Drinking Water: A Half Century of Progress

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The EPA Alumni Association (EPA AA) has developed this and six other web-based subject matter essays in support of its Half Century of Progress project. An integrated summary based on these materials is contained in Protecting the Environment: A Half Century of Progress, which is available on the Association website. The Association has developed these materials to inform high school and college students and other members of the public about the major environmental problems and issues encountered in the United States in the latter half of the 20th century, as well as the actions taken and progress made in mitigating these problems.

A number of retired EPA program managers and subject matter experts worked together to produce each of the essays. This document was reviewed by the EPA AA Board of Directors and members of the association. We welcome comments on this document, which you may email to the EPA Alumni Association.

Drinking Water

Introduction

The Safe Drinking Water Act (PL 93-523; SDWA, 1974) was enacted in December 1974. It resulted in major changes in the way drinking water is managed and treated in the United States, and it achieved substantial measurable benefits in risk reduction and public health protection. This overview describes the historical context in which the national drinking water program was launched and outlines the major elements of this historic legislation. It describes the scientific, technical, and political challenges that were faced and it recounts how EPA undertook to implement the new program. It identifies the factors that contributed to the successful implementation of the federal/state/water utility drinking water partnership. In addition, it identifies some of the major challenges to drinking water quality to be addressed in the future.

Historical Context

The quality and palatability of drinking water have been a concern throughout recorded history. The first established direct link between drinking water quality and diseases dates from the 1850s, when the physician John Snow made the observation about the Broad Street water pump contributing to a deadly epidemic of cholera in London. Previously, it was generally believed that diseases were spread through breathing contaminated air or direct contact with infected individuals. While Dr. Snow's findings were controversial at the time, the authorities did reluctantly remove the handle from the Broad Street pump, and the epidemic eventually subsided.

Within 30 years, Louis Pasteur and Robert Koch launched the science of microbiology, postulated the "germ theory of disease," and identified the specific organisms that caused typhoid and cholera. By 1900, sand filtration was widely applied to produce clear water with greatly reduced microbial content. In 1908, and not without controversy, the first continuous application of chlorination to drinking U.S. water was installed in Jersey City, N. J.

The widespread application of chlorination and filtration led to dramatic reductions in waterborne disease and child mortality rates in U.S. cities. At the turn of the 20th century, mortality among children age 1 to 5 years in some major river cities was almost one in five (NCHS, 1981). It has been estimated that clean water accounted for reductions of about half of total mortality, three-fourths of infant mortality, and two-thirds of child mortality. Clean drinking water came about by the widespread application of improved community sanitation and water treatment- coagulation, sand filtration, and disinfection at major cities, resulting in one of the greatest public health breakthroughs of the 20th century. These reforms were supported primarily by major water suppliers and interventions of state health departments.

The United States Public Health Service (USPHS) began issuing standards for drinking water quality in 1914; however, they were enforceable at only about 700 watering points for interstate transportation carriers (Pontius, 1993). The standards were updated several times up to 1962. The deteriorating state of the nation's drinking water supplies was revealed in a 1969 Community Water Supply Survey by the USPHS (NEPIS, 2015). It demonstrated major water quality and treatment problems, especially regarding microbial contamination and monitoring deficiencies. This survey covered 969 national water supplies, or about 5% of the then estimated 19,236 national water supplies serving an estimated 12% of the population. Of the 969 systems, 238 exceeded recommended limits, 159 exceeded mandatory limits for microbial contamination, and 547 had major deficiencies, such as inadequate disinfection, including 120 mostly small systems that exceeded the coliform bacteria limit. Coliform bacteria, and especially *E. coli,* populate human and animal gastrointestinal tracts. *E. coli* in water is a good indicator of probable sewage contamination, while total coliforms are an indicator of general cleanliness.

The question of drinking water quality was also impacted by breakthroughs in analytical chemistry in the 1970s that enabled the detection and quantification of previously undetectable organic chemicals at concentrations in parts per billion. In the early 1970s, EPA analytical studies in the Lower Mississippi River led to a report by the Environmental Defense Fund suggesting a potential link between drinking water and cancer mortality in Louisiana. This study received a great deal of media attention at that time (Harris and Brecher, 1974).

