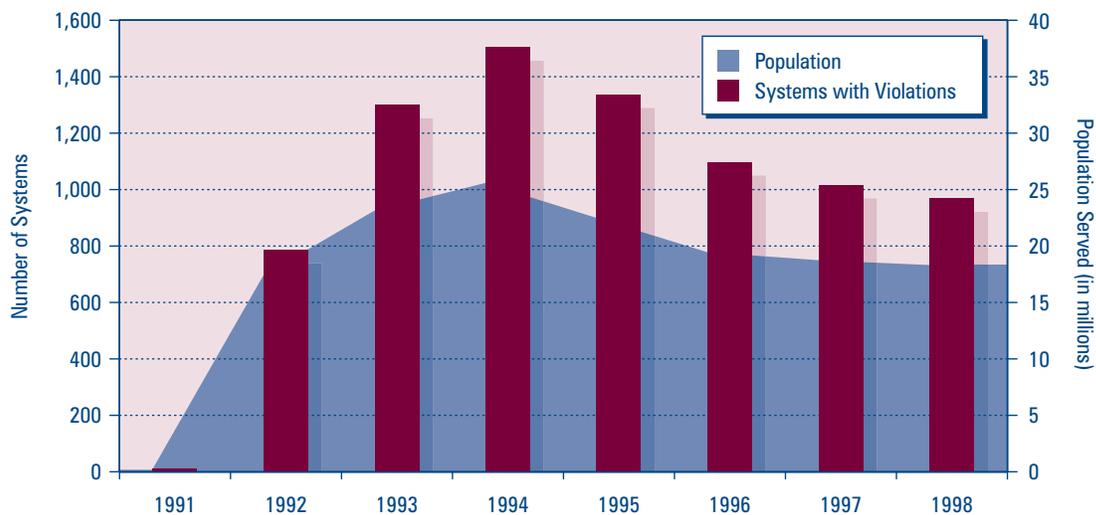
**Figure 19. Number of Community Water Systems with Monitoring/Reporting Violations for Total Coliform**



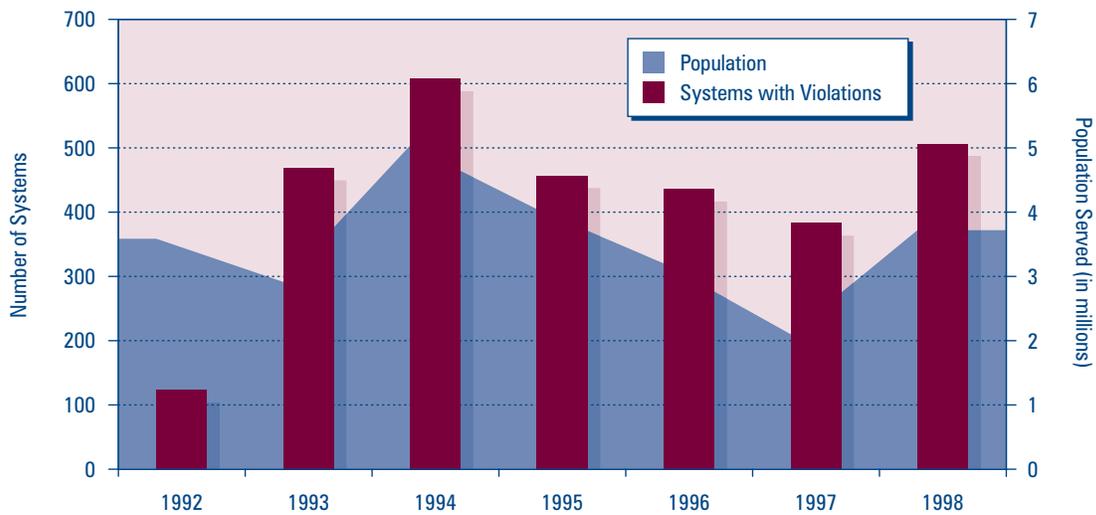
The population affected by these violations increased from about 140,000 people in 1991 to about 26 million in 1994. This population affected was higher than for any other contaminant or rule with the exception of the total coliform rule in 1993. The population affected gradually decreased to about 18 million in 1998 (see Figure 20).

The number of systems with monitoring and reporting violations of the Surface Water Treatment Rule rose from about 120 systems in 1992 to a peak of approximately 600 systems in 1994, and has generally decreased since (see Figure 21). The number of people served by systems with violations of monitoring and reporting requirements peaked at 5 million people

**Figure 20. Number of Community Water Systems with Treatment Technique Violations of the Surface Water Treatment Rule**



**Figure 21. Number of Community Water Systems with Monitoring/Reporting Violations of the Surface Water Treatment Rule**



in 1994, and declined to about 2 million in 1997. The population affected then rose to about 3.7 million in 1998 (see Figure 21).

One reason for the high number of systems with treatment technique violations as compared to monitor-

ing and reporting violations is that many systems received treatment technique violations for failure to filter. Because installing filtration is expensive, many large systems have needed more time than the regulations allow to get filtration systems in place.

### Lead and Copper Rule

The Lead and Copper Rule became effective in December 1992. The number of community water systems with treatment technique violations increased from just a few systems in the early 1990s to a peak of about 800 systems in 1994, and then decreased by about 200 systems per year to 145 systems by 1998 (see Figure 22). At its peak, less than two percent of the community water systems that must comply with the Lead and Copper Rule were in violation.

The population affected by systems with Lead and Copper treatment technique violations jumped from about 120,000 people in 1992 to about 7 million in 1993. The population affected was somewhat erratic (above 4 million) through 1997 and then dropped to about 400,000 in 1998 (see Figure 22).

The number of systems with monitoring and reporting violations for the Lead and Copper Rule rose from about 1,600 in 1992 to more than 11,000 in 1994, higher than any other contaminant or rule. This number dropped to about 2,300 systems in 1995, and has declined slightly since then (see Figure 23).

The population affected by Lead and Copper monitoring and reporting violations peaked in 1992

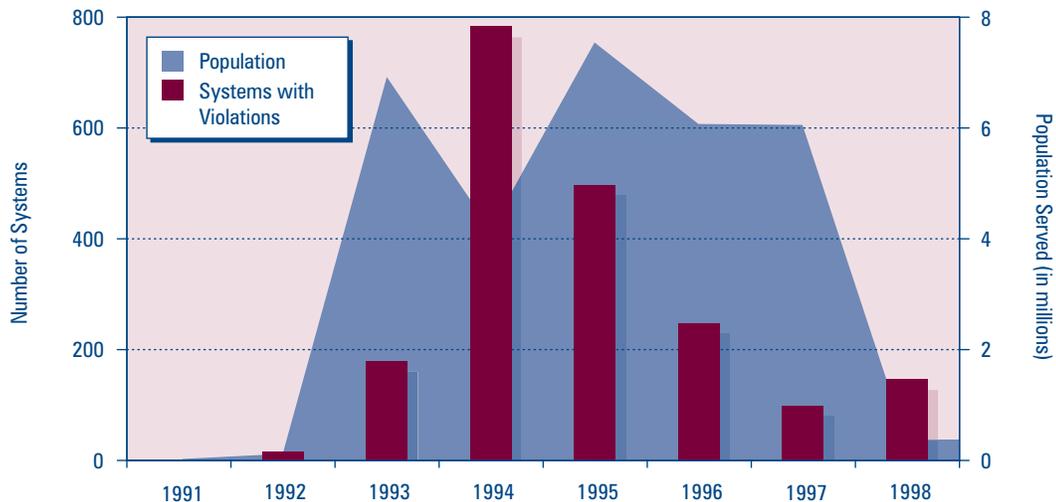
at 43 million, which is also higher than any other contaminant or rule has ever been (monitoring and reporting violations for the Total Coliform Rule peaked at 25 million in 1992). By 1994, this number dropped to 10 million and has decreased steadily since then to under two million people affected in 1998 (see Figure 23).

