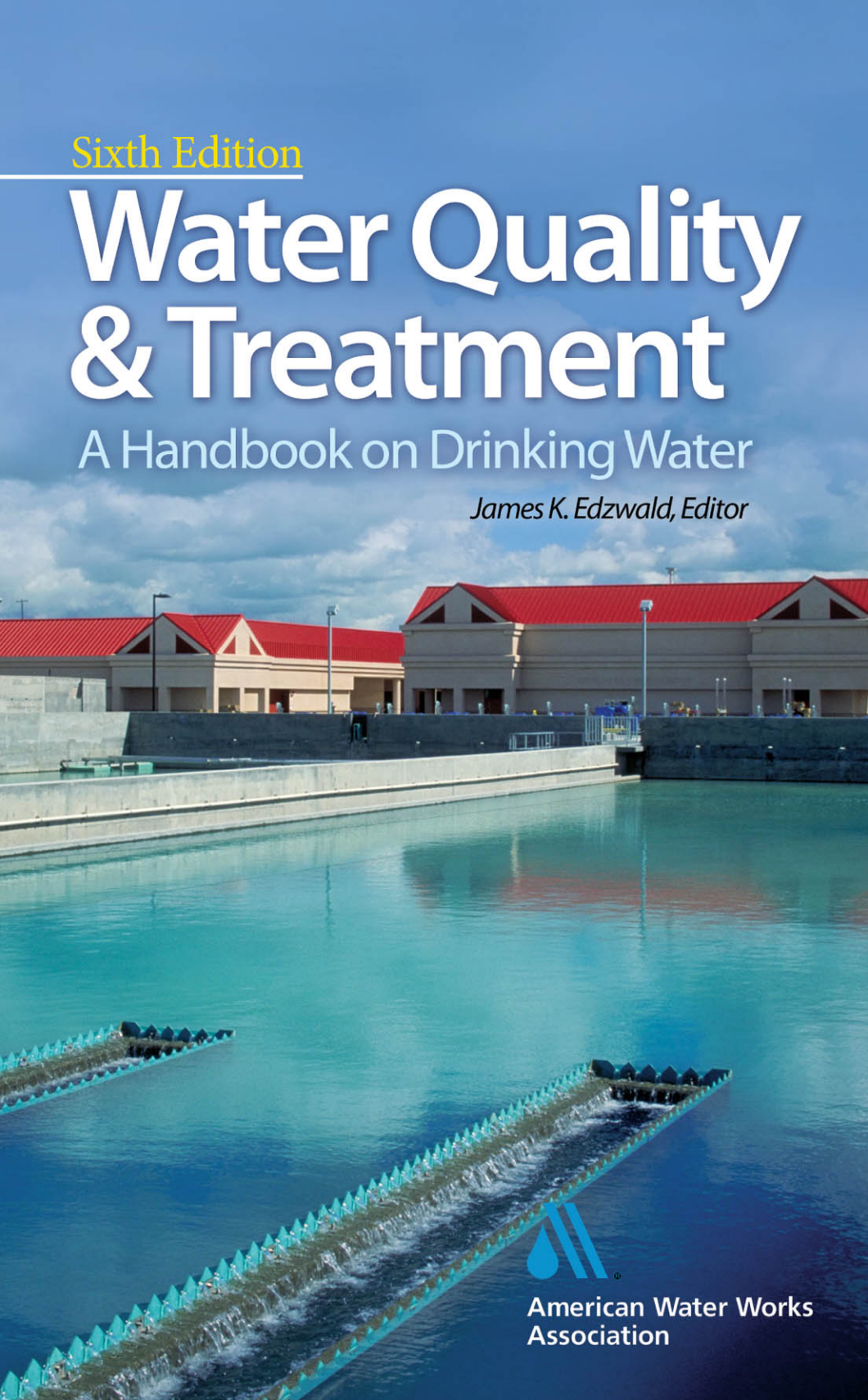
Sixth Edition

# Water Quality & Treatment

## A Handbook on Drinking Water

*James K. Edzwald, Editor*



American Water Works Association

# WATER QUALITY & TREATMENT

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## A Handbook on Drinking Water

American Water Works Association

**James K. Edzwald,** Editor

**Sixth Edition**

New York Chicago San Francisco Lisbon London Madrid
Mexico City Milan New Delhi San Juan Seoul
Singapore Sydney Toronto

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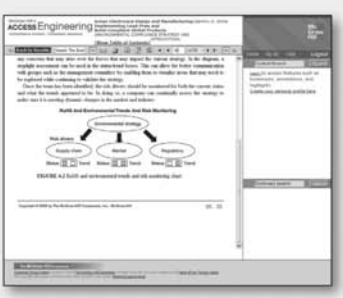


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## ABOUT THE EDITOR

**James K. Edzwald** is Professor Emeritus of the Department of Civil and Environmental Engineering at the University of Massachusetts, Amherst. He earned his B.S. and M.S. degrees in Civil Engineering and Environmental Health Engineering from the University of Maryland, and a Ph.D. in Water Resources Engineering from the University of North Carolina, Chapel Hill. He also held faculty positions at the University of Missouri, Clarkson University, and Rensselaer Polytechnic Institute. His research interests include water supply, drinking water treatment, and aquatic chemistry. Professor Edzwald has authored or coauthored over 150 publications on water quality and treatment. He is a recipient of the 2004 A.P. Black Award from AWWA for his contributions in water supply research and a recipient of the 2009 Founders' Award from the Association of Environmental Engineering and Science Professors for his contributions to environmental engineering education and practice. He is a registered professional engineer in New York.

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# PREFACE

This sixth edition of *Water Quality & Treatment: A Handbook on Drinking Water* serves as a handbook for scientists, engineers, and other professionals who study and work in drinking water—particularly the quality of water supplies, the quality of treated drinking water, and water treatment processes. It is meant as a resource for those in academics (professors and students), consulting engineering practice, water utilities, federal and state regulatory agencies, and the water process and chemical industries. The book emphasizes principles (theory) and applications (practice). It serves as a companion to the book on design, AWWA-ASCE, *Water Treatment Plant Design* (the fifth edition is in preparation, with expected publication in late 2011).

This book is an activity of the American Water Works Association's (AWWA's) Water Quality and Technology Division (WQTD). James K. Edzwald served as the technical editor and worked with the authors of the chapters in preparing the book. An ad hoc committee of the WQTD consisting of James P. Malley, Jr., Marilyn M. Marshall, and Dixie Fanning provided advice to the technical editor throughout the preparation of this book.

*Water Quality & Treatment,* sixth edition, differs greatly from the fifth edition—published in 1999; it contains significant revisions, updating of material, and new chapters. Five new chapters expand the scope of this book: Chapter 4, "Hydraulic Characteristics of Water Treatment Reactors and Their Effects on Treatment Efficiency," Chapter 15, "Natural Treatment Systems," Chapter 16, "Water Reuse for Drinking Water Augmentation," Chapter 18, "Ultraviolet Light Processes," and Chapter 19, "Formation and Control of Disinfection By-Products." A sixth chapter, Chapter 3, "Chemical Principles, Source Water Composition, and Watershed Protection," replaces one from the fifth edition on source water quality management, and it is essentially another new chapter in that it contains new material on chemical principles and additional material on source water quality.

Since publication of the fifth edition, the drinking water field has faced new regulations and concerns about the health effects of some new and previously known contaminants. Furthermore, in the last 10 years we have seen the development of new technologies and refinements of older technologies that are now covered in this edition. The sixth edition covers the health effects and treatment technologies to remove some contaminants not covered previously, such as nanoparticles, endocrine disrupting compounds, and pathogens; it contains updated material on many other contaminants, such as disinfection by-products, arsenic, and pathogens, including viruses and protozoan cysts such as *Cryptosporidium*; and it addresses subjects not adequately covered in the prior edition, such as water reuse, ultraviolet light processes, and natural treatment systems.

Several other new features are notable in this sixth edition. The International System of Units (SI) is used with U.S. units in parenthesis where appropriate. This makes the book useful to professionals outside the United States and to those within the United States working on water projects around the world. Each chapter has its own table of contents to aid readers in finding subject matter within chapters. Four new appendices provide quick references for atomic numbers and masses, physical and chemical constants, unit conversion factors, and the physical properties of water and gases.

The book is organized beginning with five foundation chapters that contain material on drinking water standards and regulations (Chap. 1); health effects (Chap. 2); chemical principles, source water composition, and watershed protection (Chap. 3);

hydraulics of treatment processes (Chap. 4); and an overview of water treatment processes (Chap. 5). This is followed by coverage of various water treatment processes in Chapters 6 through 14 that present principles and applications of the removal of various contaminants from water supplies. Chapter 15 covers natural treatment systems such as river bank filtration, and Chapter 16 deals with water reuse. Chapters 17 and 18 follow with disinfection and ultraviolet light processes, including disinfection and advanced oxidation processes. Chapters 19, 20, and 21 cover disinfection by-products, corrosion, and microbiological quality in distribution systems, respectively. Chapter 22 ends the book with the properties, treatment, and management of water treatment residuals.

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# ACKNOWLEDGMENTS

The sixth edition of *Water Quality & Treatment: A Handbook on Drinking Water* is a valuable resource for the drinking water field that is made possible through the efforts of many people. First and foremost, the quality of the book is due to the efforts of the 45 authors who prepared 22 chapters in the book.

Revision of the book began with an assessment of the fifth edition. Several professionals from water utilities, consulting engineering firms, and academics were asked to review the fifth edition and to make recommendations for new material for inclusion in the sixth edition. I wish to thank the following: William C. Becker (Hazen and Sawyer), William D. Bellamy (CH2M Hill), Steve Bishop (Metcalf and Eddy), Howard Dunn (Vice President of Operations and Technology, Aquarion Water Company of Connecticut), Harold T. Glaser (Kennedy Jenks), Raymond D. Letterman, (Syracuse University and Technical Editor of the fifth edition), Michael J. MacPhee (Malcolm Pirnie), Charles R. O'Melia (Johns Hopkins University), Vernon L. Snoeyink (University of Illinois), and John P. Walsh (formerly, Director of Operations and Distribution, Aquarion Water Company of Connecticut, now with Environmental Partners Group).

I am grateful to the reviewers who commented on draft chapters and provided comments for the authors for improving their chapters. They are Robert Andrews, Brian Arbuckle, Takashi Asano, Khalil Z. Atasi, Benoit Barbeau, William Ball, Tim Bartrand, William Becker, Ernest Blatchley III, James Bolton, Anne Camper, Sarah Clark, Joseph Cotruvo, James Crook, Brian Dempsey, Francis DiGiano, Bruce Dorvak, Jörg E. Drewes, Nicholas Dugan, Marc Edwards, Doug Elder, Tom Gillogly, Thomas Grischek, Johannes Haarhoff, Robert Howd, Kerry Howe, Michael Kavanaugh, William Knocke, Yann Le Gouellec, France Lemieux, Gary Logsdon, Michael J McGuire, James P. Malley, Jr., Margaret H. Nellor, Eva C. Nieminski, John Novak, David Pernitsky, David Reckhow, Michael Semmens, Sukalyan Sengupta, Robert Sharp, Jim Taft, Ian Watson, Paul Westerhoff, and Yuefeng Xie.

This book project was initiated by James P. Malley, Jr., Marilyn, M. Marshall, and Dixie Fanning, members of the ad hoc committee representing the Water Quality and Technology Division of AWWA. Their advice was invaluable, and I thank them. I am particularly indebted to Jim Malley for his leadership. He was also always there to give advice and help me over the hurdles. Finally, I thank the staff with AWWA Publications and with McGraw-Hill for their work in producing the book. A special thanks goes to Gay Porter De Nileon, AWWA Publications Manager, who provided essential support from AWWA; without her assistance the book could not have been completed.

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# CHAPTER 1

# DRINKING WATER STANDARDS, REGULATIONS, AND GOALS

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The initial Safe Drinking Water Act (SDWA) was signed into law on Dec. 16, 1974 (PL 93-523). The 1974 SDWA established the national regulatory structure by which the U.S. Environmental Protection Agency (USEPA), state and local regulatory agencies, and water utilities work together to ensure safe drinking water. This chapter presents the history of drinking water regulations leading to the 1974 SDWA, subsequent SDWA amendments in 1986 and 1996, and the history of the drinking water regulations that resulted from the 1974 SDWA and the 1986 and 1996 amendments. The current risk management and standard-setting processes are discussed, along with the roles of the states and the public in the standard-setting process. Standards developed at the state level, as well as international standards, are also discussed.