Employing enhanced analytical methods, studies detected trihalomethanes (THMs), chloroform, and three other related disinfection byproducts in all chlorinated public water systems. Chloroform had produced cancer in laboratory animals fed high doses, in the initial studies. The detection of a chemical that might be a cancer risk in drinking water was a major public health concern. The accumulated information, media attention, and pressure from environmental groups led the Congress to pass the Safe Drinking Water Act of 1974.

The Federal Role in Ensuring Drinking Water Quality

In the 1970s when the Safe Drinking Water Act (SDWA) was passed, the state of drinking water technology was not much different from what it was in the 1920s and 1930s. However, questions were being raised about the adequacy of current water treatment to deal with the new contaminants of concern, the uneven nature of the state supervision programs, and the lack of a focus for developing standards for the new contaminants of concern.

Prior to the enactment of the SDWA the federal role in drinking water quality was administered by the Public Health Service in collaboration with the state health departments. They used a small number of consensus standards for water quality enforceable only at the watering points for interstate transportation carriers. The federal government did provide limited technical assistance and some research related to drinking water through its laboratories in Cincinnati, Ohio.

The perception that the technological successes of the 20th century had virtually eliminated waterborne diseases led state health departments to shift priorities to other concerns, and they reduced their oversight of drinking water facilities. The state drinking water programs were highly variable, with limited oversight, monitoring, and compliance requirements. Some water works professionals were concerned about lax supervision of water utilities by the states and the microbial and chemical content being delivered. The concerns applied especially to small systems, but these issues were not being addressed by all state programs. The coverage was variable and often with limited oversight, monitoring and compliance requirements

Similarly, managers of water works generally believed that the major health issues of the past were largely resolved. They focused on expanding systems, providing reliable service through aging infrastructure, safeguarding the microbial quality of the product, and minimizing costs to customers to avoid rate increases.

The Safe Drinking Water Act of 1974

The SDWA established a federal program to create scientifically based standards for drinking water quality applicable to all public systems. These systems served more than 25 customers or 15 service connections. The program was intended to oversee compliance with standards through state regulators. It established a three-step process for quality standards. EPA was to:

1. Promulgate enforceable Interim Standards based on an update of the 1962 USPHS standards,
2. Contract with the National Research Council (NRC)/National Academy of Sciences (NAS) for a study of contaminants in drinking water that could impact public health, and
3. Issue more comprehensive revised standards based on the NRC/NAS study.

Water utilities would be responsible for monitoring and compliance with the states conducting the needed oversight function. Significant grants—$20 million initially—were provided to states to upgrade oversight programs. After a startup period, continued state eligibility for grants required specific actions to assume oversight implementation responsibilities. These included the adoption of standards at least as stringent as the federal requirement, and related oversight, record keeping, and other aspects. EPA would undertake direct supervision only if a state were unwilling or unable to accept the responsibilities. Today, the federal grant support to state public water system programs has risen to $100 million annually.

The 1996 amendments to the SDWA created a State Drinking Water Revolving Fund (SDWRF) to help water supply systems and the states achieve the health protection objectives of the SDWA. This program is administered as a shared responsibility between EPA and the states. Repayments of loans and interest are added to that states' SDWRF to help finance future drinking water improvements. Building on a federal investment of over $17.5 billion, the SDWRF has provided $30.01 billion to water systems through June 30, 2015. These transactions resulted from more than 12,166 separate agreements.

Another feature of the SDWA legislation worthy of special mention is an unprecedented requirement for "public notification" by the utilities to customers when standards were exceeded or when mandated monitoring failed to take place. Thus, there was introduced an element of additional self-interest and self-enforcement by water utility managers. Although these public notification requirements initially worried utility managers because they were unaccustomed to such transparency, they were ultimately accepted.