### System Size Affects Violation Trends

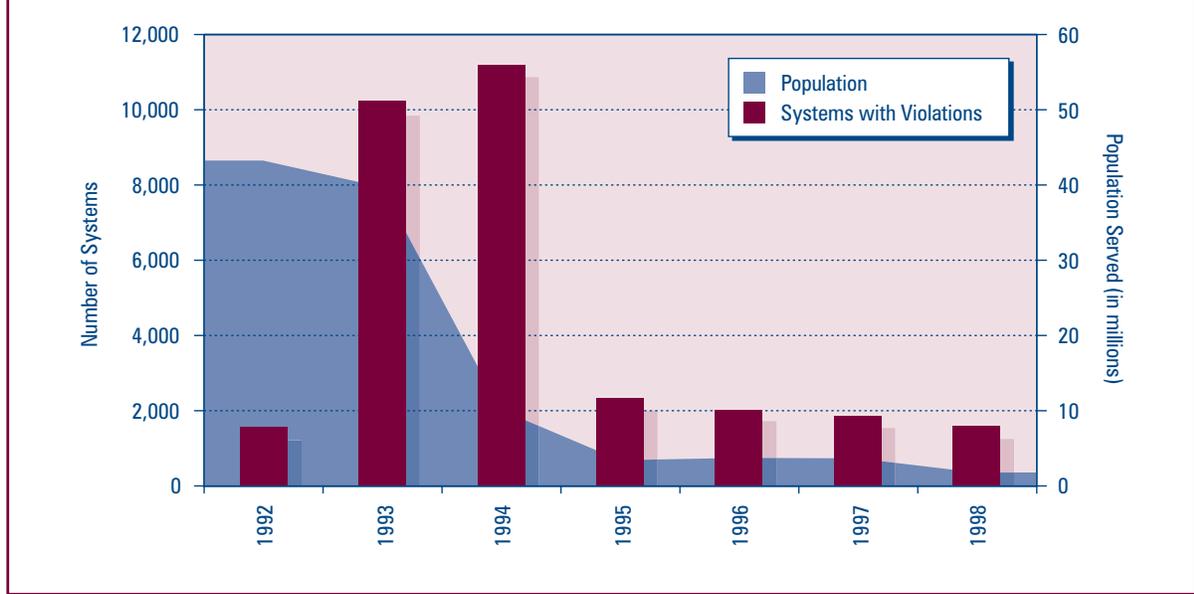
Community water systems of all sizes have generally followed the same decreasing trend in violations since 1980, except for a period in the early 1990s when systems of all sizes struggled to comply with several new regulations (see Figure 24).

Medium, large and very large systems saw a significant increase in violations in 1992 as new rules (specifically, the Surface Water Treatment Rule in late 1990) became effective. Very small and small systems saw a similar increase in 1993 (perhaps due to other new regulations, like the 1992 Lead and Copper Rule, which applies to all system sizes). This time difference in violation increases may also be partly due to the fact that some states require larger systems to begin implementing new rules earlier than smaller systems.

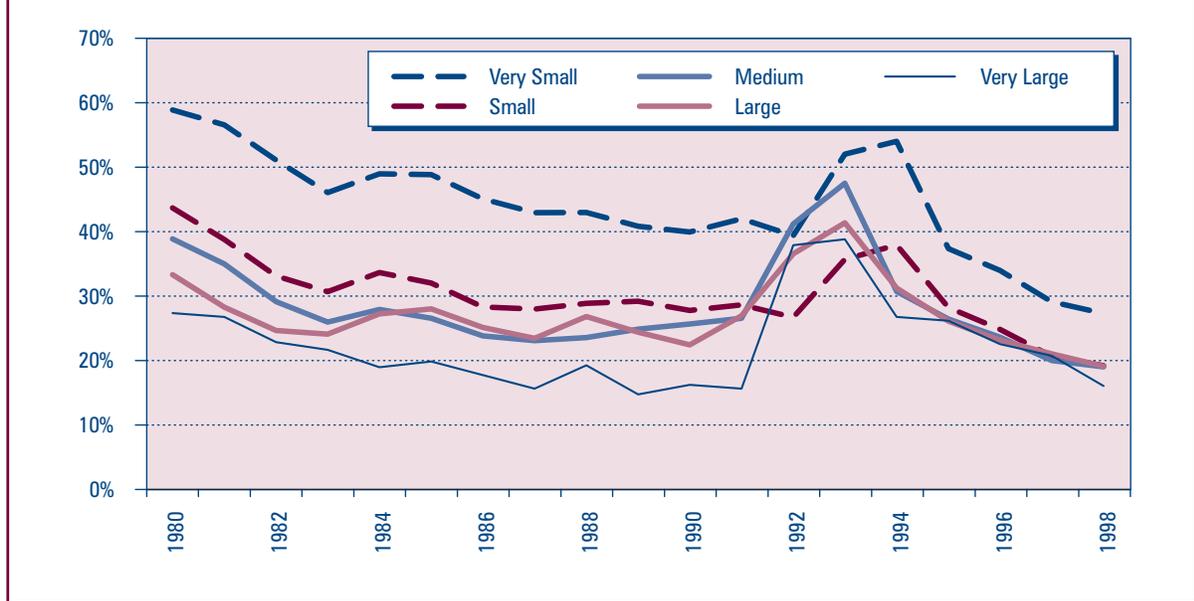
**Figure 22. Number of Community Water Systems with Treatment Technique Violations of Lead and Copper Rule**



**Figure 23. Number of Community Water Systems with Monitoring or Reporting Violations for Lead and Copper**



**Figure 24. Percent of Community Water Systems with Any Violations, by System Size**



Generally, larger systems have more resources available to comply with regulations, so fewer violations are incurred, despite the fact that larger systems must comply with more regulations than smaller systems.

In recent years, it appears that the gap between the percentage of small, medium, large and very large systems with violations has been closing. However, very small systems are still almost 50 percent more likely to incur violations than all other system sizes.

## Waterborne Disease Outbreaks

Another way to determine whether the quality of our nation’s drinking water has improved as a result of SDWA is to examine whether the number of people becoming ill from contaminated water has decreased over the last 25 years. The Centers for Disease Control and Prevention (CDC) defines an outbreak of waterborne disease caused by microorganisms as occurring when: (1) two or more persons experience a similar illness after consumption or use of water intended for drinking, and (2) epidemiologic evidence implicates the water as a source of illness. CDC also defines a single case of illness as a waterborne disease outbreak if a study indicates that the water has been contaminated by a chemical.<sup>21</sup>

Despite existing drinking water regulations, outbreaks continue to occur. Health records show that the number of outbreaks has decreased dramatically in recent decades compared to the early part of this century when typhoid and cholera epidemics were common.

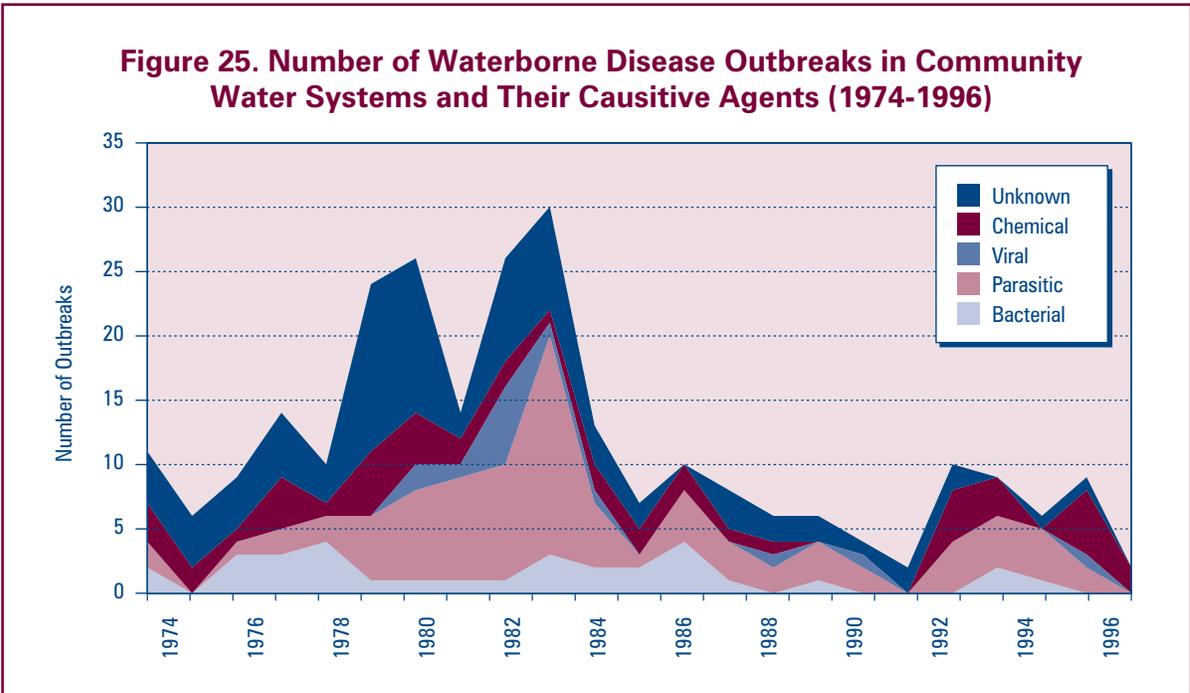
EPA and CDC believe that the vast majority of waterborne disease outbreaks and cases (people affected by outbreaks) are never identified and reported. Few states have an active outbreak surveil-

lance program and disease outbreaks are often not recognized in a community or, if recognized, are not traced to contaminated drinking water. EPA and CDC also believe that a major factor in the failure to recognize outbreaks is that the vast majority of people experiencing waterborne disease do not seek medical attention. This is because most agents of waterborne disease cause diarrhea and stomach cramps — symptoms common to many illnesses. Physicians usually cannot attribute a limited number of cases of gastrointestinal illness to any specific source, such as water, food or contact with another person.