## *REGULATORY HISTORY PRIOR TO THE 1974 SDWA*

### Early History

Protection of drinking water quality goes back several hundred years. Scientific and medical advances in the 1800s, along with the need to provide basic sanitation in the rapidly urbanizing cities, laid the foundation for today's drinking water field. Philadelphia was one of the first cities in the United States to provide piped drinking water; drinking water first flowed through mains of the Philadelphia Water Department in 1801 (Philly $H_2O$, 2008).

Connecting disease epidemics with centralized water systems was a major step in public health protection (McGuire, 2006). As part of the major cholera outbreak in London and the investigation into the area surrounding the Broad Street Pump in 1854, Dr. John Snow concluded that cholera was a waterborne disease. He removed the pump handle and no further epidemics occurred in the area surrounding that well. At that point, safe drinking water and basic sanitation started to become part of basic public health protection (Johnson, 2006). The Centers for Disease Control and Prevention (CDC) has recognized conventional drinking water treatment, i.e., the traditional multibarrier approach of using the best available source, treating the water appropriately by using filtration and disinfection, and maintaining distribution system integrity, as one of the 10 great public health improvements of the twentieth century (under the umbrella of infectious disease control) (CDC, 1999).

The first federal action taken regarding drinking water quality was passage of the Interstate Quarantine Act in 1893 (U.S. Statutes, 1893). This legislation gave the Surgeon

General of the U.S. Public Health Service (USPHS) the authority to develop and enforce regulations to prevent the introduction and transmission of communicable diseases. Interstate quarantine regulations followed the next year.

The first national drinking water regulation was adopted in 1912, a result of the nation's growing railroad network, and prohibited the use of the "common cup" on interstate train carriers (Roberson, 2006). Bringing the interstate transport challenges into current times for airlines, USEPA conducted a stakeholder effort in 2006–2007 to develop and aircraft drinking water rule. As a result of this effort, USEPA finalized a regulation for drinking water on aircraft (USEPA, 2009a).

### The U.S. Public Health Standards

The "common cup" regulatory framework was soon found to be deficient, as the "common cup" regulation could only protect public health if the water placed in the cup was safe. The task of developing these standards fell to the USPHS, which at that time was an agency within the U.S. Treasury Department. On Oct. 14, 1914, the Secretary of the Treasury promulgated Standards for Purity of Drinking Water Supplied to the Public by Common Carriers in Interstate Commerce, the first national drinking water standards (AWWA, 1990). These standards, known as the "Treasury Standards," were limited to the bacteriological quality of the water.

Even though the Treasury Standards were legally binding on interstate carriers, many state and local governments adopted these standards as guidelines for their water systems. States used these standards to develop their own regulations and provided regulatory oversight for systems in their states. These standards were the start of federal, state, and local cooperation in protecting drinking water quality at the community level that continues to this day.

The Treasury Standards were revised in 1925 by the USPHS to strengthen the bacteriological quality requirements and to add basic physical and chemical standards (USPHS, 1925). These standards were revised again in 1942, 1946, and 1962 (USPHS, 1943, 1946, 1962). The 1962 standards were the most comprehensive, covering 28 constituents, and were used by all 50 states either as standards or guidelines. However, depending on the state regulations, these standards were not legally enforceable for many systems and were only legally binding for those systems that supplied water to the interstate carriers.

## *EVOLUTION OF THE SDWA*

### Setting the Stage for the SDWA

Public concern and media attention about the presence of contaminants in the environment continued to grow in the late 1960s and early 1970s. The modern environmental movement began at this time, and the public concern and media attention translated to pressure on the federal government to act. From a federal perspective, the government wanted to keep up to date with the newest scientific developments in drinking water research and incorporate the latest results into the USPHS standards.

In 1969, the USPHS Bureau of Water Hygiene started the Community Water System Survey (CWSS) in an effort to revisit the 1962 standards and conducted a review of water systems to determine how many met these standards. The USPHS surveyed approximately 1000 public water systems (PWSs) that, at the time, served approximately 12 percent of the population. Released in 1970, the survey results showed that 41 percent of the systems did not meet the 1962 guidelines (USPHS, 1970). Many systems were deficient in one or more

components of the multibarrier approach (source water protection, filtration, disinfection, and protecting the integrity of the distribution system).

Soon thereafter, drinking water researchers in both the United States and Europe were conducting their own surveys that began to raise public awareness. Analytical methods that allowed for better separation and quantification of organic chemicals had improved. A 1972 study of the Mississippi River, which supplies New Orleans, found 36 synthetic organic chemicals (SOCs) (USEPA, 1972). In addition, researchers in the United States and the Netherlands published their seminal work on disinfection by-products (DBPs) with the discovery of trihalomethanes (THMs) (Bellar et al., 1974; Rook, 1974).

Building on these scientific reports, several national media stories raised consumers' concern about drinking water safety and put pressure on Congress for legislative action. The initial congressional hearings on drinking water were held in 1971 and 1972. Like most major legislation, there was substantial debate on the best legislative approach, and more than one session of Congress was needed to pass the initial SDWA. After four years of work, Congress passed the first SDWA in November 1974, which was signed into law on Dec. 16, 1974 (PL 93-523).

## The First 1974 SDWA

The 1974 SDWA established a partnership between the states and the federal government for the implementation of the drinking water program that continues to the present. This legislation dramatically changed the federal-state regulatory relationship. Under the SDWA, USEPA conducts the necessary research and analyses and establishes National Primary Drinking Water Regulations (NPDWRs). NPDWRs are legally enforceable standards that apply to PWSs, which are defined by the SDWA as having at least 15 service connections or regularly serving 25 residents. It should be noted that systems with fewer than 15 service connections and private wells are not covered by the SDWA and the resultant NPDWRs. These regulations protect public health by limiting the levels of contaminants in drinking water using maximum contaminant levels (MCL) or treatment techniques (TT) if analytical techniques are not economically or technologically feasible for the specific contaminant.

If individual states or American Indian tribal nations pass their own regulations that are at least as stringent as the federal regulations and have programs and enforcement authorities to ensure that PWSs within the state are in compliance with the regulations, USEPA will delegate primacy to the state or tribe. Currently, 49 states and 1 tribe have primacy and oversee PWSs (with some federal assistance and oversight).

PWSs have the ultimate responsibility for compliance with these regulations, including specific requirements for monitoring and reporting. Failure to meet any of these requirements can result in enforcement actions and, in some cases, penalties. Before the 1974 SDWA was passed, national drinking water standards were not enforceable, except for the coliform standard for interstate carriers, i.e., trains, airplanes, buses, and ships.

Soon after passage of the 1974 SDWA, USEPA published the first two national drinking water regulations (Table 1-1): the National Interim Primary Drinking Water Regulations (NIPDWRs), using the USPHS standards as the starting point; and the Total Trihalomethanes (TTHM) Rule. These two rules increased the number of regulated contaminants to 23 (Fig. 1-1).

The TTHM Rule was the first national primary drinking water regulation for which USEPA prepared detailed assessments of toxicology and health risk, occurrence and exposure, analytical methods, treatment technologies, and economic impacts. Many of the policies and procedures used to develop the economic analyses, occurrence estimates, and technologies and costs for the TTHM Rule formed the foundation of the current regulatory development process.

**TABLE 1-1** National Primary Drinking Water Regulations

| Promulgation date | Regulation | Reference |
|---|---|---|
| Dec. 24, 1975 | National Interim Primary Drinking Water Regulations | FR* 40:248:59566 |
| Nov. 29, 1979 | Total Trihalomethanes | FR 44:231:68624 |
| April 2, 1986 | Fluoride | FR 51:63:11396 |
| July 8, 1987 | Phase I Volatile Organic Chemicals | FR 52:130:25690 |
| June 29, 1989 | Surface Water Treatment Rule | FR 54:124:27486 |
| June 29, 1989 | Total Coliform Rule | FR 54:124:27544 |
| Jan. 20, 1991 | Phase II Synthetic Organic Chemicals (SOCs) and Inorganic Chemicals (IOCs) | FR 56:20:3526 |
| June 7, 1991 | Lead and Copper Rule | FR 56:110:26460 |
| July 17, 1992 | Phase V SOCs and IOCs | FR 57:138:31776 |
| Dec. 16, 1998 | Stage 1 Disinfection By-Products Rule | FR 63:241:69389 |
| Dec. 16, 1998 | Interim Enhanced Surface Water Treatment Rule | FR 63:241:69477 |
| Dec. 7, 2000 | Radionuclides | FR 65:236:76707 |
| Jan. 22, 2001 | Arsenic | FR 66:14:6975 |
| June 8, 2001 | Filter Backwash Recycling Rule | FR 66:111:31085 |
| Jan. 14, 2002 | Long Term 1 Enhanced Surface Water Treatment Rule | FR 67:91:1844 |
| Jan. 4, 2006 | Stage 2 Disinfection By-Products Rule | FR 71:2:387 |
| Jan. 5, 2006 | Long Term 2 Enhanced Surface Water Treatment Rule | FR 71:3:653 |
| Nov. 8, 2006 | Ground Water Rule | FR 71:216:65573 |

*FR – *Federal Register*

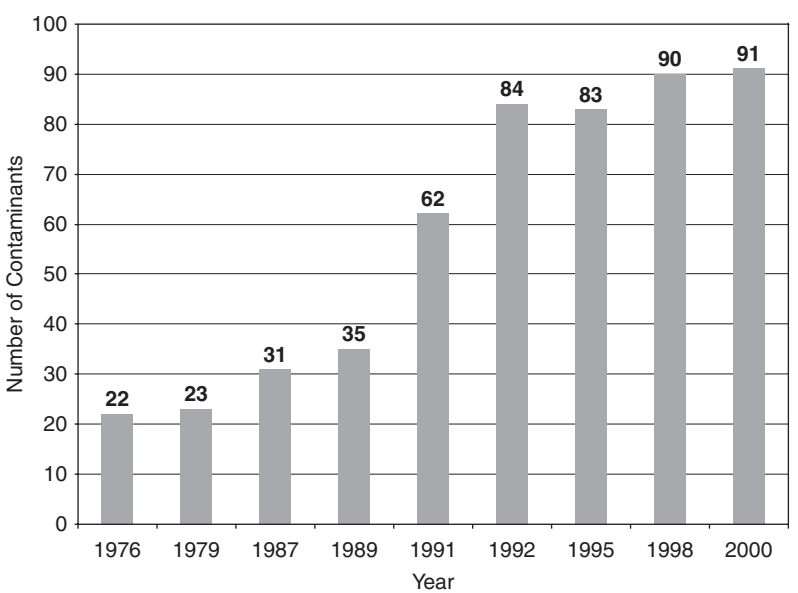



**FIGURE 1-1** Number of regulated contaminants from 1976 through 2000. (*Source: www.epa.gov/safewater/contaminants/pdfs/contam_timeline.pdf.*)

However, these analyses require a significant amount of data, and many complex technical and policy issues must be debated and resolved in order to complete these analyses. To effectively utilize taxpayer dollars and adhere to the SDWA goals, USEPA should target its drinking water research and regulatory development efforts on the contaminants that present the greatest health risk. Consequently, in 1983, USEPA, in collaboration with the Awwa Research Foundation (AwwaRF, now known as the Water Research Foundation), conducted a series of workshops with a variety of national drinking water experts to discuss the following questions (AwwaRF, 1983):

- What are the most important contaminants to regulate?
- Are there robust and reliable analytical methods for analyzing these contaminants?
- What are the health effects of these contaminants and what is the exposure?
- What treatment technologies work for these contaminants and what do these technologies cost?
- How would water utilities monitor and report compliance to the states?

Answering these questions with limited data for a large number of potential contaminants is not easy (these questions are still relevant today for drinking water risk management and regulatory development). After these workshops, USEPA continued to collect data on health effects, analytical methods, occurrence, and treatment technologies but did not issue any new national drinking water regulations until 1986.

## The 1986 SDWA Amendments

Frustrated by USEPA's lack of regulatory progress (progress being defined as an increasing number of regulations), Congress amended the SDWA in 1986 (PL 99-339). The amendments placed USEPA on a "regulatory treadmill" with requirements to regulate a specific list of 83 contaminants in the first five years and then 25 new contaminants every three years thereafter. On the basis of these statutory requirements, the number of regulated contaminants would have exceeded 250 in 2007.

USEPA increased its regulatory development process in the late 1980s and early 1990s. Seven new NPDWRs were promulgated between 1986 and 1992 (see Table 1-1). These regulations increased the number of regulated contaminants to 84 (see Fig. 1-1). The number of regulated contaminants increased sharply in 1991 and 1992, and the financial burden for utilities to monitor these contaminants also increased substantially.