Initiation of the Drinking Water Program

Implementation of EPA's national drinking water program began with a focus on rebuilding state programs to oversee compliance with existing standards, and developing new regulations for previously unregulated contaminants. Program implementation began with some troubling findings requiring immediate attention:

- The USPHS standards were limited and were the product of expert panels that left no backup records or data. In addition, they failed to meet current legal requirements for due process and public comment in setting mandatory standards.
- Most states did not have comprehensive inventories of their existing public water supplies, their sources of water, or their treatment facilities. Thus, EPA began by providing technical assistance to initiate state inventories of water systems using newly available computer-based data processing systems. Ultimately, about 150,000 public water supplies were identified, of which about 55,000 were community systems serving resident populations.
- The vast majority of citizens were served by several thousand large water systems, while the vast majority of systems served small numbers of customers and lacked professional management. Small systems required new approaches to compliance, as some water treatment was not feasible due to both the lack of professional management and high costs stemming from the absence of economies of scale.
- Recently applied analytical techniques enabled the measurement of organic contaminants at previously undetectable levels, but the techniques were generally limited to research laboratories. Standard-setting activities had to begin with national monitoring surveys of contaminants occurring in public water systems using the new analytical techniques.

A strategy called "One Step at a Time" was developed as the new program began operations, to indicate that implementation would be incremental, with the highest priority being to address the greatest health risk situations. Transparent processes would be used to ensure that all interested parties could input the implementation activities, and also that costs and feasibility would be considered in all regulatory decisions.

The SDWA anticipated that states would upgrade their drinking water oversight capabilities to meet federal requirements and then become designated for "primary enforcement authority"—that is, full authority to implement and enforce EPA-generated regulations. In 1974, very few states had the capability or legal framework to implement the new law. As a result of the high priority given to rebuilding state capabilities with EPA's regional assistance, very high levels of state program acceptance were rapidly achieved. In the first few years, 52 of the 57 potential states and territories received primary authority for their respective programs under the Act. In large part, the success of these efforts to promote state delegations was related both to the historic levels of cooperation between former USPHS officers in EPA's regional offices and state drinking water programs and, notably, to the availability of federal grants. Over time, 10 regions working with 50 states forged one consistent national program. EPA's work was assisted by the National Drinking Water Advisory Council, which reviewed and advised on major actions.

The water works industry, represented by the American Water Works Association (AWWA) and the National Association of Water Companies, was initially skeptical about the new regulatory program that they faced. Historically, they were usually subjected to minimum state regulatory oversight. They eventually became more involved when they realized that they had to conform to mandatory federal regulations. This cooperation was driven by EPA's growing technical competency, EPA's willingness to provide technical assistance, and meaningful opportunities to participate in and influence program development with other stakeholders. Environmental groups remained impatient for quicker reforms, and were not pleased with the time it took to produce the new drinking water regulations. However, they realized that much development work was underway.

Development of Drinking Water Standards

Interim standards for drinking water quality were issued as enforceable regulations on schedule in 1975 and became effective in 1977, as required by the SDWA. The standards were based on the last set of USPHS standards issued in 1962. They were generally accepted by the water industry, since they had been in use by many for years.

The NRC/NAS Study

The NRC report provided chemical-specific summary health information on some industrial chemicals and pesticides using the available data. However, it was not sufficiently broad or detailed to allow direct use in setting the new regulations (NAS, 1977). However, the report did propose a science policy approach using mathematical models to estimate the potency of nonthreshold chemicals like genotoxic carcinogens (i.e., chemicals that interact with DNA) that was useful for later regulatory development.

Regulation Development

EPA's Research and Development laboratory conducted two national surveys of organic contaminants in drinking water using the new sensitive analytical methods. The surveys revealed that THMs, were present in all chlorinated waters, and also that several other volatile organic chemicals were occasionally found mostly in systems drawing on groundwater sources. The discovery of THMs was particularly troubling, as they were byproducts of disinfection—the same process widely associated with the virtual elimination of the major waterborne diseases of the past. The THM standard created by EPA was designed to serve as a measurable grouping of several chemicals. In that way, it was an indicator of other unmeasured disinfection byproducts that would also be managed as measures were taken to reduce THM levels. The regulatory methodology and supporting information on regulatory impact developed with the THM regulation became a model for subsequent regulations.