The gathering and reporting of waterborne disease outbreak data by states is largely a voluntary effort. States that have active outbreak surveillance programs often appear to have more outbreaks than states without active programs. An obstacle to reliable waterborne disease outbreak recognition and reporting is often a lack of formal communication among the state agencies responsible for public health and water suppliers.

The number of outbreaks reported to CDC in any given year may also depend on the resources allocated to CDC and other organizations to seek outbreak information from states and published literature.

**Figure 25. Number of Waterborne Disease Outbreaks in Community Water Systems and Their Causitive Agents (1974-1996)**



Despite these hindrances, EPA and CDC have been working together since 1971 to gather information on waterborne disease outbreaks across the country. According to this data (see Figure 25), the number of outbreaks in the U.S. since 1974 was highest in the early 1980s, but appears to have generally decreased since then.

Of the waterborne disease outbreaks that were reported in community water systems from 1974 to 1996, 12 percent were caused by bacterial pathogens, 33 percent were caused by parasites, five percent were caused by viruses, 18 percent were caused by chemical contaminants, and 31 percent were caused by undetermined agents.<sup>22</sup>

Although the number of reported outbreaks in the U.S. over the past 25 years has declined, some of the more recent outbreaks have been very serious, causing numerous people to become ill and, in some cases, even causing death.

The largest outbreak reported in the U.S. since health officials began tracking waterborne disease in 1920 occurred in Milwaukee, Wisconsin in 1993. After drinking water contaminated with the single-celled parasite *Cryptosporidium parvum*, over 400,000 people suffered from gastrointestinal illness and it is estimated that at least 50 people died from the disease cryptosporidiosis.<sup>23</sup>

Table 2 contains examples of other significant waterborne disease outbreaks that have occurred in U.S. community water systems.<sup>24-30</sup>

In the last ten years, EPA has taken several regulatory steps to minimize the number of outbreaks and incidence of waterborne disease. The Total Coliform Rule (1989) strengthened microbial monitoring requirements. The Surface Water Treatment Rule (1989) and Interim Enhanced Surface Water Treatment Rule (1998) place stringent treatment requirements on systems using surface water as a source. In the near future, EPA plans to propose regulations requiring public water systems that draw their water from underground sources and are vulnerable to fecal contamination, to remove the sources of contamination, switch to an alternative water supply, or treat the water.

**Table 2**

Year	State/Territory	Cause of Disease	No. of People Affected
1985	MA	<i>Giardia lamblia</i> (protozoan)	703 illnesses
1987	GA	<i>Cryptosporidium parvum</i> (protozoan)	13,000 illnesses
1987	PR	<i>Shigella sonnei</i> (bacterium)	1,800 illnesses
1989	MO	<i>E. coli</i> O157 (bacterium)	243 illnesses 4 deaths
1991	PR	Unknown	9,847 illnesses
1993	MO	<i>Salmonella typhimurium</i> (bacterium)	650 illnesses 7 deaths
1993	WI	<i>Cryptosporidium parvum</i> (protozoan)	400,000 illnesses 50+ deaths

PR = Puerto Rico

## The Cost of Safe Drinking Water

Operational costs for drinking water suppliers are rising to meet the needs of an aging infrastructure, comply with public health standards, and expand service areas. In most cases, these increasing costs over the years have caused water suppliers to raise their water rates to generate more revenue. In fact, the majority of water industry revenues come directly from water sales, and water rates are the primary mechanism by which customers are charged for service. As shown in figure 26, the revenue earned from residential customers has generally increased since 1975 for all system sizes and is rising at a faster pace than inflation (see Figure 27). Systems serving 10,000 or fewer people have consistently charged higher residential rates than larger systems because they have a smaller customer base among which to spread costs.

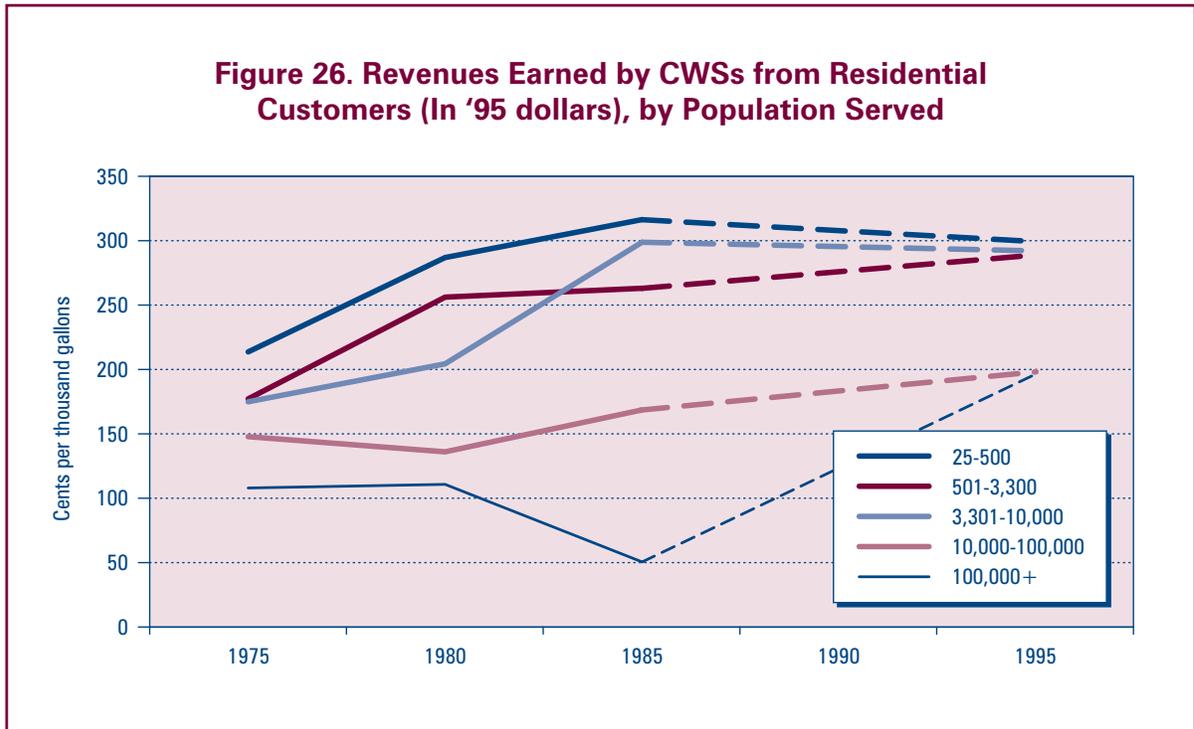
The remainder of water system revenues are generated from fees (e.g., connection or inspection fees), fines and penalties, and other non-consumption-based charges.<sup>18</sup>

Due to historic underpricing, the rates most water systems have charged their customers have not reflected the true cost of treating drinking water and making necessary infrastructure improvements.