Despite its best efforts, USEPA was unable to meet multiple regulatory deadlines and was sued by the Bull Run Coalition (Bull Run Coalition v. Reilly, 1993). USEPA negotiated new regulatory deadlines, then missed those new deadlines, and had to renegotiate again. This process frustrated everyone involved in the regulatory development process, including:

- Water utilities, because they never knew when new regulations were coming out and did not know how to plan for capital investments for treatment improvements that would last 50 to 100 years
- USEPA, because it was continually being sued
- Congress, because statutory deadlines were continually being missed

Throughout the early 1990s, pressure increased to amend the SDWA and allow USEPA to jump off the regulatory treadmill and more appropriately focus its limited resources. Congress began holding hearings and debating potential SDWA amendments in the

103rd Congress in 1993 and 1994 and ultimately passed the 1996 SDWA Amendments (PL 104-208) in the 104th Congress.

### The 1996 SDWA Amendments

The 1996 SDWA Amendments can be divided into the following areas:

- A new standard-setting process with specific statutory language on how to select contaminants for potential regulation and then how to set the regulation.
- Priority regulations with specific deadlines for contaminants such as arsenic, sulfate, and radon and the Microbial/Disinfection By-Product (M/DBP) cluster.
- New state programs for source water assessments, capacity development, operator certification, and a drinking water state revolving loan fund.
- New public information programs, such as the Consumer Confidence Report (CCR) for utilities, and revision of the Public Notification Regulation (PNR) by USEPA.

USEPA promulgated nine new or revised NPDWRs between 1998 and 2006 (see Table 1-1). These regulations increased the number of regulated contaminants to 91 (see Fig. 1-1). The nine NPDWRs promulgated by USEPA since the 1996 SDWA Amendments are primarily new or expanded treatment technique requirements. Therefore, although the number of contaminants with MCLs has not increased significantly, the complexity of the treatment techniques, i.e., the more complex turbidity requirements in the Interim and Long Term 1 Enhanced Surface Water Treatment Rules, and more advanced compliance treatment technologies, i.e., ion exchange for arsenic removal, have significantly increased costs for many PWSs.

### The Bioterrorism Act of 2002

Prior to September 11, 2001, water security had not been a significant problem for water utilities and there were no legislative or regulatory requirements. After 9/11, Congress reacted to address security concerns for critical infrastructure (CI), with the water sector (both drinking water and wastewater) being one of the CI sectors. To address water security concerns, the SDWA was amended through the Public Health Security and Prevention Preparedness Act of 2002 (the Bioterrorism Act, PL 107-188). The legislation required water utilities serving more than 10,000 people to meet five new statutory requirements: (1) conduct a vulnerability assessment (VA); (2) submit the VA to USEPA (USEPA had statutory requirements to develop policies and procedures for protection of the VAs that were submitted); (3) certify to USEPA that the VA was properly conducted and met the requirements of the Bioterrorism Act; (4) conduct or revise the utility emergency response plan (ERP) based on the knowledge derived from the VA; and (5) certify to USEPA that the new or revised ERP has been completed.

Although not part of the SDWA, the Homeland Security Act (PL 107-296) was also passed in 2002 and created the Department of Homeland Security (DHS) by merging parts of 22 different federal agencies into one. DHS has the overall responsibility for homeland security, and USEPA has been designated as the lead agency for the water sector. DHS created an overall risk management framework for critical infrastructure through the National Infrastructure Protection Plan (NIPP) (DHS, 2006). Under the NIPP framework, the water sector developed its own Water Sector-Specific Plan (SSP). The Water SSP, along with the other SSPs, was released by DHS in 2007 (DHS, 2007). See other publications for more detail on water security issues (States, 2010; Roberson and Morley, 2006; Mays, 2004).

## THE RISK MANAGEMENT AND STANDARD-SETTING PROCESSES

The 1996 SDWA Amendments established a scientific, risk-based approach to targeting, assessing, and managing health risks from contaminants in PWSs. This approach targets research, assessment, and regulatory activities on the contaminants that have the greatest likelihood of presenting health risks from drinking water. The amendments also recognized that over time, better information becomes available and requires USEPA to regularly reassess and reprioritize its risk management efforts.

The mechanisms required by the SDWA for USEPA to gather and assess data to prioritize contaminants for risk management actions include: (1) the Contaminant Candidate List (CCL), (2) the Unregulated Contaminant Monitoring Rules (UCMRs), (3) regulatory determinations, and (4) the review of NPDWRs (six-year review). The risk management actions that SDWA authorizes include: (1) NPDWRs, (2) National Secondary Drinking Water Regulations, and (3) Health Advisories and Other Actions.

This section discusses each of these targeting and risk management processes. Figure 1-2 provides an overview of how these different processes fit together in the development of regulations.

### Contaminant Candidate List

The Contaminant Candidate List (CCL) is developed by USEPA as a listing of priority contaminants for regulatory decision making and information collection. The SDWA requires that every five years, USEPA publish a list of unregulated contaminants that are known or anticipated to occur in PWSs and that may require regulation. In developing a CCL, USEPA must consider the contaminants identified in section 101(14) of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA, or Superfund) and substances registered as pesticides under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). USEPA must also consult with the scientific community and request and consider public comment on a draft list.

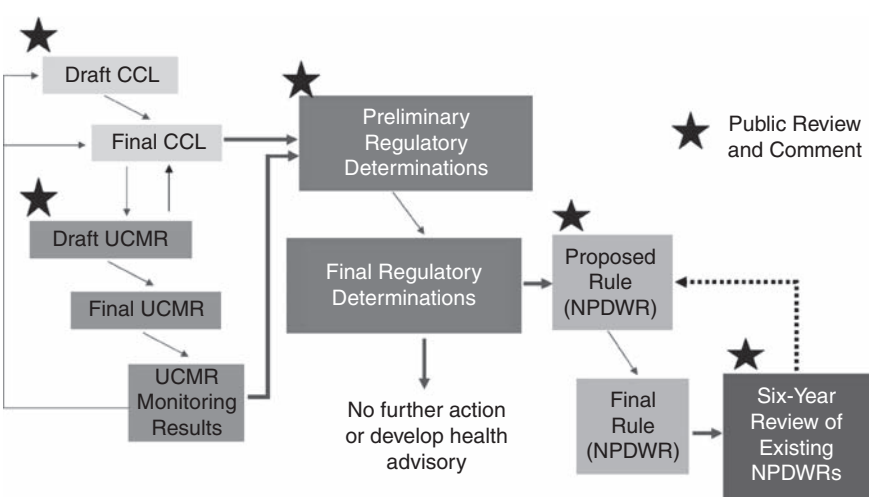



**FIGURE 1-2** Overview of SDWA regulatory processes.

USEPA published the first CCL (CCL1) in 1998 (USEPA, 1998a). CCL1 contained 50 chemicals and 10 microbial contaminants. USEPA consulted with the scientific community to develop a process to identify CCL1 contaminants. The process used a combination of expert judgment for microbial contaminants and screening and evaluation criteria to identify chemical contaminants.

In response to comments that a more comprehensive and reproducible approach was needed for selecting contaminants for future CCLs, USEPA sought advice from the National Academies of Science–National Research Council (NRC). The NRC recommended that USEPA continue to use expert judgment and public involvement to identify future contaminants for the CCLs (NRC, 2001a). The NRC also recommended that USEPA first screen a broad universe of contaminants of potential concern to identify a preliminary CCL (PCCL) based on available health risk data and likelihood of occurrence in drinking water. Then USEPA would assess the PCCL contaminant data in a more detailed manner, using classification tools and expert judgment to evaluate the likelihood that specific contaminants could occur in drinking water at levels and at frequencies that pose a public health risk.

To ensure broad stakeholder input, USEPA also consulted with the National Drinking Water Advisory Council (NDWAC) on its implementation of the NRC-recommended CCL process. The NDWAC endorsed the NRC recommendations, which it described as a three-step process, as depicted in Fig. 1-3 (NDWAC, 2004). The NDWAC provided specific recommendations for implementing each step. Because of differences in the information available for microbes and chemicals, the NDWAC recommended these contaminants be evaluated in parallel procedures. The NDWAC also recommended that USEPA move forward using a step-wise adaptive management approach to build upon advances in technology and the experience it has gained in developing previous CCLs.

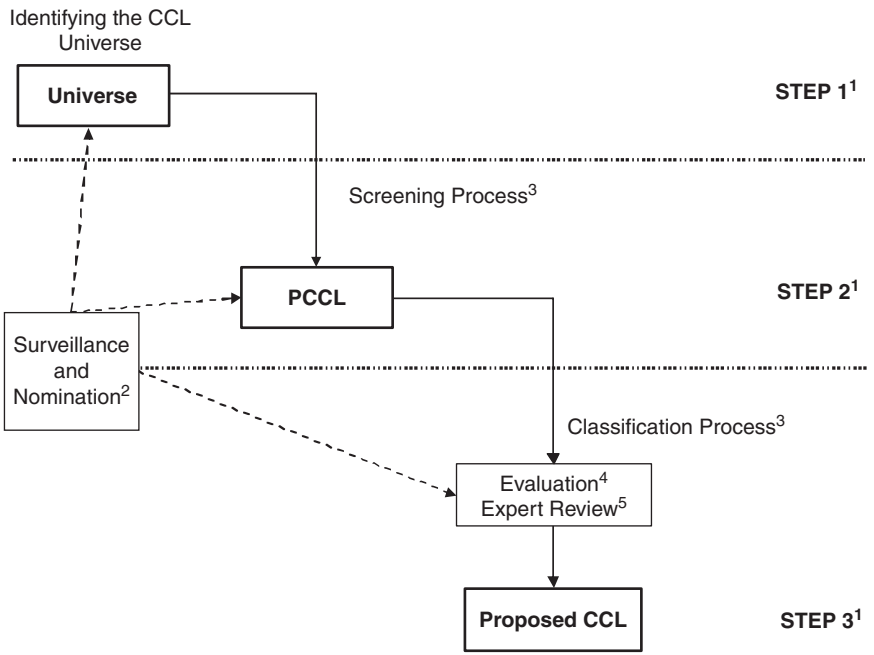
USEPA did not implement the NRC and NDWAC recommendations for the second CCL (CCL2) published in 2005 because the recommended processes would not have been completed in time (USEPA, 2005a). However, the agency described the improved process it would implement for future CCLs. CCL2 consisted of the 51 (42 chemical and 9 microbial) contaminants for which USEPA had not yet made regulatory determinations.

USEPA published the draft of the third CCL (CCL3) for public comment in February 2008 (USEPA, 2008a). This draft included 104 contaminants—93 chemicals and 11 microbiological contaminants. The draft CCL3 was developed using the NRC/NDWAC-recommended process to evaluate approximately 7500 chemical and microbial contaminants. USEPA also considered the contaminant nominations and information received from the public in preparing the draft CCL3. The final CCL3 was published in October 2009 and included 116 contaminants (104 chemicals and 12 microbiological contaminants), as listed in Table 1-2 (USEPA, 2009b).

Research plays a significant role in filling the data gaps identified in the CCL process. The final CCL3 contained a table on regulatory determination data/information needs for each contaminant, broken down into health effects, occurrence, and need for analytical methods (USEPA, 2009b). This table shows the depth and breadth of the potential research agenda for USEPA's drinking water program, as there are numerous data/information needs for the CCL3 contaminants.

## Regulatory Determinations

A regulatory determination is a decision made by USEPA on whether to initiate a national primary drinking water rulemaking for a contaminant. The SDWA requires that every five years USEPA make regulatory determinations for at least five contaminants on the CCL. Section 1412(b)(1) of the SDWA specifies three criteria that must be met for USEPA to make a determination to develop a national regulation for a contaminant: "(1) the contaminant may




Notes:

1. Steps are sequential, as are components of each step, with the exception of surveillance and nomination. This generalized process is applicable to both chemical and microbial contaminants, though the specific execution of particular steps may differ in practice.

2. Surveillance and nomination provide an alternative pathway for entry into the CCL process for new and emerging agents, in particular. Most agents would be nominated to the CCL Universe. Depending on the timing of the nomination and the information available, a contaminant could move onto the PCCL or CCL, if justified.

3. Expert judgment, possibly including external expert consultation, will be important throughout the process, but particularly at key points, such as reviewing the screening criteria and process from the Universe to the PCCL; assessing the training data set and classification algorithm performance during development of the PCCL to CCL classification step.

4. After implementing the classification process, the prioritized list of contaminants would be evaluated by experts, including a review of the quality of information.

5. The CCL classification process and draft CCL list would undergo a critical Expert Review by us EPA and by outside experts before the CCL is proposed.