The THM rule was carefully crafted so as not to increase the risk of waterborne microbial diseases. It was initially applied only to large water supplies that had the wherewithal to reduce THMs while maintaining disinfection efficacy. Although the water works industry expressed great concerns initially, it turned out that compliance was not as difficult as facility managers had originally thought. They could comply with the standard by more closely by controlling water treatment and modifying where chlorine was introduced in the treatment process. In addition to covering the first new group of organic chemicals to be controlled, this regulation attracted international attention and was adopted by several countries. It has led to a great deal of research on all disinfectants and their byproducts, their toxicology, and treatment technologies, as well as epidemiology studies attempting to relate these chemicals to cancer risks.

When the THM regulation was proposed, EPA also proposed a regulation that would have required the application of granular activated carbon to replace sand filters in facilities whose source waters were determined to be subjected to significant industrial chemical contamination. After a contentious public comment period, that proposal was not promulgated, because of a number of technical and economic uncertainties related to a specific decision tool for reactivating granular activated carbon. In retrospect, it was the appropriate decision, and since then, contamination of source waters has been significantly reduced through Clean Water Act requirements. Improved treatment techniques are being applied in wastewater treatment plants. Essentially all wastewaters now receive significant treatment prior to their discharge to rivers. Chemical discharges to sewage systems are treated prior to discharge, and they are controlled by legal permitting processes.

Comprehensive Drinking Water Regulations

Over the years, regulatory protection has been extended by group or individual maximum contaminant levels (MCLs) or by treatment requirements that include additional chemicals, radionuclides, and microbial contaminants. MCLs determine the maximum level of each covered substance at the tap deemed safe. They also include requirements for monitoring, remediation, and public notice when standards are exceeded. There are now MCLs for 88 individual organic and inorganic chemicals, including groups like THMs and haloacetic acids, and *E. coli* bacteria indicator microorganisms. In addition, treatment technology requirements that include specifications for surface water filtration and groundwater disinfection cover protozoa, viruses, and other bacteria. Radionuclides are regulated using two group-screening techniques, along with radium and radon. Corrosion control requirements use the presence of lead and copper as indicators of water's aggressiveness to plumbing and to reduce amounts of lead and copper in drinking water (EPA, 1991).

Drinking Water Health Advisories

Promulgating regulations is a lengthy and tedious legal and technical process. More contaminants were being detected at low concentrations by the new analytical methods, and states and communities needed rapid guidance to make decisions for protecting public health. In 1981, EPA's Drinking Water Office created and began issuing Drinking Water Health

Advisories to provide risk guidance for short-, medium-, and long term-exposure situations, to assist in managing the detection of unregulated contaminants. This type of guidance proved so valuable that it was immediately used by other EPA programs. It has since been codified in the 1996 amendments to the SDWA (SDWA, 1996). Health advisories for over 200 chemicals are now available on EPA's web site. In addition, EPA's Pesticide Program has published acute (short-term) and chronic (long-term) risk-based exposure guidance, called Human Health Benchmarks, for more than 350 pesticides in drinking water. These health advisories are invaluable for making rapid decisions to respond to spills and emergencies created by the detection of solvents, pesticides, and other chemical contaminants for which there are no standards.

Program Accomplishments

The net public health beneficial effect of the SDWA program has been reliably safer national drinking water, as evidenced by a progressive reduction in the number of waterborne disease outbreaks reported by the Centers for Disease Control and Prevention since 1980, when implementation became fully operational. This reduction has occurred during a period when surveillance and detection have improved significantly, and causes are more identifiable. Comprehensive science-based water quality standards are applied in over 150,000 public water supplies. Regular monitoring of water quality of public water supplies is mandatory. Virtually all the states have improved their drinking water supervision programs, and regulations are being enforced.

Since 1996, federal funds (capitalizing self-sustaining state revolving funds) and other resources have been made available to help water suppliers improve their systems and the quality of the drinking water that they provide. There has been great improvement in the professionalism of utility management, largely enhanced through the training and education programs of their professional organizations. For example, the larger utilities formed and funded the AWWA Research Foundation to give them an independent source of information on emerging drinking water science and technology issues. This organization, now called the Water Research Foundation, has grown into one of the largest research programs devoted to drinking water issues in the world. Improved public awareness about the condition of public water supplies and water quality is also occurring. The water utilities routinely provide consumers with information about water quality and known problems in their mandatory Consumer Confidence Reports.