Despite rate increases, water is generally still a bargain when compared to other utility services. Even when drinking water, wastewater and other public services (e.g. garbage collection) are combined, the annual bill for those services is less than what households pay, on average, for natural gas, electricity or telephone services annually (see Figure 28).<sup>31</sup>

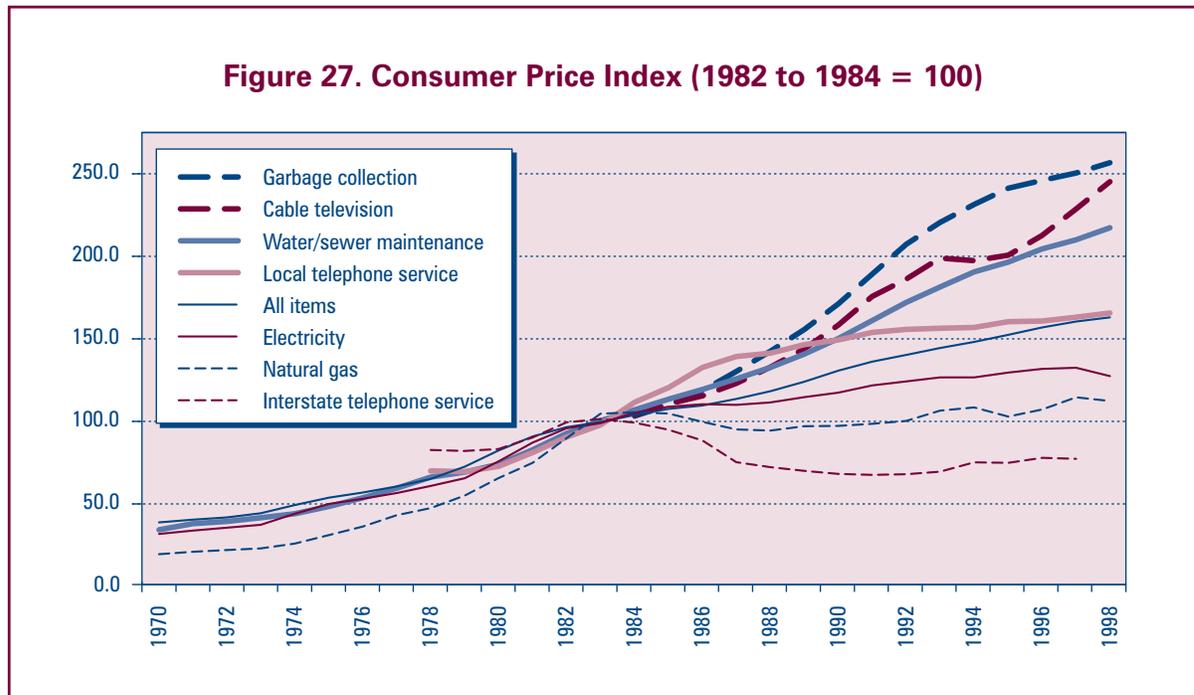
The demand for water (aggregate, per capita and household) has generally declined during the latter part of this century, while demand for other utilities like electricity and telephone service has risen. Enhanced public awareness of water resource issues, active conservation programs in many states, and the required installation of more water-efficient appli-

**Figure 26. Revenues Earned by CWSs from Residential Customers (In '95 dollars), by Population Served**



\* Data not available for 1990.

**Figure 27. Consumer Price Index (1982 to 1984 = 100)**



ances and practices are partially responsible for the decline in demand.<sup>31</sup>

While the decline in *demand* is a good sign for the future of drinking water, the decrease in water *supply* is not. Because water is a constrained resource, the marginal cost of new sources of supply is expected to rise. The water industry is looking for cost effective alternatives and is evaluating water conservation and reuse practices, as well as the use of desalinization processes.<sup>31</sup>

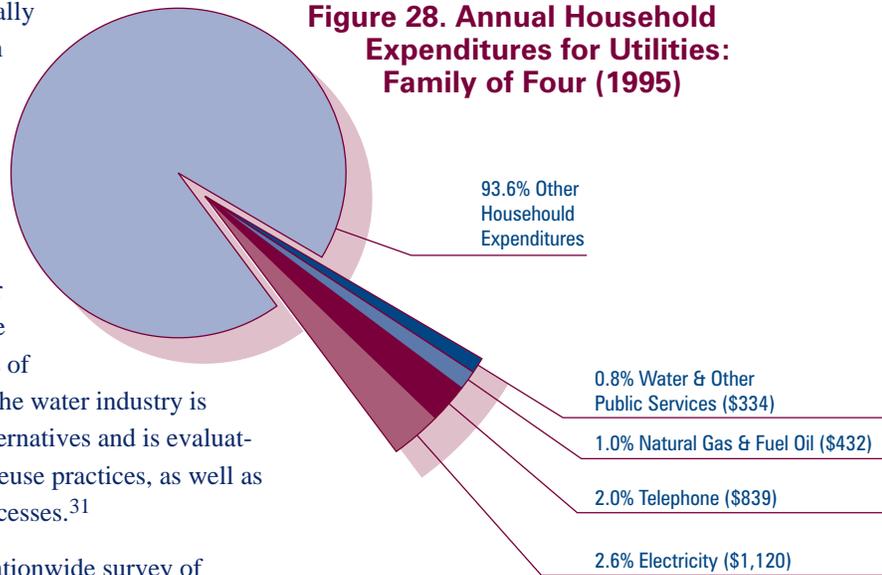
In 1995, EPA conducted a nationwide survey of community water system infrastructure needs through the year 2014. The survey showed infrastructure need as approximately \$138 billion over the 20-year period, which is more than what the entire estimated assets of the water industry were in 1995 (\$131.9 billion).<sup>14, 16</sup> More than half of the identified need was for transmission and distribution system installation and replacement. Treatment improvements constituted the second largest category of need, followed by storage and source water improvements (*see Figure 29*). In 1995, it was estimated that an investment of \$34.4 billion would be needed for SDWA compliance and SDWA-related improvements.<sup>32</sup>

Efforts have been made in recent years to meet the water industry's infrastructure needs through government assistance. With the establishment of the DWSRF in 1996, Congress appropriated \$1.3 billion in 1997. The annual Congressional appropriations in 1998 and 1999 were \$725 million and \$775 million, respectively. Although states and water systems are taking advantage of this funding source to make infrastructure improvements, government funding will cover only a portion of the total investment needed.

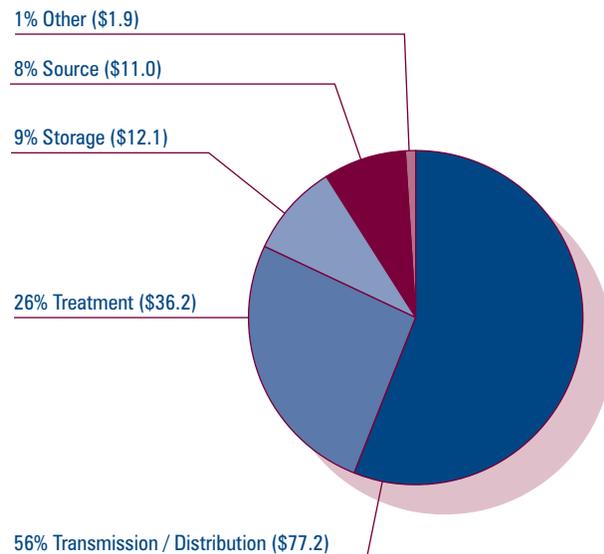
### Issues Facing Small Systems

Since the crafting of SDWA in the early 1970s, Congress has recognized the unique challenges that face small drinking water systems (those serving 3,300 or fewer people). The original Act in 1974, and the major amendments in 1986, focused on develop-

**Figure 28. Annual Household Expenditures for Utilities: Family of Four (1995)**



**Figure 29. Total 20 Year Need of All Community Water Systems (in Billions of Jan. '95 Dollars)**



ing and implementing a strong regulatory program based on monitoring and treatment. The general sentiment was that water systems would make the changes necessary to comply with new regulations.

The Act authorized training and technical assistance to help systems, and provided exemptions for systems that faced compelling economic circumstances. These exemptions could be extended for very small systems

(those serving 25–500 people). However, by the late 1980s and early 1990s, it was clear that small systems were having great difficulty keeping up with the rapidly expanding SDWA-mandated regulations. Consolidation had not occurred to the extent that was hoped for in the 1970s. There was also a growing recognition that, separate from any regulatory mandates, there was a significant need for basic infrastructure repair and replacement for small systems.

In addition to being part of a rising cost industry, another challenge faced by small systems is a lack of sufficient customer base among which to spread costs, or what is also referred to as economies of scale. Depending on how a small system designs its rates, fewer customers can mean less revenue for infrastructure improvements, repayment of loans, and hiring operators and other staff with technical expertise.

Compared with larger systems, small systems are the least able to gain access to outside capital to finance needed infrastructure improvements.<sup>32</sup> Large systems tend to have a higher percentage of industrial, commercial and agricultural customers, whereas small systems serve primarily residential customers, who, as a group, generally are less able to pay substantial amounts for their water. Small, rural communities typically have residents with lower incomes, higher unemployment rates, and larger populations of aging residents. These communities also have more difficulty obtaining loans than larger, metropolitan communities.

Many small systems find it difficult to strike a balance between charging customers enough to cover their costs and ensuring that services are affordable. It has been a widely held view in the drinking water industry that water in many areas has historically been underpriced. In theory, water prices are primarily a function of the cost of providing water service to customers. However, when systems do not establish rates that allow them to collect sufficient revenue to cover service costs, they inevitably lack resources to make needed infrastructure improvements and protect public health.