**FIGURE 1-3** Overview of CCL process recommended by NDWAC Work Group and incorporated by USEPA into CCL3. (*Source: National Drinking Water Advisory Council, 2004; www.epa.gov/safewater/ndwac/pdfs/report_ccl_ndwac_07-06-04.pdf.*)

have an adverse effect on the health of persons; (2) the contaminant is known to occur or there is a substantial likelihood the contaminant will occur in public water systems with a frequency and at levels of public health concern; and (3) in the sole judgment of the Administrator, regulation of the contaminant presents a meaningful opportunity for health risk reductions for persons served by public water systems."

**TABLE 1-2** Third Contaminant Candidate List

**Microbial Contaminants (12)**

Adenovirus
Caliciviruses
*Campylobacter jejuni*
Enterovirus
*Escherchia coli* (O157)
*Helicobacter pylori*
Hepatitis A virus
*Legionella pneumophila*
*Mycobacterium avium*
*Naegleria fowleri*
*Salmonella enterica*
*Shigella sonnei*

**Chemical Contaminants (104)**

| *Common name—registry name* | CASRN* |
|---|---|
| alpha-Hexachlorocyclohexane | 319-84-6 |
| 1,1,1,2-Tetrachloroethane | 630-20-6 |
| 1,1-Dichloroethane | 75-34-3 |
| 1,2,3-Trichloropropane | 96-18-4 |
| 1,3-Butadiene | 106-99-0 |
| 1,3-Dinitrobenzene | 99-65-0 |
| 1,4-Dioxane | 123-91-1 |
| 17alpha-estradiol | 57-91-0 |
| 1-Butanol | 71-36-3 |
| 2-Methoxyethanol | 109-86-4 |
| 2-Propen-1-ol | 107-18-6 |
| 3-Hydroxycarbofuran | 16655-82-6 |
| 4,4'-Methylenedianiline | 101-77-9 |
| Acephate | 30560-19-1 |
| Acetaldehyde | 75-07-0 |
| Acetamide | 60-35-0 |
| Acetochlor | 34256-82-1 |
| Acetochlor ethanesulfonic acid (ESA) | 187022-11-3 |
| Acetochlor oxanilic acid (OA) | 184992-44-4 |
| Acrolein | 107-02-8 |
| Alachlor ethanesulfonic acid (ESA) | 142363-53-9 |
| Alachlor oxanilic acid (OA) | 171262-17-2 |
| Aniline | 62-53-3 |
| Bensulfide | 741-58-2 |
| Benzyl chloride | 100-44-7 |
| Butylated hydroxyanisole | 25013-16-5 |
| Captan | 133-06-2 |
| Chloromethane (Methyl chloride) | 74-87-2 |
| Clethodim | 110429-62-4 |
| Cobalt | 7440-48-4 |
| Cumene hydroperoxide | 80-15-9 |
| Cyanotoxins (3) | |
| Dicrotophos | 141-66-2 |
| Dimethipin | 55290-64-7 |
| Dimethoate | 60-51-5 |
| Disulfoton | 298-04-4 |

(*Continued*)

**TABLE 1-2** Third Contaminant Candidate List (*Continued*)

| | |
|---|---|
| Diuron | 330-54-1 |
| Equilenin | 517-09-9 |
| Equilin | 474-86-2 |
| Erythromycin | 114-07-8 |
| Estradiol (17-beta estradiol) | 50-28-2 |
| Estriol | 50-27-1 |
| Estrone | 53-16-7 |
| Ethinyl Estradiol (17-alpha ethynyl estradiol) | 57-63-6 |
| Ethoprop | 13194-48-4 |
| Ethylene glycol | 107-21-1 |
| Ethylene oxide | 75-21-8 |
| Ethylene thiourea | 96-45-7 |
| Fenamiphos | 22224-92-6 |
| Formaldehyde | 50-00-0 |
| Germanium | 7440-56-4 |
| HCFC-22 | 75-45-6 |
| Hexane | 110-54-3 |
| Hydrazine | 302-01-2 |
| Mestranol | 72-33-3 |
| Methamidophos | 10265-92-6 |
| Methanol | 67-56-1 |
| Methyl bromide (Bromomethane) | 74-83-9 |
| Methyl-*tert*-butyl-ether (MTBE) | 1634-04-4 |
| Metolachlor | 51218-45-2 |
| Metolachlor ethanesulfonic acid (ESA) | 171118-09-5 |
| Metolachlor oxanilic acid (OA) | 152019-73-3 |
| Molinate | 2212-67-1 |
| Molybdenum | 7439-98-7 |
| Nitrobenzene | 98-95-3 |
| Nitroglycerin | 55-63-0 |
| N-methyl-2-pyrrolidone | 872-50-4 |
| N-nitrosodiethylamine (NDEA) | 55-18-5 |
| N-nitrosodimethylamine (NDMA) | 62-75-9 |
| N-nitroso-di-n-propylamine (NDPA) | 621-64-7 |
| N-nitrosodiphenylamine | 86-30-6 |
| N-nitrosopyrrolidine (NPYR) | 930-55-2 |
| Norethindrone (19-Norethisterone) | 68-22-4 |
| *n*-Propylbenzene | 103-65-1 |
| *o*-Toluidine | 95-53-4 |
| Oxirane, methyl- | 75-56-9 |
| Oxydemeton-methyl | 301-12-2 |
| Oxyfluorfen | 42874-03-3 |
| Perchlorate | 14797-73-0 |
| Perfluorooctane sulfonic acid (PFOS) | 1763-23-1 |
| Perfluorooactanoic acid (PFOA) | 335-67-1 |
| Premethrin | 52645-53-1 |
| Profenofos | 41198-08-7 |
| Quinoline | 91-22-5 |
| RDX (Hexahydro-1,3,5-trinitro-1,3,5-triazine) | 121-82-4 |
| *sec*-Butylbenzene | 135-98-8 |
| Strontium | 7440-24-6 |

(*Continued*)

**TABLE 1-2** Third Contaminant Candidate List (*Continued*)

| | |
|---|---|
| Tebuconazole | 107534-96-3 |
| Tebufenozide | 112410-23-8 |
| Tellurium | 13494-80-9 |
| Terbufos | 13071-79-9 |
| Terbufos sulfone | 56070-16-7 |
| Thiodicarb | 59669-26-0 |
| Thiophanate-methyl | 23564-05-8 |
| Toluene diisocyanate | 26741-62-5 |
| Tribufos | 78-48-8 |
| Triethylamine | 121-44-8 |
| Triphenyltin hydroxide (TPTH) | 76-87-9 |
| Urethane | 51-79-6 |
| Vanadium | 7440-62-2 |
| Vinclozolin | 50471-44-8 |
| Ziram | 137-30-4 |

*Chemical Abstracts Service Registry Number

USEPA developed a comprehensive approach for evaluating these criteria with significant input from the NRC (NRC, 1999a, 1999b) and the NDWAC (USEPA, 2003a). To evaluate the first criterion, USEPA evaluates best available, peer-reviewed assessments[2] to characterize the health effects that may result from consuming the contaminant in drinking water (USEPA, 2008b). From this information, USEPA estimates a health reference level (HRL) that takes into account the potential for other routes of exposure (e.g., food). To evaluate the second criterion, USEPA analyzes data from nationally representative occurrence studies[3] and compares these data to the HRL to determine the frequency at which PWSs exceed this level of concern. To evaluate the third statutory criterion, USEPA evaluates the potential health risks in the populations above the health reference level. USEPA also evaluates the nondrinking water route of exposure to determine if removing the contaminant from drinking water will significantly reduce the population's exposure to the contaminant.

USEPA has made regulatory determinations for 20 contaminants, 9 from CCL1 and 11 from CCL2, as listed in Table 1-3 (USEPA, 2000, 2008b). For all of these contaminants, USEPA has made a determination not to regulate them because they did not occur frequently in PWSs at levels of health concern and/or there was not a meaningful opportunity for health risk reduction through a national primary drinking water rule.

USEPA requested comment on a preliminary regulatory determination to not regulate perchlorate in October 2008 (USEPA, 2008c). In August 2009, USEPA published a supplemental request for comments on alternative analysis of the perchlorate regulatory determination (USEPA, 2009c). In this notice, USEPA presented a broader range of alternatives for interpreting the available data on: (1) the level of concern, (2) the frequency of occurrence of perchlorate in drinking water, and (3) the opportunity for health-risk reduction through a national perchlorate standard.

[2]USEPA has relied upon peer-reviewed risk assessments from the agency's Integrated Risk Information System (IRIS) or the pesticide reregistration eligibility decisions (RED), as well as from the National Academy of Sciences (NAS) or the Agency for Toxic Substances and Disease Registry (ATSDR).

[3]USEPA has relied on data from the Unregulated Contaminant Monitoring (UCM) Program, the National Inorganic and Radionuclide Survey (NIRS), and the first Unregulated Contaminant Monitoring Rule (UCMR1) in making its regulatory decisions for CCL1 and CCL2 contaminants.

**TABLE 1-3** Contaminants Not Regulated by First and Second Regulatory Determinations

| First regulatory determinations (9) | Second regulatory determinations (11) |
|---|---|
| Managanese | Boron |
| Sodium | Dachtal mono-acid degradate |
| Sulfate | Dachtal di-acid degradate |
| Aldrin | 1,1-dichloro-2,2-bis(p-chlorophenyl)ethylene |
| Dieldrin | 1,3-dichloropropene |
| Metribuzin | 2,4-dinitrotoluene |
| Hexachlorobutadiene | 2,6-dinitrotoluene |
| Napthalene | *s*-ethyl dipropulthiocarbamate |
| *Acanthamoeba* | Fonofos |
| | Terbacil |
| | 1,1,2,2-tetrachloroethane |

## Unregulated Contaminant Monitoring Regulations

Unregulated contaminant monitoring regulations (UCMRs) require the collection of drinking water contaminant occurrence data that can be used by USEPA to identify contaminants for the CCL, to support regulatory determinations, and to develop national primary drinking water regulations. The 1986 SDWA Amendments provided authority for USEPA to gather information on unregulated contaminants. USEPA included unregulated contaminant monitoring (UCM) requirements in the Phase I and Phase II regulations. The UCM monitoring continued until the 1996 SDWA Amendments required substantial revisions to the program. Under the 1996 SDWA Amendments, USEPA is required to: (1) publish a list of not more than 30 unregulated contaminants every five years, i.e., the UCMR; (2) identify a representative sample of PWSs serving 10,000 or fewer people to monitor, with USEPA paying the cost of analyzing samples from those systems; (3) place the monitoring data in the National Contaminant Occurrence Database; and (4) notify consumers that the monitoring results are available.

USEPA selects contaminants for the UCMR by evaluating contaminants that have been targeted through prioritization processes (i.e., the CCL). The agency identifies additional contaminants through an evaluation of current research on occurrence and health-effects risk factors. USEPA does not list contaminants that do not have an analytical reference standard or contaminants whose analytical methods are not ready for widespread use under UCMR.

The first UCMR (UCMR1), which was promulgated in 1999 (USEPA, 1999a), listed 12 contaminants for assessment monitoring (List 1) at all large water systems (serving more than 10,000 people) and a representative sample of 800 small water systems (serving fewer than 10,000 people). UCMR1 also listed 14 contaminants for screening monitoring (List 2) at 300 randomly selected large and small water systems. Surface water systems were required to collect four quarterly samples, and groundwater systems were required to collect two semiannual samples. Monitoring data for UCMR1 were reported to USEPA from 2001 to 2005 and are available on the Internet at www.epa.gov/safewater/ucmr/data.html#2.

USEPA promulgated the second UCMR (UCMR2) in 2007 (USEPA, 2007a). The UCMR2 lists 10 contaminants for assessment monitoring (List 1) at all large systems and

at 800 selected small systems. UCMR2 also requires screening monitoring (List 2) for 15 contaminants from all very large systems (serving more than 100,000 people) and from 600 selected medium and small systems. Monitoring for the UCMR2 is to be performed during a 12-month period from January 2008 to December 2010.

## National Primary Drinking Water Regulations

National Primary Drinking Water Regulations (NPDWRs), which are legally enforceable standards that apply to PWSs, protect public health by limiting the levels of contaminants in drinking water. NPDWRs take the form of MCLs or TTs. An MCL is the maximum permissible level of a contaminant in water that is delivered to any user of a PWS. A treatment technique is an enforceable procedure or level of technological performance that PWSs must follow to ensure control of a contaminant. Examples of TT rules are the Surface Water Treatment Rule (disinfection and filtration for inactivation/removal of target pathogens) and the Lead and Copper Rule (optimized corrosion control). More details on the individual rules are found in the next section.