Scientific knowledge and research about drinking water have greatly expanded within the academic community. The sophistication of water management systems and the treatment technologies, available through consulting engineers and system professionals, have been significantly enhanced. The need to upgrade water works has also attracted significant private-sector stakeholders who see these facilities as potential markets for new technologies, applications of information technologies, and improved management systems.

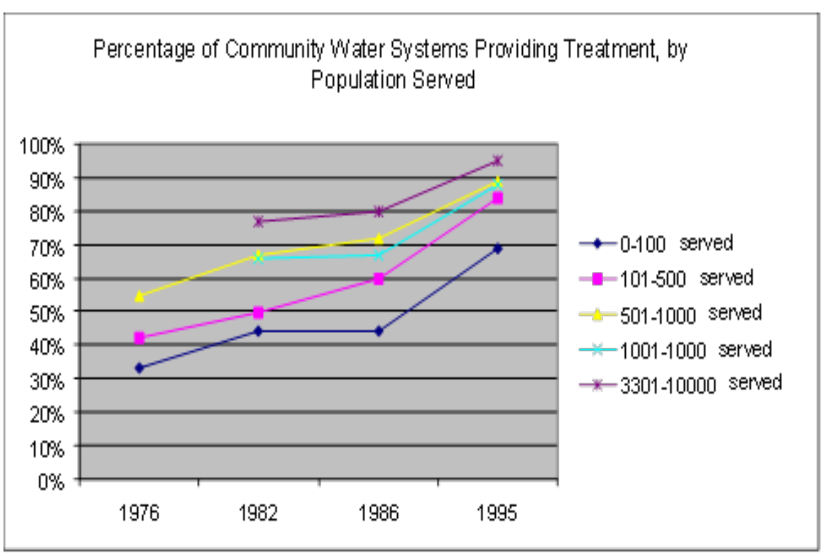
Future challenges

Microbial disease risks will always be the most significant public health concerns, and their prevention will always require diligent management at all levels, from regulators to water system operations.

Disinfection byproducts (DBPs) are the most common trace chemical residues in drinking water, but their regulation is complex because they result from essential microbial controls. Numerous DBPs have been regulated, but there are still unresolved issues to be addressed. The principal water quality concerns are now associated with distribution systems, rather than the quality of the source water. This includes a need to better understand and control *Legionella* and related disease organisms that regrow in distribution and plumbing systems, and are most likely the most significant water risks in the developed world. Some organisms like *Legionella* are inhalation risks spread by aerosols inhaled during showering and emitted from cooling towers.

The most significant public health and institutional challenges facing the country and water systems is the need to upgrade and replace aging infrastructure. Most systems contain pipes that are over 100 years old and beyond their designed and useful lives. Myriad health and economic problems are affected by deteriorating infrastructure. Some of these include water recontamination by the infiltration of chemicals and microbials, pipe leaks requiring emergency repairs, and the need to detect and fix cross-contamination and back siphonage in plumbing systems. Cost estimates prepared by the American Society of Civil Engineers have ranged from $384 billion to a trillion dollars over the next 20 years. The respective future roles of the federal and state governments and local communities and the future role of the state revolving loan funds need to be resolved. Paying for these critical improvements will be a major challenge to public finance in the years to come.

Small drinking water systems have always been a vexing problem. Fortunately, most small systems utilize groundwater, which is generally more stable and of higher quality than surface waters. Where feasible, opportunities to connect to or share management with nearby compliant systems are often the most practical way to comply with regulations. However, when treatment is needed, small systems face great difficulties due to their greater financial and personnel disadvantages. Treatment technologies are becoming more complex, so even if a technology is installed, the operation and maintenance issues are substantial. Therefore, there is a need to develop more training and career opportunities for qualified operators.



Direct and indirect potable reuse and desalination technologies are becoming more widely used to increase access to water in areas where population increases and droughts have placed pressure on access to sufficient quantities of drinking water. EPA and the states have roles to play in facilitating appropriate solutions and new technologies and promoting expanded conservation measures.