During the late 1980s and early 1990s, a few states were implementing initiatives which sought to promote small system compliance and address small system problems by ensuring that systems had the necessary underlying technical, managerial, and financial capacity. Eventually the concept of capacity development emerged.

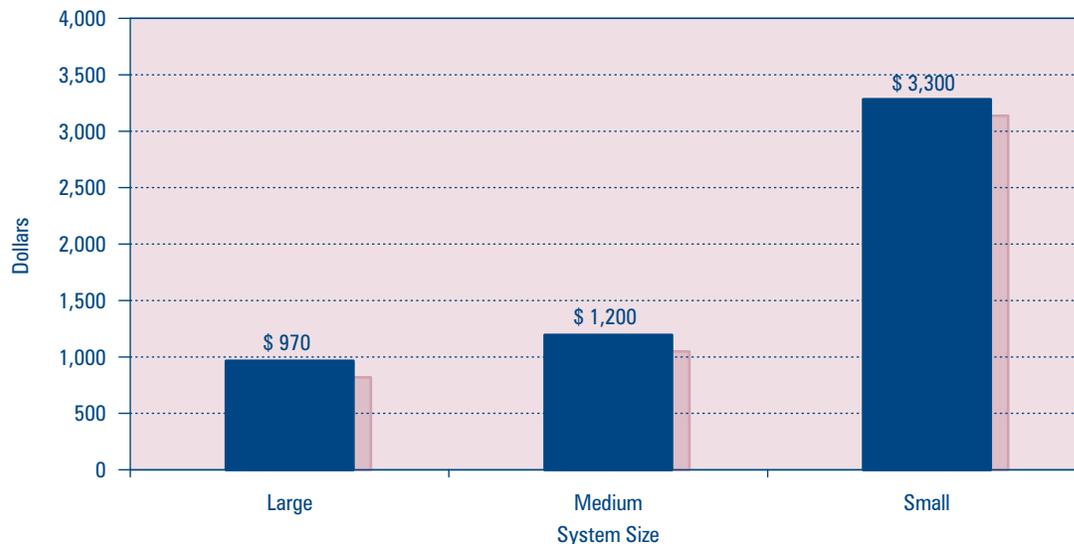
The capacity development concept includes components of the prevention, compliance and public participation elements of SDWA that were emphasized in the 1996 Amendments. It weaves together all existing state drinking water program activities. The 1996 SDWA Amendments require states to ensure that no new systems are created that lack capacity to meet drinking water standards now and in the future. States are also required to develop a strategy to address capacity issues affecting systems within the state.

In 1995, the projected 20-year costs (through 2014) small systems faced to make infrastructure improvements to their facilities was estimated at \$37.2 billion, about 27 percent of the total national need.<sup>32</sup> Although small systems have less total need than medium or large systems, their customers face the largest per-household costs, at \$3,300 per household through 2014 (*see Figure 30*). While the provisions of the 1996 SDWA Amendments will help small systems improve the quality of their drinking water, they may also increase operational costs.

The loan fund created by the 1996 Amendments emphasizes providing assistance to small and disadvantaged communities and to programs that encourage pollution prevention as a tool for ensuring safe drinking water. A portion of the state's grant can also be used by states to administer specific aspects of the drinking water program, such as assessing source water quality, certifying treatment plant operators, and implementing capacity development programs.

The 1996 SDWA Amendments assisted small systems in another way. When setting new drinking water standards, EPA must identify technologies that achieve compliance and are affordable for systems serving fewer than 10,000 people. When such technologies cannot be identified, EPA must identify

**Figure 30. Average Cost Per Household to Meet Water System's 20-Year Infrastructure Need (Total Need in Jan. '95 Dollars)**



affordable technologies that maximize contaminant reduction and protect public health.

## Successes and Challenges Ahead

Obtaining safe drinking water is a problem civilizations have faced for thousands of years. While tremendous progress has been made in improving the testing, treatment, protection, and provision of drinking water to the public, numerous challenges remain.

As the U.S. population has grown and American lifestyles have become more sophisticated, so have the number of drinking water problems grown and their required solutions become more technically complex. Despite these challenges, the quality of drinking water in the U.S. has improved over the last 25 years, largely due to the efforts of drinking water and health professionals in the public and private sectors and the foundation that the Safe Drinking Water Act has provided them.

Public health protection has been, and remains, the national drinking water program's most important focus. As a result, we have seen a steady increase over

the years in the percentage of people served by water systems that meet all health-based standards. This increased public health protection came about from the implementation of a multiple barrier approach which recognizes that contaminants reach drinking water via many pathways. Implementation activities include:

- improved detection and treatment technologies;
- new and ongoing research about drinking water contaminants;
- a variety of source water protection programs;
- other statutes, such as the Clean Water Act, that complement SDWA;
- increased cooperation among local, state and federal drinking water professionals;
- consumers who are more informed about drinking water issues, such as contaminant health risks and the need for water conservation; and
- voluntary programs like the Partnership for Safe Water (*see Appendix A*)

However, even greater effort will be needed to deal with new and ongoing challenges.

With an increasing survival rate among cancer patients, a higher percentage of elderly citizens, and a growing HIV/AIDS population, it will become increasingly critical that drinking water health information be provided in a timely fashion to immuno-compromised populations. To continue learning about the health effects of known and/or regulated contaminants, and to begin studying emerging contaminants (e.g., newly discovered microbes, perchlorate), it will be imperative that the public and private sectors work together to more effectively and efficiently conduct sound scientific research in the future.

Given the national increase in population, urbanization and development, it will be especially important for all communities to participate in water conservation measures and source water protection activities to lessen the negative impacts that these trends can have on the availability and quality of drinking water.

It is important that consumers recognize that their actions affect the quality of their source water and the level of treatment that is required to allow safe drinking water to flow from their taps. The public must also recognize that high quality tap water comes at a price, but one that can be significantly less than alternatives such as buying bottled water. Drinking water professionals and community leaders must

continue to work together to educate and update the public about these issues.

Water professionals will also need to continue to evaluate the structure of the drinking water provision system and determine whether restructuring (e.g., consolidation) or other activities can help alleviate small system compliance problems. They will also need to determine whether funds to cover infrastructure and other costs can be more efficiently allocated, especially for economically-disadvantaged communities.

EPA and its partners must work to minimize deficiencies in compliance data to ensure that water systems are providing drinking water that meets standards and to have the necessary data to track progress over time.

Despite the many challenges faced by the national drinking water program, the U.S. has provided some of the safest public drinking water in the world. To maintain this high quality water supply, it will be critical for the drinking water community to work in concert with the public to ensure that all Americans have safe drinking water and that the Safe Drinking Water Act continues to provide the framework necessary to achieve that goal.



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# Appendix A

## Glossary

### **Acute Health Effect**

An immediate (i.e., within hours or days) adverse health effect that may result from exposure to certain drinking water contaminants (e.g., pathogens).

### **Chronic Health Effect**

The possible result of exposure over many years to a drinking water contaminant at levels above its maximum contaminant level.

### **Coliform**

A group of related bacteria whose presence in drinking water may indicate contamination by disease-causing microorganisms (see pathogens).

### ***Cryptosporidium***

A microbe commonly found in lakes and rivers which is highly resistant to disinfection. *Cryptosporidium* has caused several large outbreaks of gastrointestinal illness, with symptoms that include diarrhea, nausea, and/or stomach cramps. People with severely weakened immune systems are likely to have more severe and more persistent symptoms than healthy individuals.

### **Disinfection Byproducts**

Chemicals that may form when disinfectants (such as chlorine) react with plant matter and other naturally-occurring materials in the water. These byproducts may pose health risks in drinking water.

### **Distribution System**

A network of pipes leading from a treatment plant to customers' plumbing systems.

### **Gastroenteritis**

A general category of gastrointestinal illness which may result from drinking water contaminated with pathogenic viruses, bacteria or protozoa. Symptoms include diarrhea, cramps, fatigue, nausea and vomiting.

**Giardia lamblia**

A microorganism frequently found in rivers and lakes, which, if not treated for properly, may cause diarrhea, fatigue, and cramps after ingested.

**Hepatitis A**

One of numerous diseases (e.g., meningitis, ulcers, myocarditis, typhoid fever, cholera) that may result from ingestion of fecally contaminated drinking water containing pathogens. This disease is caused by the Hepatitis A virus. Symptoms of Hepatitis A include diarrhea, jaundice, fatigue, abdominal pain, intermittent nausea, and loss of appetite.

**Inorganic Chemicals**

Mineral-based compounds such as metals, nitrates and asbestos. These contaminants are naturally-occurring in some water, but can also get into water through farming, chemical manufacturing, and other human activities. EPA has set legal limits on 15 inorganic chemicals.