To propose a new or revised NPDWR, the 1996 SDWA Amendments require USEPA to undertake a number of steps, including:

- Establish a maximum contaminant level goal (MCLG). The MCLG is the maximum level of a contaminant in drinking water at which no known or anticipated adverse effect on the health of persons would occur, allowing for an adequate margin of safety. MCLGs are nonenforceable public health goals.
- Set the MCL as close as feasible to the MCLG. The feasible level is the level that may be achieved with the use of the best available technology, TTs, and other means that USEPA finds (after examination for efficiency under field conditions and not solely under laboratory conditions) are available, taking cost into consideration. When there is no reliable method that is economically and technically feasible to measure a contaminant, USEPA establishes a TT for control of that contaminant.
- Prepare a health-risk reduction cost analysis (HRRCA) that includes estimates of the quantifiable and nonquantifiable costs and benefits of the regulatory alternatives, including the feasible level that is closest to the MCLG.
- Determine if the costs justify the benefits at the feasible level. If not, USEPA may set the MCL at a level that maximizes health risk reduction benefits at a cost that is justified by the benefits.
- List the technologies that achieve compliance with the MCL or TT. USEPA can update the list at any time after promulgating a standard to list new or innovative technologies that achieve compliance with a standard.
- Identify affordable small-system compliance technologies. If none are available, USEPA must identify small-system variance technologies that remove the contaminant to the maximum extent affordable and are protective of public health.

The SDWA specifies that USEPA use the "the best available, peer-reviewed science" in the decision-making processes (i.e., CCL, regulatory determinations, and developing NPDWRs). The SDWA also specifies that USEPA must propose a NPDWR within 24 months of making a determination to regulate a contaminant and promulgate a final regulation within 18 months of proposal. At the Administrator's discretion and public notification, USEPA can extend this deadline for the final rule by up to nine months.

Although USEPA has not yet made a determination to regulate a CCL contaminant because none of the CCL contaminants have met the three SDWA criteria previously discussed, the agency has implemented the standard-setting processes required by the 1996 SDWA Amendments in developing the priority regulations (e.g., Arsenic, Radionuclides, The Microbial and Disinfection By-Products Rules).

## National Primary Drinking Water Regulation Review

The National Primary Drinking Water Regulation Review, or six-year review, is an evaluation by USEPA of the available information on health effects, analytical methods, treatment technologies, and any other factors for existing NPDWRs to determine if revisions are appropriate. The SDWA requires that USEPA review and revise as appropriate each NPDWR every six years. The SDWA also requires that each revision shall maintain or provide for greater protection of public health.

USEPA has developed a protocol based upon input from the NDWAC to systematically evaluate NPDWRs to determine if a revision presents a meaningful opportunity to improve the level of public health protection or to achieve cost savings while maintaining or improving the level of health protection, as shown in Fig. 1-4 (USEPA, 2003b). In carrying out the six-year review, USEPA compiles the available, peer-reviewed information on health effects, analytical feasibility, and treatment for regulated contaminants to determine if the data indicate a need to reevaluate a contaminant's NPDWR. If no new data are available, USEPA assumes the existing NPDWRS remain appropriate. However, if new data are available, USEPA determines whether changes in the NPDWR for that contaminant are warranted.

For example, if the current MCL for a contaminant was set at the level of analytical feasibility and a new or improved analytical method is now available for a contaminant, USEPA then determines if the lower analytical quantitation level is feasible. USEPA also determines if there is a meaningful opportunity to improve public health by changing the standard. For example, based on contaminant occurrence data collected from states, USEPA will estimate the population served by systems where the concentration of the contaminant exceeds the potentially lower new standard.

USEPA completed the first six-year review in 2003 (USEPA, 2003c); the agency reviewed NPDWRs for 69 contaminants and concluded that it was appropriate to revise one NPDWR, the Total Coliform Rule (TCR) at that time. The TCR revisions are discussed later in this chapter.

## National Secondary Drinking Water Regulations

National Secondary Drinking Water Regulations, referred to as secondary maximum contaminant levels (SMCLs), are nonenforceable guidelines for contaminants that may cause cosmetic effects in consumers (e.g., skin discoloration) or aesthetic effects in drinking water (e.g., taste, odor, or color) (USEPA, 1992). PWSs are not required to comply with SMCLs unless their states have chosen to adopt them as an enforceable standard. The SDWA defines an SMCL as a regulation that USEPA determines is "requisite to protect the public welfare." USEPA has established SMCLs for 15 contaminants, as shown in Table 1-4 (USEPA, 1979, 1986, 1991).

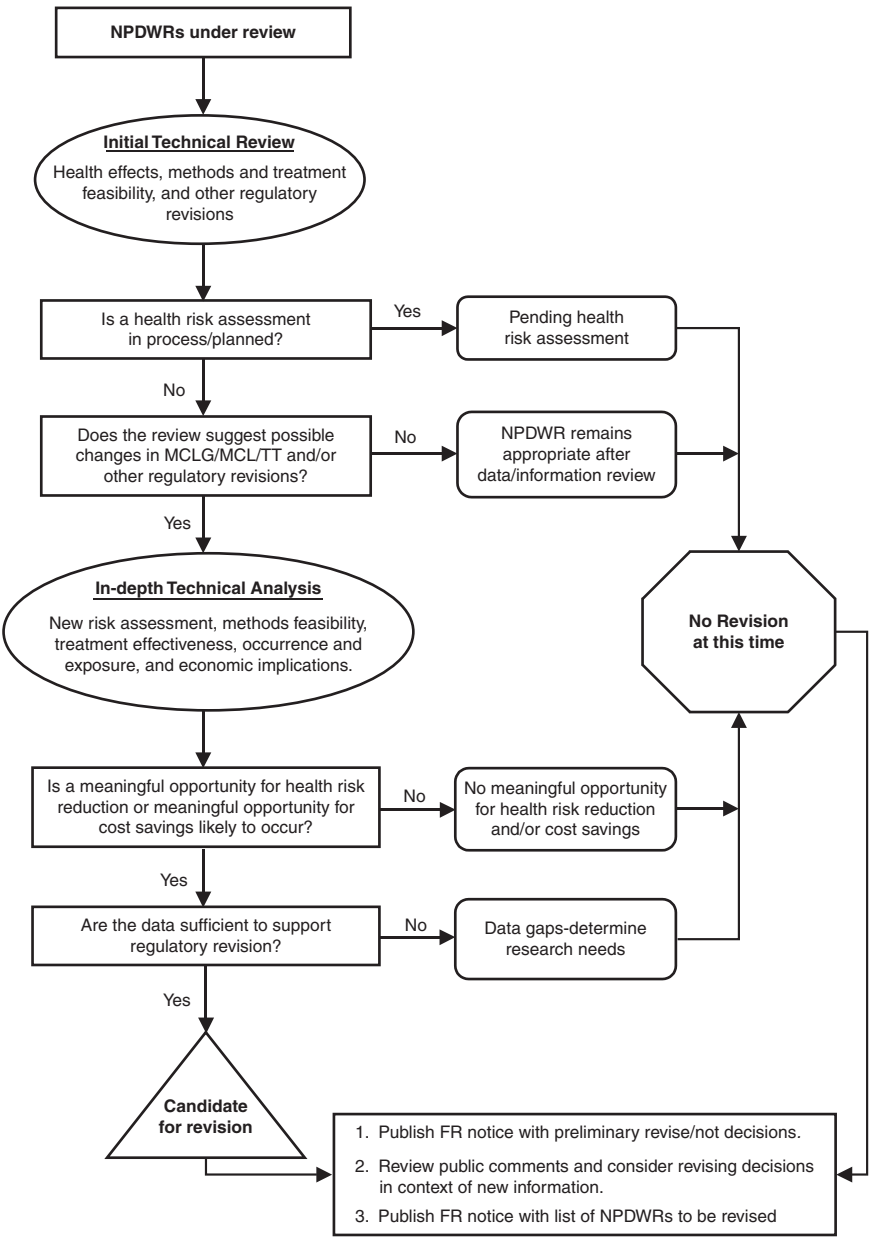



**FIGURE 1-4** Overview of the six-year review protocol and making the revise/not revise decision. (*Source: EPA Protocol for the Review of Existing National Primary Drinking Water Regulations, EPA-815-R-03-002, 2003; www.epa.gov/safewater/standard/review/pdfs/support_6yr_protocal_final.pdf.*)

**TABLE 1-4** National Secondary Drinking Water Standards

| Contaminant | Effect(s) | SMCL, mg/L |
|---|---|---|
| Aluminum | Colored water | 0.05–0.2 |
| Chloride | Salty taste | 250 |
| Color | Visible tint | 15 color units |
| Copper | Metallic taste; blue-green stain | 1.0 |
| Corrosivity | Metallic taste; corrosion; fixture staining | Noncorrosive |
| Fluoride | Tooth discoloration | 2 |
| Foaming agents | Frothy, cloudy; bitter taste; odor | 0.5 |
| Iron | Rusty color; sediment; metallic taste; reddish or orange staining | 0.3 |
| Manganese | Black to brown color; black staining; bittermetallic taste | 0.05 |
| Odor | "Rotten egg," musty, or chemical smell | 3 TON |
| pH | Low pH: bitter metallic taste, corrsosion high pH: slippery feel, soda taste, deposits | 6.5–8.5 |
| Silver | Skin discoloration; greying of the white part of the eye | 0.10 |
| Sulfate | Salty taste | 250 |
| Total dissolved solids (TDS) | Hardness; deposits; colored water; staining; salty taste | 500 |
| Zinc | Metallic taste | 5 |

***Source:*** Letterman, 1999

## Health Advisories and Other Actions

Health advisories are documents prepared by USEPA that provide information on contaminants that can cause human health effects and are known or anticipated to occur in drinking water. Health advisories provide nonenforceable guidance values (HA values) based on noncancer health effects for different durations of exposure (e.g., 1-day, 10-day, and lifetime). Health advisories also provide technical guidance on health effects, analytical methodologies, and treatment technologies associated with drinking water contaminants. These advisories were first developed in 1987 before USEPA had established many of the NPDWRs in effect today. USEPA has issued health advisories in association with its regulatory determinations, and has recently issued or revised health advisories for more than 170 contaminants (USEPA, 2006a).

In addition to health advisories, USEPA takes other actions to address concerns associated with drinking water contaminants. These actions include issuing drinking water advisories (DWAs), which are similar to a health advisories in that they provide a nonenforceable guidance value. However, the DWA value is based on aesthetic values (taste, odor, and color). USEPA has published DWAs for sulfate, methyl-*tert*-butyl-ether (MTBE), and sodium (USEPA, 2006a).

## CURRENT DRINKING WATER REGULATIONS

### Individual Rules

USEPA finalized 18 NPDWRs between 1975 and 2006 (see Table 1-1). Typically, minor technical corrections are needed after final rule promulgation, and a separate *Federal Register* notice is issued for these corrections. The number of regulated contaminants has varied from 90 to 91 since the 1996 SDWA Amendments (see Fig. 1-1). The secondary standards are listed in Table 1-4, and the MCLGs and MCLs for the primary drinking water standards are listed in Table 1-5.

The 1996 SDWA Amendments mandated specific deadlines for a handful of regulations that were known as the "priority" regulations. These regulations address the following:

- *Disinfectants and disinfection by-products*. This set of regulations was to be finalized in accordance with the regulatory schedule listed in the 1994 proposed Information Collection Rule (ICR). The Stage 1 Disinfection By-Product Rule (DBPR) and Interim Enhanced Surface Water Treatment Rule (IESWTR) were promulgated in 1998, the Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR) was promulgated in 2002, and the Stage 2 DBPR and Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) were promulgated in 2006.
- *Arsenic*. The arsenic regulation was to be proposed by Jan. 1, 2000, and finalized by Jan. 1, 2001. The arsenic regulation was promulgated in 2001.
- *Sulfate*. Regulatory determination was to be made for sulfate by August 2001 as part of the first regulatory determinations. USEPA made a final determination not to regulate sulfate in July 2003 (USEPA, 2003a).
- *Filter backwash*. A regulation to address filter backwash was to be finalized by August 2000. This rule was promulgated in 2001.
- *Radon*. The radon regulation was to be proposed by August 1999 and finalized by August 2000. USEPA proposed a radon in drinking water rule in November 1999 but has not promulgated a final rule (USEPA, 1999b).
- *Groundwater*. A rule to address potential groundwater contamination was to be finalized sometime between August 1999 and publication of the final Stage 2 DBPR. The Ground Water Rule (GWR) was promulgated in 2006.

USEPA has also promulgated other national drinking water regulations that are not NPDWRs. Many of these regulations mandate specific monitoring, such as the ICR, and the first and second Unregulated Contaminant Monitoring Rule (UCMR1 and UCMR2). This category of regulations also includes the Consumer Confidence Report (CCR), a report on water quality that must be sent annually to customers. The CCR is an important part of the improved public education component of the 1996 SDWA Amendments. Table 1-6 lists other significant national drinking water regulations.