Although the nation's drinking water is safer than ever, there is need to maintain the federal and state regulatory and oversight institutions to address new issues as they become identified, and to avoid potential backsliding in monitoring and compliance with existing standards. Continued efforts to prevent contamination of source waters are also necessary to reduce the treatment burdens on water suppliers.

Summary

The SDWA has been successful by improving public health protection through the efforts of dedicated water professionals at the water utility, state, and federal levels. EPA can be proud of its essential role in the success of that joint enterprise.

The implementation of the SDWA has achieved better and more uniform levels of water quality across the United States. Improvements in analytical chemistry have enabled the detection of trace levels of previously unknown contaminants. Continuing research has also led to introductions of improved treatment technologies and modernization of many water supplies.

Water-related gastrointestinal disease outbreaks have been reduced considerably since the SDWA's implementation, while surveillance and detection of such events have also improved. Most waterborne diseases are now associated with the distribution system. There is always the need to look back and refine and update aspects, such as the numbers and identities of regulated substances, eliminating those that are no longer relevant, adding some, and making adjustments reflecting the best available science and technology, and perhaps expanding the number of Drinking Water Health Advisories.

A six-year review cycle is built into the SDWA. Over time, should provide opportunities for some necessary refinements to remove unnecessary regulations and address new issues as they evolve. However, although continuous reevaluations are always necessary, many of the fundamental regulatory decisions have been made and implemented. A broad consensus has been reached by professionals that the system is functioning and drinking water is safe and measurably safer than prior to implementation of the SDWA.

Water for drinking and cooking is only about 1% of water provided by public water suppliers. Many members of the public are exercising their options to consume more bottled water and use home treatment devices. A recent survey indicated that 56% of respondents were concerned or very concerned about their tap water, 77% were regular users of bottled water, and 43% used some type of home treatment device (WQA, 2015). These findings are probably due to convenience and the greater availability of bottled water and home treatment devices, and more discretionary income among many consumers. However, this trend is also driven by consumers' dislike of the taste of some tap waters, as well as their reactions to media reports that stimulate concerns about hypothetical risks that may be related to drinking water. Thus, the water industry and regulators will continue to face the challenges of how to promote the public's acceptance and confidence in their drinking water supplies and to maintain the public's support for needed improvements.

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Authors

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Victor J Kimm joined EPA at its inception, serving five years as the Deputy Director of the Office of Planning and Evaluation and a decade as the first Office Director for the drinking water program implementing the Safe Drinking Water Act of 1974. He then served ten years as Deputy Assistant Administrator for OPTS, the senior career official responsible for controlling industrial chemicals, promoting pollution prevention and licensing pesticides. He also provided expertise on environmental management problems in Central and Latin America, Asia and the Middle East. He subsequently taught public policy for five years at the University of Southern California's graduate school of Public Administration and 15 years community service as CEO of Share Inc. an all-volunteer non-profit organization serving the working poor in northern Virginia. Mr. Kimm holds a Bachelor's degree in Civil Engineering from Manhattan College, a Master's degree in Civil Engineering from New York University and a NIPA fellowship from the Woodrow Wilson School of Princeton University.

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The Standards division developed comprehensive national drinking water regulations and risk assessments for microbial contaminants, organic and inorganic chemicals and radionuclides, THM disinfection by-products, surface water filtration, and lead and copper corrosion control. It also initiated EPA's Drinking Water Health Advisory Program for unregulated contaminants and emergencies. He was also Director of the Risk Assessment Division in OPPT. Joe is president of Joseph Cotruvo and Associates, LLC, Water, Environment and Public Health Consultants, and holds a doctorate in Physical Organic Chemistry from Ohio State University. He is Board Certified in Environmental Sciences and is a Research Professor in the Departments of Chemistry and of Environmental Sciences at the University of Toledo, and a member of the UT School of Green Chemistry and Engineering Science Advisory Board. For many years he has worked on the World Health Organization's Drinking Water Guidelines, and serves on numerous expert advisory panels on drinking water quality, desalination, and large scale wastewater and potable water reuse. He was chairman of the Water Quality Committee of the Board of Directors of the Washington DC Water and Sewer Authority.

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