**Legionnaire's Disease**

A type of pneumonia that results when aerosols containing some types of the bacteria *Legionella* are inhaled by susceptible persons, not when people drink water containing *Legionella*. (Aerosols may come from showers, hot water taps, whirlpools and heat rejection equipment such as cooling towers and air conditioners.) Other types of *Legionella*, if inhaled, can cause a much less severe disease called Pontiac Fever. The symptoms of Pontiac Fever may include muscle pain, headache, coughing, nausea, dizziness and other symptoms.

**Maximum Contaminant Level (MCL)**

The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.

**Maximum Contaminant Level Goal (MCLG)**

The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.

**Membrane**

A thin, porous structure produced from a variety of materials which is used in some treatment processes to filter contaminants out of drinking water. Water is forced through the membrane and contaminants are left behind.

**Microbes (microorganisms)**

Tiny living organisms that can only be seen with the aid of a microscope. Some microbes can cause acute health problems when consumed (see pathogens).

**National Primary Drinking Water Regulations**

Legally enforceable standards that apply to public water systems. These standards protect drinking water quality by limiting the levels of specific contaminants that can adversely affect public health and are known or anticipated to occur in public water supplies.

**National Secondary Drinking Water Regulations**

Non-enforceable federal guidelines regarding cosmetic effects (such as tooth or skin discoloration) or aesthetic effects (such as taste, odor, or color) of drinking water.

**Organic Chemicals**

Carbon-based chemicals, such as solvents and pesticides, which can get into water through runoff from cropland or discharge from factories. EPA has set legal limits on 56 organic chemicals.

### Partnership for Safe Water

A unique cooperative effort between EPA, American Water Works Association, Association of Metropolitan Water Agencies, National Association of Water Companies, and Association of State Drinking Water Administrators. The Partnership encourages and assists U.S. public water suppliers to voluntarily enhance their water systems' performance, for greater control of *Cryptosporidium*, *Giardia* and other microbial contaminants.

### Pathogens

Disease-causing organisms such as some bacteria, viruses, and protozoa.

### Perchlorate

A contaminant that exists in the environment as a part of other chemical compounds such as ammonium, potassium, or sodium perchlorate. The concerns surrounding perchlorate contamination involve its ability to affect the thyroid gland, which can affect metabolism, growth, and development. EPA is co-chairing an Interagency Perchlorate Steering Committee (IPSC) to disseminate scientific information and frame policy issues regarding potential perchlorate contamination of drinking water.

### Primacy

Primary enforcement authority for the drinking water program. Under the Safe Drinking Water Act, states, U.S. territories, and Indian tribes that meet certain requirements (including setting regulations that are at least as stringent as EPA's) may apply for, and receive, primary enforcement authority.

### Radionuclides

An unstable form of a chemical element that radioactively decays, resulting in the emission of nuclear radiation. Prolonged exposure to radionuclides increases the risk of cancer. All of the radionuclides known to occur in drinking water are currently regulated, except for radon and naturally-occurring uranium, both of which were proposed for regulation in October, 1999.

### Safe Drinking Water Information System (SDWIS)

EPA's national drinking water database which stores information on all of the public water systems in the United States.

### Total Trihalomethanes (TTHMs)

A group of four organic chemicals which form when the disinfectant chlorine reacts with natural organic matter in water. These chemicals (chloroform, bromodichloromethane, dibromochloromethane, and bromoform) are regulated under one standard.

### Treatment Technique

A required process intended to reduce the level of a contaminant in drinking water.

### Turbidity

The cloudy appearance of water caused by the presence of tiny particles. High levels of turbidity may interfere with proper water treatment and monitoring.



## Appendix B

### Contaminants Regulated Under the 1962 Public Health Service Standards<sup>3</sup>

Alkyl Benzene Sulfonate (ABS)  
Arsenic  
Barium  
Beta and photon emitters  
Cadmium  
Carbon Chloroform Extract (CCE)  
Chloride  
Chromium  
Color  
Copper  
Cyanide  
Fluoride  
Gross alpha emitters  
Iron  
Lead  
Manganese  
Nitrate  
Phenols  
Radium-226  
Selenium  
Silver  
Strontium-90  
Sulfate  
Threshold Odor Number  
Total Coliform  
Total Dissolved Solids  
Turbidity  
Zinc



## Appendix C

### Commonly Used Drinking Water Treatment Technologies

(many technologies can be used to treat for multiple contaminant types)

#### Primarily for Removal/Inactivation of Microbial Contaminants:

**Disinfection** — A process used to reduce the number of pathogenic microbes in water. Examples of disinfection include:

**Chlorination** — A disinfection process using chlorine. Treats microbes, tastes, odors, and color.

**Chloramination** — A disinfection process using chloramine (not chlorine) as the treatment agent. Mainly used as a disinfectant residual (to maintain disinfection throughout distribution systems).

**Ozonation** — A disinfection process using ozone as the treatment agent. Helps reduce the formation of TTHMs by virtue of being an alternative to chlorine. Also serves to treat tastes, odors, and color.

#### Ultra Violet (UV) Irradiation

— A disinfection process in which ultraviolet wavelengths are used to kill pathogenic microorganisms in water.

#### For Removal of Microbes and Particulate Matter:

**Coagulation/Filtration** — A process that removes particulate matter from water through the following steps: coagulation, flocculation, sedimentation, and filtration. Treats microbes, iron, manganese, color, turbidity, disinfection byproducts, synthetic organic chemicals, inorganic chemicals, and radionuclides.

**Coagulation** — A process that involves adding certain chemicals (coagulants) to water to cause smaller particles to clump together and form larger particles (called “floc”), which can then be removed by sedimentation or filtration.

**Flocculation** — A process that partly overlaps the coagulation

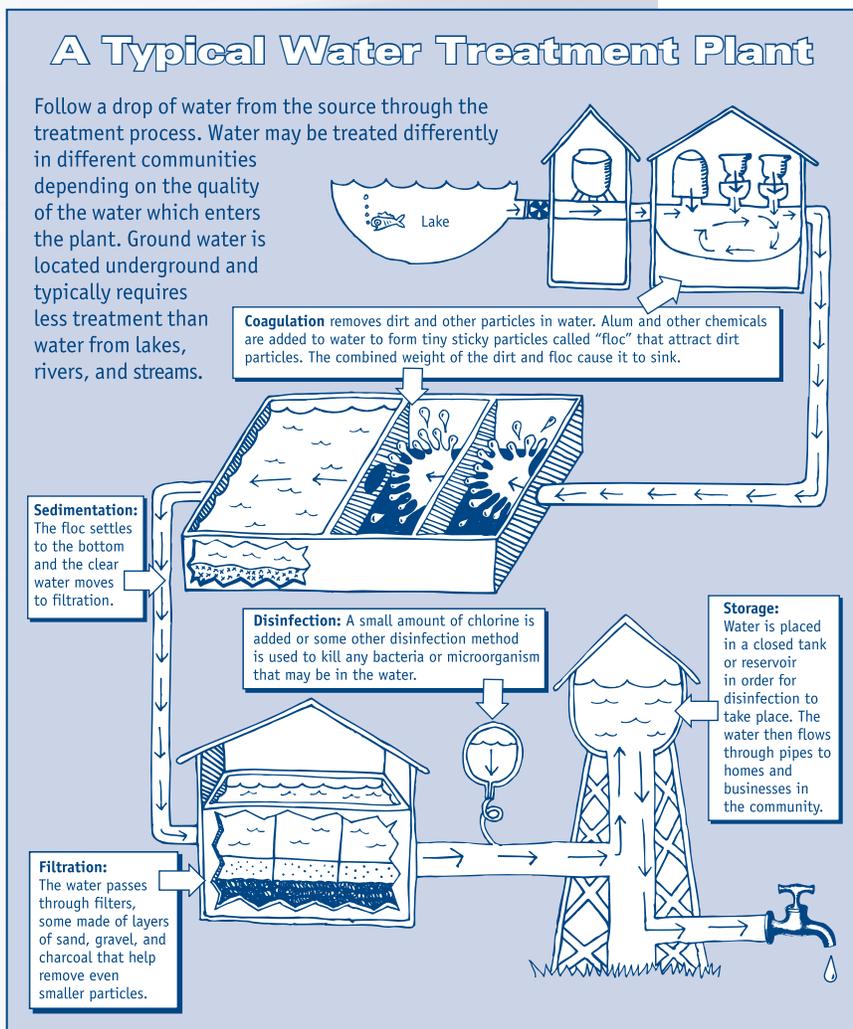


Figure courtesy of American Water Works Association

process, whereby water is gently mixed to promote the formation and sedimentation of floc.