As previously discussed, USEPA has taken other regulatory actions, such as CCLs and regulatory determinations, that are not regulations in the sense that compliance by PWSs is not required. However, these actions form the foundation of the regulatory development process by identifying contaminants that may require regulation.

For most regulations, USEPA develops a variety of publications in order to provide compliance assistance for water utilities and state agencies. These publications typically include fact sheets on the regulations and a variety of guidance manuals that provide detailed information on technical issues that cannot be found in USEPA's regulatory language and preamble. It should be noted that these guidance manuals are suggestions and

**TABLE 1-5** National Primary Drinking Water Standards

| Contaminant | MCLG, mg/L | MCL, mg/L | Potential health effects | Sources of drinking water contamination |
|---|---|---|---|---|
| **Fluoride Rule** | | | | |
| Fluoride | 4.0 | 4.0 | Skeletal and dental fluorosis | Natural deposits; fertilizer, aluminum industries; drinking water additive |
| **Phase I Volatile Organics** | | | | |
| Benzene | zero | 0.005 | Cancer | Some foods; gas, drugs, pesticide, paint, plastic industries |
| Carbon tetrachloride | zero | 0.005 | Cancer | Solvents and their degradation products |
| *p*-Dichlorobenzene | 0.075 | 0.075 | Cancer | Room and water deodorants and mothballs |
| 1,2-Dichloroethane | zero | 0.005 | Cancer | Leaded gas, fumigants, paints |
| 1,1-Dichloro-ethylene | 0.007 | 0.007 | Cancer, liver, kidney effects | Plastics, dyes, perfumes, paints |
| Trichloro-ethylene | zero | 0.005 | Cancer | Textiles, adhesives, metal degreasers |
| 1,1,1-Tri-chloroethane | 0.2 | 0.2 | Liver, nervous system effects | Adhesives, aerosols, textiles, paints, inks, metal degreasers |
| Vinyl chloride | zero | 0.002 | Cancer | May leach from PVC pipe; formed by solvent breakdown |
| **Surface Water Treatment Rule and Total Coliform Rule** | | | | |
| *Giardia lamblia* | zero | TT | Gastroenteric disease | Human and animal fecal wastes |
| *Legionella* | zero | TT | Legionnaire's disease | Natural waters; can grow in water heating systems |
| Heterotrophic plate count | N/A | TT | Indicates water quality, effectiveness of treatment | |
| Total coliform | zero | < 5%+ | Indicates gastroenteric pathogens | Human and animal fecal wastes |
| Turbidity | N/A | TT | Interferes with disinfection | Soil runoff |
| Viruses | zero | TT | Gastroenteric disease | Human and animal fecal wastes |
| **Phase II Rule Inorganics** | | | | |
| Asbestos (>10 μm) | 7 MFL | 7 MFL | Cancer | Natural deposits; asbestos cement in water systems |
| Barium | 2 | 2 | Circulatory system effects | Natural deposits; pigments, epoxy sealants, spent coal |
| Cadmium | 0.005 | 0.005 | Kidney effects | Galvanized pipe corrosion; natural deposits; batteries, paints |
| Chromium 0.1 (total) | 0.1 | 0.1 | Liver, kidney, circulatory disorders | Natural deposits; mining, electroplating, pigments |
| Mercury (inorganic) | 0.002 | 0.002 | Kidney, nervous system disorders | Crop runoff; natural deposits; batteries, electrical switches |
| Nitrate | 10 | 10 | Methemoglobulinemia | Animal waste, fertilizer, natural deposits, septic tanks, sewage |

| | | | | |
|---|---|---|---|---|
| Nitrite | 1 | 1 | Methemoglobulinemia | Same as nitrate; rapidly converted to nitrate |
| Nitrate + nitrite | 10 | 10 | | |
| Selenium | 0.05 | 0.05 | Liver damage | Natural deposits; mining, smelting, coal/oil combustion |
| **Phase II Rule Organics** | | | | |
| Acrylamide | zero | TT | Cancer, nervous system effects | Polymers used in sewage/waste-water treatment |
| Alachlor | zero | 0.002 | Cancer | Runoff from herbicide on corn, soybeans, other crops |
| Aldicarb | delayed | delayed | Nervous system effects | Insecticide on cotton, potatoes, other crops; widely restricted |
| Aldicarb sulfone | delayed | delayed | Nervous system effects | Biodegradation of aldicarb |
| Aldicarb sulfoxide | delayed | delayed | Nervous system effects | Biodegradation of aldicarb |
| Atrazine | 0.003 | 0.003 | Mammary gland tumors | Runoff from use as herbicide on corn and noncropland |
| Carbofuran | 0.04 | 0.04 | Nervous, reproductive system effects | Soil fumigant on corn and cotton; restricted in some areas |
| Chlordane | zero | 0.002 | Cancer | Leaching from soil treatment for termites |
| Chlorobenzene | 0.1 | 0.1 | Nervous system, liver effects | Waste solvent from metal degreasing processes |
| 2,4-D | 0.07 | 0.07 | Liver and kidney damage | Runoff from herbicide on wheat, corn, rangelands, lawns |
| *o*-Dichloroethylene | 0.1 | 0.1 | Liver, kidney, blood cell damage | Paints, engine cleaning compounds, dyes, chemical |
| *cis*-1,2-Dichloroethylene | 0.07 | 0.07 | Liver, kidney, nervous, circulatory system effects | Waste industrial extraction solvents |
| *trans*-1,2-Dichloroethylene | 0.1 | 0.1 | Liver, kidney, nervous, circulatory system effects | Waste industrial extraction solvents |
| 1,2-Dibromo-3-chloropropane | zero | 0.0002 | Cancer | Soil fumigant on soybeans, cotton, pineapple, orchards |
| 1,2-Dichloropropane | zero | 0.005 | Liver, kidney effects; cancer | Soil fumigant; waste industrial solvents |
| Epichlorohydrin | zero | TT | Cancer | Water treatment chemicals; waste epoxy resins, coatings |
| Ethylbenzene | 0.7 | 0.7 | Liver, kidney, nervous system effects | Gasoline; insecticides; chemical manufacturing wastes |
| Ethylene dibromide | zero | 0.00005 | Cancer | Leaded gas additives; leaching of soil fumigant |
| Heptachlor | zero | 0.0004 | Cancer | Leaching of insecticide for termites, very few crops |
| Heptachlor epoxide | zero | 0.0002 | Cancer | Biodegradation of heptachlor |
| Lindane | 0.0002 | 0.0002 | Liver, kidney, nervous system, immune system, circulatory system effects | Insecticide on cattle, lumber, gardens; restricted in 1983 |
| Methoxychlor | 0.04 | 0.04 | Growth; liver, kidney, nervous, system effects | Insecticide for fruits, vegetables, alfalfa, livestock, pets |

(*Continued*)

**TABLE 1-5** National Primary Drinking Water Standards (*Continued*)

| Contaminant | MCLG, mg/L | MCL, mg/L | Potential health effects | Sources of drinking water contamination |
|---|---|---|---|---|
| Pentachlorophenol | zero | 0.001 | Cancer; liver, kidney effects | Wood preservatives, herbicide, cooling tower wastes |
| PCBs | zero | 0.0005 | Cancer | Coolant oils from electrical transformers; plasticizers |
| Styrene | 1 | 1 | Liver, nervous system effects | Plastics, rubber, resin, drug damage industries; leachate from city landfills |
| Tetrachloroethylene | zero | 0.005 | Cancer | Improper disposal of dry cleaning and other solvents |
| Toluene | 1 | 1 | Liver, kidney, nervous system, circulatory system effects | Gasoline additive; manufacturing and solvent operations |
| Toxaphene | zero | 0.003 | Cancer | Insecticide on cattle, cotton, soybeans; cancelled in 1982 |
| 2,4,5-TP (Silvex) | 0.05 | 0.05 | Liver, kidney damage | Herbicide on crops, rights-of-way, golf courses; cancelled in 1983 |
| Xylenes (total) | 10 | 10 | Liver, kidney, nervous system effects | By-product of gasoline refining; paints, inks, detergents |
| **Lead and Copper Rule** | | | | |
| Lead | zero | TT[#] | Kidney, nervous system effects | Natural/industrial deposits; plumbing solder, brass alloy faucets |
| Copper | 1.3 | TT[##] | Gastrointestinal irritation | Natural/industrial deposits; wood preservatives, plumbing |
| **Phase V Inorganics** | | | | |
| Antimony | 0.006 | 0.006 | Cancer | Fire retardents, ceramics, electronics, fireworks |
| Beryllium | 0.004 | 0.004 | Bone, lung damage | Electrical, aerospace, defense industries |
| Cyanide | 0.2 | 0.2 | Thyroid, nervous system damage | Electroplating, steel, plastics, mining, fertilizer |
| Nickel | 0.1 | 0.1 | Heart, liver damage | Metal alloys, electroplating, batteries, chemical production |
| Thallium | 0.0005 | 0.002 | Kidney, liver, brain, intestinal effects | Electronics, drugs, alloys, glass |
| **Phase V Organics** | | | | |
| Adipate, (di(2-ethylhexyl)) | 0.4 | 0.4 | Decreased body weight | Synthetic rubber, food packaging, cosmetics |
| Benzo(a)pyrene (PAHs) | zero | 0.0002 | Cancer | Coal tar coatings; burning organic matter; volcanoes, fossil fuels |
| Dalapon | 0.2 | 0.2 | Liver, kidney effects | Herbicide on orchards, beans, coffee, lawns, roads, railways |
| Di(2-ethylhexyl) phathalate | zero | 0.006 | Cancer | PVC and other plastics |
| Dichloromethane | zero | 0.005 | Cancer | Paint stripper, metal degreaser, propellant, extractant |

| | | | | |
|---|---|---|---|---|
| Di(2-ethylhexyl) phathalate | zero | 0.006 | Cancer | PVC and other plastics |
| Dinoseb | 0.007 | 0.007 | Thyroid, reproductive organ damage | Runoff of herbicide from crop and noncrop applications |
| Diquat | 0.02 | 0.02 | Liver, kidney, eye effects | Runoff of herbicide on land and aquatic weeds |
| Dioxin | zero | $3 \times 10^{-8}$ | Cancer | Chemical production by-product; impurity in herbicides |
| Endothall | 0.1 | 0.1 | Liver, kidney, gastrointestinal effects | Herbicide on crops, land/aquatic weeds; rapidly degraded |
| Glyphosate | 0.7 | 0.7 | Liver, kidney damage | Herbicide on grasses, weeds, brush |
| Hexachlorobenzene | zero | 0.001 | Cancer | Pesticide production waste by-product |
| Hexachlorocyclopentadiene | 0.05 | 0.05 | Kidney, stomach damage | Pesticide production intermediate |
| Oxamyl (Vydate) | 0.2 | 0.2 | Kidney damage | Insecticide on apples, potatoes, tomatoes |
| Picloram | 0.5 | 0.5 | Kidney, liver damage | Herbicide on broadleaf and woody plants |
| Simazine | 0.004 | 0.004 | Cancer | Herbicide on grass sod, some crops, aquatic algae |
| 1,2,4-Trichlorobenzene | 0.07 | 0.07 | Kidney, liver damage | Herbicide production; dye carrier |
| 1,1,2-Trichloroethane | 0.003 | 0.003 | Kidney, liver, nervous system damage | Solvent in rubber, other organic products; chemical production wastes |
| **Disinfectants and Disinfection By-Products** | | | | |
| Bromate | zero | 0.010 | Cancer | Ozonation by-product |
| Bromodichloromethane | zero | see TTHMs | Cancer, kidney, liver, reproductive effects | Chlorination by-product |
| Bromoform | zero | see TTHMs | Cancer, kidney, liver, nervous system effects | Chlorination by-product |
| Chlorine | 4 (as $Cl_2$) (MRDLG) | 4.0 (as $Cl_2$) (MRDL) | | |
| Chloramies | 4 (as $Cl_2$) (MRDLG) | 4.0 (as $Cl_2$) (MRDL) | | |
| Chlorine dioxide | 0.8 (as $ClO_2$) (MRDLG) | 0.8 (as $ClO_2$) (MRDL) | | |
| Chloral hydrate | 0.04 | TT | Liver effects | Chlorination by-product |
| Chlorite | 0.08 | 1.0 | Developmental neurotoxicity | Chlorine dioxide by-product |
| Chloroform | zero | see TTHMs | Cancer, kidney, liver reproductive effects | Chlorination by-product |
| Dibromochloromethane | 0.06 | see TTHMs | Nervous system, kidney, liver, reproductive effects | Chlorination by-product |
| Dichloroacetic acid | zero | see HAA5 | Cancer, reproductive, developmental effects | Chlorination by-product |

(*Continued*)

**TABLE 1-5** National Primary Drinking Water Standards (*Continued*)

| Contaminant | MCLG, mg/L | MCL, mg/L | Potential health effects | Sources of drinking water contamination |
|---|---|---|---|---|
| **Disinfectants and Disinfection By-Products** | | | | |
| Haloacetic acids (HAA5)** | zero | 0.060 | Cancer and other effects | Chlorination by-product |
| Trichloroacetic acid | 0.3 | see HAA5 | Liver, kidney, spleen, mental effects | Chlorination by-product |
| Total trihalomethanes (TTHMs) | zero | 0.010 | Cancer and other effects | Chlorination by-product |
| **Radionuclides** | | | | |
| Beta/photon emitters | zero | 4 mrem/yr | Cancer | Natural and man-made deposits |
| Alpha particles | zero | 15 pCi/L | Cancer | Natural deposits |
| Radium 226 and 228 | zero | 5 pCi/L | Bone cancer | Natural deposits |
| Uranium | zero | 0.03 | Cancer | Natural deposits |
| **Arsenic** | | | | |
| Arsenic | zero | 0.010 | Skin, nervous system toxicity; cancer | Natural deposits; smelters, glass, electronics wastes; orchards |

Notes:
# Action level = 0.015 mg/L
## Action level = 1.3 mg/L
TT = treatment technique requirement
MFL = million fibers per liter
*For water systems analyzing at least 40 samples per month, no more than 5.0 percent of the monthly samples may be positive for total coliforms. For systems analyzing fewer than 40 samples per month, no more than one sample per month may be positive for total coliforms.
**Sum of the concentrations of mono-, di-, and trichloroacetic acids and mono- and dibromoacetic acids.
Alternatives allowing public water systems the flexibility to select compliance options appropriate to protect the population served were proposed.