**Sedimentation** — A process that follows coagulation/flocculation whereby floc settles out of the water.

**Filtration** — the passage of water through a porous medium, such as sand, anthracite, or other granular material, to remove floc and other particulates.

**Direct Filtration** — A treatment process similar to coagulation/filtration except there is no sedimentation step. Treats microbes, turbidity, synthetic organic chemicals, inorganic chemicals, and radionuclides.

**Industrial Cartridge Filters** — Disposable cartridges are used to filter drinking water, removing microbes and turbidity.

**In-Line Filtration** — The simplest form of direct filtration, wherein filtration is preceded by the addition of chemicals and rapid mixing. Treats microbes, turbidity, synthetic organic chemicals, inorganic chemicals, and radionuclides.

**Microfiltration, Ultrafiltration, Nanofiltration** — Types of membrane filtration which remove particulates and microorganisms above a specific size as delineated by the filter used. Micro and Ultra remove microbes and turbidity. Nano removes microbes, color, turbidity, hardness, disinfection byproducts and inorganic chemicals.

**Reverse Osmosis** — A pressure-driven treatment process using a specially prepared membrane that permits the flow of water through the membrane, but acts as a selective barrier to contaminants. Water is forced through the membrane and contaminants are left behind. Treats for microbes, salts, iron, manganese, color, turbidity, hardness, synthetic organic chemicals, inorganic chemicals (inorganic ions), and radionuclides.

**Slow Sand Filtration** — A treatment process that uses a deep bed of sand to remove particles and microbes from water. Treats microbes and turbidity.

### **Primarily for Removal of Inorganic Contaminants:**

**Activated Alumina** — A form of ion exchange in which charged contaminants in the drinking water are exchanged with elements on the alumina. Treats inorganic chemicals.

**Ion Exchange** — A process whereby a positively or negatively charged ion exchanges itself with a similarly charged contaminant ion in the drinking water. Treats hardness, inorganic chemicals, and radionuclides.

### **For Removal of Synthetic and Volatile Organic Chemicals:**

**Diffused Aeration** — Water is run on a bed containing air jets. The contaminant is transferred from the water to the air where it then dissipates. Treats iron, manganese, disinfection byproducts, volatile organic chemicals, and radionuclides.

**Granular Activated Carbon** — A filter allows activated carbon to bond with specific contaminants (such as synthetic organic chemicals) and traps them inside the filter. Also treats tastes and odors, disinfection byproducts, synthetic and volatile organic chemicals, and radionuclides.

**Packed Tower Aeration** — A treatment process in which drinking water is transferred out of a solution in water to a solution in air. The extent of the removal of contaminants from water is determined by the length of the column and the volatility of the contaminant. Treats disinfection byproducts, volatile organic chemicals, and radionuclides.

### **Primarily for Control of Aesthetic Problems:**

**Greensand Filtration** — Similar to slow sand filtration, except a specially coated material (greensand) is used to remove iron, manganese, taste, and odors from water.

**Lime Softening** — A treatment process to reduce hardness of water caused by the presence of calcium and magnesium compounds. May also be used to remove other inorganic contaminants.

## Appendix D

### Legislation Related to Safe Drinking Water Act (SDWA)

The following laws work in concert with SDWA by reducing the release of pollutants that can affect water and/or instituting policies that positively impact sources of drinking water:

#### **The Clean Water Act (former Federal Water Pollution Control Act)**

The aim of this law is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters. This is done by reducing the discharge of pollutants and toxins into navigable waters, by providing assistance to construct publicly owned waste treatment facilities, by encouraging research to develop technology necessary to eliminate the discharge of pollutants into navigable waters, and by developing policy for the control of nonpoint source pollution.

#### **The Coastal Zone Management Act (CZMA)**

The goal of this law is to protect natural resources, including wetlands, floodplains, estuaries, beaches, dunes, barrier islands, coral reefs, and fish and wildlife and their habitat, within coastal zones. The Act also aims to improve, safeguard, and restore the quality of coastal waters, and to protect natural resources and existing uses of those waters.

#### **The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)**

Under this law, EPA regulates hazardous substances and establishes limits for the quantities released to the environment. By law, a National Response Center is available to respond to emergency situations regarding hazardous waste accidents. A National Priority List of hazardous waste sites is maintained indicating the order in which sites in the U.S. are to be cleaned up. Priority is given to those sites that have contributed to the closing of drinking water wells or the contamination of a public drinking water supply.

#### **The Emergency Planning and Community Right-to-Know Act (EPCRA)**

Enacted in 1986 as part of CERCLA, this law has two major purposes: 1) to increase public knowledge of,

and access to, information on the presence of toxic chemicals in communities, releases of toxic chemicals into the environment, and waste management activities involving toxic chemicals; and 2) to encourage and support planning for responding to environmental emergencies.

### **The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)**

As required by this statute, EPA registers pesticides for general, restricted, or prohibited use. To prevent unreasonable risk to the natural environment, EPA can restrict distribution, sale, or use of any pesticide. This law is helpful to SDWA because it seeks to prevent any pesticide of unreasonable risk from seeping into ground water supplies or running off land into surface water supplies.

### **The National Environmental Policy Act (NEPA)**

NEPA requires that proposed projects which use federal land or federal dollars be evaluated to determine their potential impact on the environment. Environmental impact assessments are conducted to evaluate the proposed action and alternatives to ensure that measures are taken to reduce or eliminate impacts on the natural environment.

### **The Pollution Prevention Act**

Passed in 1990, the Pollution Prevention Act focused industry, government, and public attention on reducing the amount of pollution entering the environment through cost-effective changes in production, operation, and raw materials use. Opportunities for preventing pollution at its source (source reduction) are often not realized because of existing regulations, and the industrial resources required for compliance focus mostly on treatment and disposal. Source reduction is fundamentally different and more desirable than waste management or pollution control. Pollution prevention also includes other practices that increase efficiency in the use of energy, water, or other natural resources, and protect our resource base through conservation. These practices include recycling, source reduction, and sustainable agriculture.

### **Resource Conservation and Recovery Act (RCRA)**

In 1976, Congress enacted this comprehensive law which covers the generation, transportation, storage, and disposal of hazardous materials and waste. RCRA requires the cleanup of hazardous releases (such as chemical spills, or landfills containing hazardous waste) at facilities permitted under RCRA and facilities applying for a permit under RCRA's corrective action rules. Restoring hazardous sites is often also covered under CERCLA. Many states have primacy for RCRA programs.

### **The Toxic Substances Control Act (TSCA)**

This statute calls for the development of research and the accumulation of data on chemical substances and their effect on public health and the environment. EPA can regulate chemicals which present an unreasonable risk of injury to health or the environment if there is no other statute which provides that authority. This Act helps SDWA by contributing to source water protection.

## Appendix E

### Types of Underground Injection Wells

**Class I wells** are wells that inject large volumes of hazardous and non-hazardous wastes into deep, isolated rock formations that are separated from the lowermost underground source of drinking water by many layers of impermeable clay and rock.

**Class II wells** inject fluids associated with oil and natural gas production. Most of the injected fluid is brine (very salty water) that is produced when oil and gas are extracted from the earth (about 10 barrels for every barrel of oil).

**Class III wells** inject super-hot steam, water, or other fluids into mineral formations, which is then pumped to the surface and extracted. Generally, the fluid is treated and reinjected into the same formation. More than 50 percent of the salt and 80 percent of the uranium extraction in the U.S. is produced this way.

**Class IV wells** inject hazardous or radioactive wastes into or above underground sources of drinking water. These wells are banned under the Underground Injection Control program because they directly threaten the quality of underground sources of drinking water.

**Class V wells** use injection practices that are not included in the other classes. Some Class V wells are technologically advanced wastewater disposal systems used by industry, but most are low-tech holes in the ground. Generally, they are shallow and depend upon gravity to drain or inject liquid waste into the ground above or into underground sources of drinking water. Their simple construction provides little or no protection against possible ground water contamination, so it is important to control what goes into them.