**TABLE 1-6** Other Significant National Drinking Water Regulations

| Promulgation date | Regulation | Reference |
|---|---|---|
| July 19, 1979 | Secondary Standards | FR* 44:140:42195 |
| May 14, 1996 | Information Collection Rule | FR 61:94:24354 |
| Aug. 14, 1998 | Variance and Exemption Rule | FR 63:157:43833 |
| Aug. 16, 1998 | Consumer Confidence Report Rule | FR 63:160:44511 |
| Sept. 17, 1999 | First Unregulated Contaminant Monitoring Rule | FR 64:180:50555 |
| May 4, 2000 | Public Notification Rule | FR 65:87:25891 |
| Jan. 4, 2007 | Second Unregulated Contaminant Monitoring Rule | FR 72:2:367 |
| Oct. 10, 2007 | Short-Term Revisions to the Lead and Copper Rule | FR 72:195:57781 |

*FR – *Federal Register*

guidance and do not have the same enforcement implications as the regulatory language. More information on USEPA guidance manuals can be found on the USEPA Web site listed in the section "The Internet as a Resource."

### The Traditional and Negotiated Rulemaking Processes

In the traditional rulemaking process, USEPA publishes the proposed regulation in the *Federal Register* and accepts comments from the public on various aspects of the regulation. Then, USEPA evaluates the comments, develops a comment response document, and finalizes the regulation. The 1996 SDWA Amendments allow PWSs three years after the regulation has been finalized for compliance, and the compliance deadline can be extended, in conjunction with the state primacy agency, by an additional two years if additional time is needed for capital improvements.

For some of its more recent and more complex rulemakings, USEPA has used a negotiated rulemaking process to develop the substance of the regulation. In the late 1980s and early 1990s, USEPA considered revising the 1979 TTHM Rule but realized the enormous regulatory challenge in simultaneously balancing the risks from DBPs against the microbial risks. This risk–risk balancing did not lend itself to the traditional rulemaking process in which the national standard is set at the appropriate risk level.

From 1992 to 1993, USEPA used a negotiated rulemaking process to develop the proposed ICR, the proposed Stage 1 DBPR, and the proposed IESWTR. Later, for more regulatory negotiations, a Federal Advisory Committee was formed under the auspices of the Federal Advisory Committee Act (FACA) to provide regulatory recommendations through additional Agreement in Principles (AIPs) to USEPA. The members of these committees represented a broad range of stakeholders in the drinking water community including utilities, USEPA, state regulators, tribes, local government, public health authorities, consumer advocates, and environmental advocates. To marshal the widely divergent views, a facilitator was hired by USEPA to run the face-to-face meetings.

For the Microbial/Disinfection By-Product (M/DBP) cluster of regulations, USEPA used negotiated rulemaking/FACA processes in:

- 1992 to 1993 for the proposed ICR, the proposed Stage 1 DBPR, and the IESWTR
- 1997 for finalizing the Stage 1 DBPR and the IESWTR because the ICR was not completed in time for those regulations as originally anticipated in 1992 to 1993
- 1999 to 2000 for the proposed Stage 2 DBPR and the LT2ESWTR

As previously discussed, USEPA decided in 2003 to revise the TCR in its first six-year review of existing drinking water regulations. Due to the inherent complexities with the

myriad of distribution systems, USEPA, in 2007, elected to form the Total Coliform Rule Distribution System Advisory Committee (TCRDSAC). The TCRDSAC met from July 2007 to September 2008 to develop proposed revisions to the TCR and to develop recommendations for distribution system research. In September 2008, the members of the TCRDSAC signed the AIP that will be used as the foundation for proposed TCR revisions (TCRDSAC AIP, 2008).

These Federal Advisory Committees are both time and resource intensive for all committee members. The face-to-face meetings typically take two days and are sometimes preceded by a Technical Work Group (TWG) meeting. The TWG typically provides substantial data analysis and technical support for the committee. For example, the TWG conducted many variations of analyses of the ICR data that were used to support the development of the Stage 2 DBPR and the LT2ESWTR. The output from some of these analyses was eventually compiled into an ICR data analysis book that was edited by three TWG members (McGuire et al., 2002). Even in cases where USEPA serves as a Federal Advisory Committee (FAC) and signs the AIP, USEPA still has the responsibility for developing the proposed preamble and regulatory language, conducting the analyses previously discussed, and considering public comments before issuing a final regulation.

### Going Beyond the Regulations

Systems sometimes develop their own water quality goals that are stricter than the regulations. These goals might be for particular contaminants that occur in their source water. One reason that systems adopt this approach is because they want to be leaders in the drinking water community and serve their customers the highest quality water possible. Another reason is that systems do not want to have any violations for any reason and want to have a considerable margin of safety relative to the standards.

Programs have been developed to assist utilities in going beyond the regulations to work toward optimizing treatment. The Partnership for Safe Water is a voluntary cooperative effort between USEPA, AWWA, and other drinking water organizations (AWWA, 2009). More than 200 surface water utilities serving more than 85 million people involved in the Partnership have improved the quality of their drinking water by optimizing system operations and improving filtration performance. Another similar collaborative program between USEPA and several state primacy agencies is the Area-Wide Optimization Program (AWOP) (Barr, 2007). AWOP started in 1989 and now operates in 21 states and focuses on treatment optimization.

## *ROLE OF STATE AGENCIES*

### State Agencies and USEPA as Co-regulators

USEPA and states are co-regulators under the SDWA. USEPA assesses contaminants and establishes NPDWRs. State agencies that obtain primacy ensure water systems comply with the drinking water standards. USEPA provides technical assistance and oversight to states in their efforts to ensure compliance with the regulations. States' experience in implementing NPDWRs provide a valuable perspective when developing new regulations. State agencies work closely with USEPA in a state-USEPA workgroup in the initial drafting of a proposed regulation, but USEPA is ultimately responsible for issuing both the proposed and final regulations.

## Primacy

If state and tribal regulations are passed that are at least as strict as the federal standards and oversight programs and enforcement mechanisms are in place, primacy for PWS supervision is retained by the state or tribe. Some state agencies further delegate these responsibilities to county or local health departments. All states except Wyoming have primacy. For each new regulation, states and tribes must submit a primacy package on those regulations to USEPA for review and approval.

State agency oversight of PWSs goes beyond simply ensuring compliance with the numerous standards. Sanitary surveys are a critical oversight activity that entails looking at all aspects of a utility's operations and management proactively in order to get ahead of any potential compliance problems. The identification and correction of significant deficiencies are now required under the IESWTR, LT1ESWTR, and GWR and provide a significant new tool for state regulators to use in bringing systems back into compliance.

Other state oversight activities include: (1) review and approval of construction plans and specifications, typically for treatment plants and larger transmission and distribution piping; (2) technical assistance, ranging from assisting with treatment evaluation and selection to assisting with evaluation of water rates to filling out the required paperwork and everything in between; and (3) sample collection and analysis (in some states). These activities help move the PWSs towards compliance.

The primacy agencies make the initial compliance determination. Systems may incur violations not only for MCLs and TTs but also for monitoring and reporting (M&R). The primacy agency works with systems to bring them back into compliance However, if the systems remain out of compliance, USEPA can step in to enforce the regulations.

The violations listed in the state-level data management system are transferred to the USEPA data system, or Safe Drinking Water Information System–Federal (SDWIS-FED). From 1997 to 2007, national compliance with the NPDWRs, based on population served, has increased slightly from 86.5 percent in 1997 to 91.5 percent in 2007 (USEPA, 2008d). The highest rate was in 2003 with 93.6 percent compliance. The national compliance rate is important to USEPA, because USEPA uses this metric to meet its obligations under the Government Performance and Results Act (GPRA) to measure how well they are performing. USEPA set an objective in its strategic plan that by 2008, 95 percent of the population served by community water systems would meet all applicable health-based standards.

USEPA's regional offices also play a role in the national drinking water program. USEPA divides the states and territories into 10 regions, as shown on Fig. 1-5. These regional offices assist state and tribal agencies that hold primacy with their regulatory oversight. In USEPA Region 3 (the District of Columbia) and USEPA Region 8 (Wyoming), the regional office directly implements the drinking water program.

USEPA provides funding to the primacy agencies for their drinking water programs through Public Water System Supervision (PWSS) grants. Since 2004, the total amount of PWSS grants has effectively been held constant (USEPA, 2008e), despite the increasing complexity of regulations such as the Filter Backwash Recycling Rule (FBRR), the IESWTR, and the LT1ESWTR. While some state agencies charge a fee for service to the utilities and/or their consultants for some of the previously mentioned activities, other states are prohibited from charging any fees. States agencies' resources continue to be challenged. In 2003, the Association of State Drinking Water Administrators (ASDWA) released a report on the funding gap for the states' drinking water programs (ASDWA, 2003). This report found a gap in 2002 of approximately $230 million between the funds expended at the state level for drinking water programs and the estimated $535 million needed. The funding shortfall was estimated to increase to approximately $369 million by 2006, and this shortfall will continue to grow as the number of regulations increases, the population increases, and water systems expand.

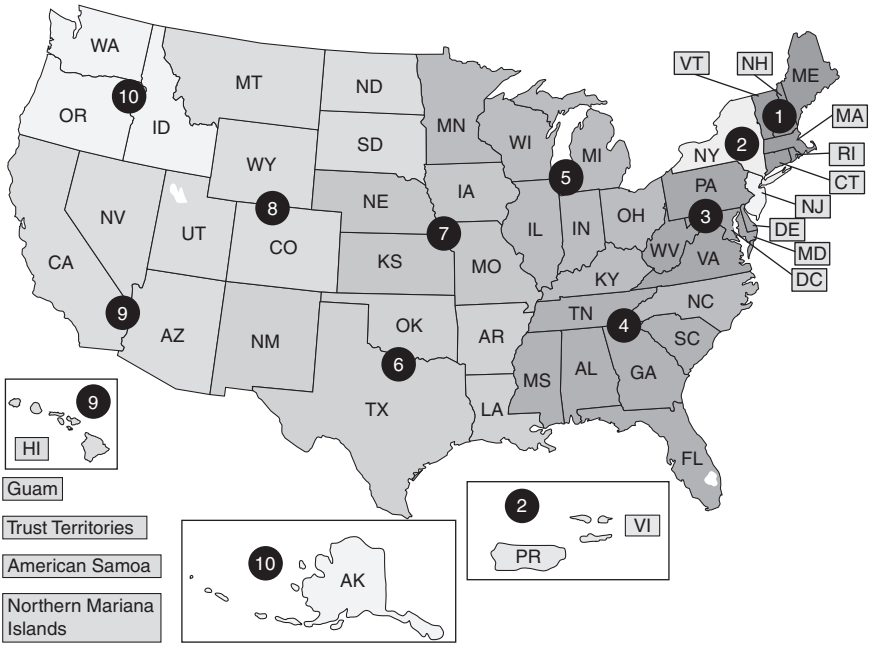



**FIGURE 1-5** Map of USEPA regions. (*Source: www.epa.gov/epafiles/samples/map.html#eparegions.*)

## New State Programs from the 1996 SDWA Amendments

State agencies' resources have been squeezed further by four new state programs that resulted from the 1996 SDWA Amendments: (1) source water assessments, (2) capacity development, (3) Drinking Water State Revolving Funds, and (4) operator certification.