## Appendix F

### Data from the Safe Drinking Water Information System (SDWIS)

SDWIS data presented in this report was taken from the following sources:

- Fiscal year 1998 data taken from SDWIS fiscal year 1998 fourth quarter frozen violations table (except for chemical monitoring/reporting violations)
- Fiscal year 1998 chemical monitoring/reporting violations data taken from SDWIS fiscal year 1999 first quarter frozen violations table
- Fiscal year 1997 and earlier data taken from SDWIS fiscal year 1998 first quarter frozen violations table

There are three main types of violations:

- (1) *MCL violation (MCL)* — occurs when tests indicate that the level of a contaminant in treated water is above EPA or the state’s legal limit (states may set standards equal to, or more protective than, EPA’s). These violations indicate a potential health risk, which may be immediate or long-term.
- (2) *Treatment technique violation (TT)* — occurs when a water system fails to treat its water in the way prescribed by EPA (for example, by not disinfecting). Similar to MCL violations, treatment technique violations indicate a potential health risk to consumers.
- (3) *Monitoring and reporting violation (M/R)* — occurs when a system fails to test its water for certain contaminants, or fails to report test results in a timely fashion. If a water system does not monitor its water properly, no one can know whether or not its water poses a health risk to consumers.

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Fiscal Year	Data	Total Coliform		TTHMs		Volatile Organic Chemicals	
		MCL	M/R	MCL	M/R	MCL	M/R
1980	# systems violating	6,950	19,669		0		
	population served	20,155,272	37,557,188		0		
1981	# systems violating	5,895	16,943	1	29		
	population served	24,320,435	34,342,722	279,000	3,198,214		
1982	# systems violating	5,853	15,163	6	28		
	population served	18,251,933	29,205,396	1,350,221	4,603,726		
1983	# systems violating	6,182	15,020	20	133		
	population served	16,601,676	28,364,575	1,206,016	5,993,505		
1984	# systems violating	6,622	16,430	63	114		
	population served	19,946,928	25,459,949	2,370,202	3,368,914		
1985	# systems violating	6,654	15,621	66	177		
	population served	19,510,616	27,696,135	2,174,846	10,495,059		
1986	# systems violating	6,573	13,074	50	128		5
	population served	18,613,894	25,355,726	3,452,482	7,104,502		3,308
1987	# systems violating	6,045	11,767	53	87	4	239
	population served	13,998,878	20,748,306	1,274,179	2,061,012	1,015,874	369,187
1988	# systems violating	5,410	11,709	35	158	13	299
	population served	14,035,668	25,865,485	793,650	4,396,930	1,140,356	2,922,055
1989	# systems violating	5,781	10,856	45	142	50	367
	population served	13,977,229	21,017,696	1,170,371	4,559,423	1,504,366	2,785,737
1990	# systems violating	5,718	10,537	38	132	53	406
	population served	12,496,524	18,921,525	843,426	4,648,053	1,453,139	1,176,086
1991	# systems violating	5,421	11,556	24	93	61	876
	population served	19,140,847	27,219,513	411,810	2,574,039	475,036	1,679,010
1992	# systems violating	4,428	11,464	33	82	72	891
	population served	19,062,907	25,823,120	595,546	2,293,532	535,679	997,474
1993	# systems violating	4,843	10,308	31	59	67	1,158
	population served	27,924,828	20,601,721	2,338,625	1,488,610	570,670	2,319,270
1994	# systems violating	4,106	9,203	28	79	62	2,262
	population served	22,950,752	17,430,321	392,622	2,016,127	581,607	4,896,150
1995	# systems violating	3,866	8,591	29	64	42	2,031
	population served	19,201,098	15,236,421	274,481	1,631,559	469,980	4,797,581
1996	# systems violating	3,682	7,734	26	65	43	1,817
	population served	12,052,298	13,919,636	175,479	2,597,489	441,663	4,173,318
1997	# systems violating	3,156	7,518	13	70	40	835
	population served	10,223,348	14,727,604	113,556	1,946,668	357,138	2,795,476
1998	# systems violating	3,238	7,026	8	69	25	735
	population served	7,889,248	17,282,627	85,915	2,391,444	59,793	1,486,482

Fiscal Year	Data	Synthetic Organic Chemicals		Nitrates		Inorganic Chemicals	
		MCL	M/R	MCL	M/R	MCL	M/R
1980	# systems violating		409	257	4,427	599	4,681
	population served		3,768,307	580,347	9,545,513	1,188,550	12,190,775
1981	# systems violating	1	391	282	2,815	555	3,011
	population served	40	4,321,113	1,565,805	5,565,641	1,376,771	8,805,446
1982	# systems violating	1	1,536	317	2,089	491	2,444
	population served	40	3,686,973	727,318	2,762,225	1,131,257	5,335,259
1983	# systems violating	0	1,491	286	1,881	559	2,108
	population served	0	3,557,337	467,091	6,571,327	806,218	7,844,309
1984	# systems violating	8	1,455	317	1,808	694	1,873
	population served	141,954	3,644,715	806,153	8,324,716	1,332,122	8,338,724
1985	# systems violating	3	1,699	338	3,228	615	3,393
	population served	1,212	4,773,311	818,721	10,889,095	1,248,128	10,503,714
1986	# systems violating	0	477	304	2,816	426	2,892
	population served	0	2,304,553	878,975	7,115,688	1,015,183	6,086,626
1987	# systems violating	2	509	313	3,002	325	3,036
	population served	52,162	2,768,248	776,725	7,689,063	925,980	7,261,321
1988	# systems violating	5	694	291	3,857	315	3,951
	population served	45,171	3,322,529	968,883	7,792,320	969,856	7,724,764
1989	# systems violating	10	548	262	3,633	242	3,640
	population served	139,266	2,488,408	793,017	7,414,642	885,489	7,176,603
1990	# systems violating	16	570	241	3,138	241	3,278
	population served	150,242	3,515,647	472,890	6,488,679	550,902	6,497,037
1991	# systems violating	26	810	227	2,325	255	2,899
	population served	153,958	2,661,023	414,575	3,640,853	588,177	4,297,070
1992	# systems violating	8	490	227	1,066	187	1,719
	population served	15,546	2,125,488	451,731	2,210,998	493,677	2,162,610
1993	# systems violating	24	551	287	4,104	176	2,443
	population served	220,100	3,060,626	639,684	9,721,547	546,499	11,594,971
1994	# systems violating	53	708	284	5,088	147	2,620
	population served	253,685	3,970,429	310,403	8,579,539	473,669	11,260,999
1995	# systems violating	60	1,035	234	3,697	134	2,409
	population served	101,842	9,472,823	469,855	5,550,154	345,147	6,852,317
1996	# systems violating	36	1,251	238	3,689	129	1,850
	population served	92,274	4,222,342	576,633	6,829,547	291,226	5,807,655
1997	# systems violating	36	379	191	2,216	95	508
	population served	116,751	909,623	369,327	6,276,149	491,710	2,466,025
1998	# systems violating	17	292	188	1,735	101	540
	population served	48,535	958,658	747,805	2,245,724	747,040	1,882,462

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Fiscal Year	Data	Radionuclides		Lead and Copper Rule		Surface Water Treatment Rule	
		MCL	M/R	TT	M/R	TT	M/R
1980	# systems violating population served	131 271,028	8,533 33,053,790				
1981	# systems violating population served	210 486,796	6,447 18,074,018				
1982	# systems violating population served	231 472,328	4,457 7,909,652				
1983	# systems violating population served	263 606,959	1,741 7,876,602				
1984	# systems violating population served	340 1,211,445	2,002 4,920,593				
1985	# systems violating population served	358 1,329,834	1,676 3,453,708				
1986	# systems violating population served	382 1,449,755	2,163 3,860,359				
1987	# systems violating population served	326 1,367,158	2,866 4,855,510				
1988	# systems violating population served	365 1,388,484	3,220 4,628,503				
1989	# systems violating population served	363 1,110,104	2,795 3,324,698				
1990	# systems violating population served	352 1,112,573	2,506 2,840,013				
1991	# systems violating population served	370 1,190,791	2,228 4,223,450	1 2,450		11 138,008	
1992	# systems violating population served	415 1,968,629	1,603 3,901,374	15 120,558	1,573 42,964,777	788 17,386,790	123 3,601,988
1993	# systems violating population served	360 1,842,846	1,316 3,369,649	178 6,903,107	10,231 39,459,385	1,301 23,112,397	469 2,911,090
1994	# systems violating population served	318 1,700,562	1,297 3,248,151	780 4,157,223	11,194 10,038,434	1,505 25,567,283	608 5,021,526
1995	# systems violating population served	312 1,732,199	1,155 3,242,322	495 7,525,675	2,337 3,393,119	1,338 22,470,881	457 4,038,597
1996	# systems violating population served	293 1,671,283	917 1,532,561	246 6,059,150	2,023 3,704,254	1,098 19,433,638	436 3,193,011
1997	# systems violating population served	215 979,302	447 447,837	98 6,039,121	1,856 3,646,741	1,017 18,718,619	383 2,099,902
1998	# systems violating population served	200 701,891	249 235,334	145 373,038	1,585 1,729,673	971 18,301,744	506 3,709,231