As part of the 1996 SDWA Amendments, USEPA was required to develop source water protection guidance. Within 18 months of publication of this guidance, state agencies were required to develop source water assessment programs. The programs were to delineate the source water areas for PWSs, identify potential sources of contamination, and assess the susceptibility of the system to contamination. State agencies were required to complete all source water assessments by 1999. State agencies and utilities were further encouraged to develop voluntary source water protection programs.

USEPA was also required to review existing state assessment programs of the technical, financial, and managerial capacity of PWSs, and to publish guidance on how to strengthen these programs. State agencies must have the legal authority to require systems to demonstrate adequate capacity and a strategy to identify and assist systems that have capacity deficiencies. The objective of these capacity development programs is to ensure system viability for the long term.

The creation of the Drinking Water State Revolving Fund (DWSRF) provided a new funding mechanism for PWSs to construct necessary improvements. Most state agencies established drinking water state SRFs that are parallel to their existing Wastewater SRFs. Congress, which annually appropriates funding for the DWSRFs, started the fund with an appropriation of $1.2 billion. Between 1997 and 2007, the DWSRF provided $12.6 billion in funding for 5,555 projects; 39 percent of this funding has gone to systems serving fewer than 10,000 people (USEPA, 2007b). The American Recovery and Reinvestment Act

(ARRA) of 2009 provided additional funding of $2 billion for the DWSRF program on a one-time basis (USEPA, 2009d).

USEPA is required by the 1996 SDWA Amendments to conduct a national needs survey every four years that is used to establish the percent allocated to each state for its SRF. The 2007 Drinking Water Needs Survey identified a 20-year (2007–2026) capital investment need of $334.8 billion for PWSs eligible for SRF funding, noting that private systems and projects resulting from population and system growth are not eligible for SRF funding (USEPA, 2005b). The majority, approximately 60 percent ($200.8 billion), of the total national need is for transmission and distribution projects. Approximately $52 billion (16 percent) can be attributed to the NPDWRs. Each state agency develops its own process for identifying and prioritizing projects for potential SRF funding by developing a state-level intended use plan (IUP).

One notable feature of the drinking water SRF is the ability of state agencies to use a portion of their SRF funding for these new programs. State agencies can use up to 10 percent for source water protection, capacity development, and operator certification, as well as for the overall drinking water program. Up to another 15 percent can be used by systems for preparation of source water assessments, source water protection loans, capacity development, and wellhead protection. It should be noted that these "set-asides" take funding away from needed construction improvements. Between 1997 and 2007, state agencies "set aside" $1.4 billion from the DWSRF.

Most state agencies have had operator certification programs for many years, but these programs varied significantly from state to state. In 1999, USEPA developed guidelines for these programs, with eight elements that operator certification programs must contain. The objective was to not have any state agencies lower their standards for operator certification but rather to establish a national base level for these programs. These guidelines also mandated the development of programs for certifying distribution system operators, which was an expansion of traditional certification programs for treatment plant operators. The 1996 SDWA Amendments also provided for grants to state agencies to reimburse operators of systems serving fewer than 3300 people for training and certification costs.

The 1996 SDWA Amendments provided for some type of earmarked allocation to states for these programs. These allocations helped the states meet the requirements of these new programs. However, combined with the new regulations and their increasing complexity, state resources continue to be challenged.

## State Standards

States and tribes must pass their own regulations that are at least as strict as the federal standard in order to retain primacy, but some states pass stricter standards or develop their own standards that are not regulated by USEPA. California, New York, New Jersey, and Massachusetts are some of the states that have more or stricter standards than those of USEPA. Tracking the development of state standards across all states can be a substantial effort. ASDWA has links to each state's drinking water program on its Web site (see "The Internet as a Resource") (ASDWA, 2008). For information about a drinking water standard for a particular state or tribe, the appropriate state drinking water program agency should be contacted directly.

Even when the regulations adopted by primacy agencies are no more stringent than the federal regulations, differences in implementation at the state level can make them operationally different from the system's perspective. For example, under the TCR, the state of Ohio used to report missing repeat samples as an MCL violation as opposed to an M&R violation, which caused them to have a disproportionately high number of MCL violations. Other states have differing definitions of significant deficiencies under sanitary surveys previously

discussed; consequently, in many cases, even when the numerical standards are the same, variation in implementation can make regulations look different from state to state.

## PEER REVIEW, OUTSIDE CONSULTATION, AND PUBLIC INVOLVEMENT

USEPA regularly conducts peer review of its reports and assessments and also consults with outside parties to provide recommendations on specific technical and science policy issues to incorporate into its regulatory development process. The parties that USEPA uses for each consultation and the specific technical and science policy issues USEPA asks for input on are specific to each regulation. The intent of these outside consultations is to provide recommendations and advice to USEPA in meeting the SDWA requirement and to use the "…best available, peer-reviewed science…" in its regulations, as required by Section 1412(b)(3)(A) of the SDWA. USEPA also has to meet its own internal guidelines for peer review and information quality (USEPA, 2002, 2006b).

### The National Academy of Sciences

USEPA has repeatedly gone to the National Academy of Sciences (NAS) for advice and recommendations on scientific and technical issues to apply into its regulatory development process. Some NAS studies have been mandated by Congress, while others were solely at USEPA's request. As a result of the 1974 SDWA, the NRC of the NAS conducted a study to assess human exposure via drinking water and the toxicology of contaminants in drinking water. USEPA published the NAS study recommendations in 1977 and used this report as the basis for revising its drinking water regulations (USEPA, 1977).

More recently, the NRC provided recommendations to USEPA on the CCL and regulatory determination processes (NRC, 1999a, 1999b, 2001a). The NRC has also assessed the health effects of fluoride, radon, arsenic, and copper and reviewed and provided recommendations for USEPA's fluoride standards (NRC, 1993, 1999c, 1999d, 2000, 2001b, 2005, 2006).

### The Science Advisory Board

Congress established USEPA's Science Advisory Board (SAB) in 1978 to provide guidance regarding scientific and technical issues to support the agency throughout its regulatory development process. The SAB develops reports and advisories that review the approaches to regulatory science, reviews research programs, critiques analytical methods such as mathematical modeling, and provides other science policy and technical advice as necessary.

The USEPA Administrator appoints members of the SAB and nominations from the public are solicited for the SAB and the SAB standing committees. The SAB currently has six standing committees, including a Drinking Water Committee. Ad hoc committees and panels are formed as needed to address specific topics. Section 1412 of the SDWA mandates USEPA to consult with the scientific community, including the SAB, as part of its development of draft CCLs. USEPA regularly consults with the SAB Drinking Water Committee on a wide variety of drinking water regulatory issues.

### The National Drinking Water Advisory Council

Section 1446 of the SDWA mandates the formation of the NDWAC. This section also details representation of the general public, state and local agencies, and private groups for the 15 NDWAC members; the members' terms; and the rotation of the members' terms.

NDWAC members are appointed by the USEPA Administrator. The NDWAC provides policy guidance to USEPA on individual regulations and other regulatory issues.

The NDWAC typically sends letters to the USEPA Administrator after its review of a specific issue. The council often forms a working group to review more complex issues and make more detailed policy recommendations to USEPA. These working groups are usually comprised of two to four NDWAC members plus additional subject matter experts representing a broad range of stakeholders' perspectives. Past NDWAC working groups included Benefits, CCR, Drinking Water SRF, Health Care Providers, Occurrence and Contaminant Selection, Operator Certification, Right-to-Know, Small Systems, Small System Affordability, Source Water, Arsenic Cost, CCL and Six-Year Review, CCL Classification Process, Research, Water Security, and Public Education Requirements of the LCR.

### The Office of Management and Budget

Under Executive Order (EO) 12866, the Office of Information and Regulatory Affairs (OIRA) in the Office of Management and Budget (OMB) conducts a regulatory review of each proposed and final regulation by any federal agency, including USEPA. These reviews are typically conducted with a 90-day deadline, and completion of these reviews typically signifies that the proposed or final regulations will be published soon thereafter in the *Federal Register*. These reviews are conducted to ensure that the agencies are following other Executive Orders (EOs) that provide guidance on the use of benefit–cost analysis (BCA) in the regulatory development process.

### Public Involvement

The public plays an important role in the provision of safe drinking water. Because the public is the ultimate consumer of the treated drinking water, it has a vested interest in the USEPA regulatory development process, as well as state and USEPA oversight of the utilities. At the national level, the public can play a role and have some influence on Congress in future SDWA reauthorizations and other legislation that might impact drinking water quality. Members of Congress are always willing to listen to the public regarding issues (such as drinking water) that are important to their constituents that ultimately vote to elect or re-elect them to office. The public can play a role in USEPA's regulatory development process by participating in USEPA's stakeholder efforts as previously described. The public can also submit comments on USEPA's proposed regulatory actions; these comments are published in the *Federal Register* (see the stars in Fig. 1-2). The public can also play a role in the development of state-level drinking water regulations by providing input at public hearings and providing comments on the states' proposed regulations. At the local level, the public can attend board meetings of their local utility and provide input during any public comment period at rate hearings.

### The Consumer Confidence Report and the Public Notification Rule

Increased consumer education was one improvement that resulted from the 1996 SDWA Amendments. One important component of that increased consumer education was that USEPA must develop a new regulation that requires utilities to prepare annual water quality reports and for these reports to be delivered to their customers. These reports are known as Consumer Confidence Reports (CCRs), and the initial CCR regulation was based on a report from an NDWAC workgroup (USEPA, 1998b).

The CCR regulation requires utilities to develop a water quality report that includes the following:

- Identification of water source and treatment characterization
- Susceptibility of the source water to contamination based on the source water assessment and how to get a copy of the assessment
- Contaminants that are found in the water and their likely sources
- The levels of the contaminants, a comparison to the standard, and the health effects
- An educational statement for vulnerable populations about *Cryptosporidium* and additional information statements on nitrate, arsenic, and lead
- Sources of additional information, such as the utility's main phone number and USEPA's SDWA Hotline

The CCR regulation also requires utilities to send the CCR to customers annually, by July 1 of each year, and to provide methods to get the report in languages other than English if English is not the primary language for a significant portion of customers.

Revisions of the PNR provide another avenue for consumer education. Public notification has always been a part of the NPDWRs; however, over the years, this component has evolved with each new NPDWR. USEPA conducted a stakeholder effort from 1998 to 1999 to revise to the PNR and published the revised PNR in 2000 (USEPA, 2000). The objectives of the revised PNR are to provide faster notice in the event of an emergency, provide fewer notices overall in order to minimize confusion, and ensure that public notices are easy to understand by using clearer language and less scientific and technical jargon. USEPA and the stakeholders developed new guidance for the revised PNR that includes several templates that utilities can use for compliance.

## *OTHER COUNTRIES AND INTERNATIONAL STANDARDS*

### Canada

In Canada, drinking water guidelines are developed by Health Canada; if they choose to, the provinces and territories use these guidelines as a basis for developing enforceable standards. This regulatory approach is different from the U.S. regulatory approach in that the provinces and territories are not required to adopt the Health Canada guidelines. Health Canada's Water Quality and Health Bureau takes the lead by developing *Guidelines for Canadian Drinking Water Quality* through a collaborative effort with the provinces, territories, utilities, and the public. Development of the Guidelines generally parallels USEPA's regulatory development process, with the initial identification of substances that have been found in source waters and are known or suspected to be harmful. A maximum acceptable concentration (MAC), which is comparable to USEPA's MCL, is then established. More information on the Canadian guidelines can be found at the Web site listed in the section "The Internet as a Resource."

### Australia

Australia's regulatory approach warrants discussion because it is based on a preventive risk management approach for water supplies. This approach was jointly developed by the Cooperative Research Centres and the National Health and Medical Research Council

(NHMRC). The 2004 *Australian Drinking Water Guidelines* (ADWG) were developed by the NHMRC, in collaboration with the Natural Resource Management Ministerial Council (NRMMC). The guidelines incorporate a "Framework for the Management of Drinking Water Quality" and provide guidance on what constitutes safe drinking water. This risk-based approach takes a holistic view of the watershed and/or aquifer, treatment plant, and distribution system; analyzes for any potential weaknesses or vulnerabilities; and then develops a plan to address these potential weaknesses or vulnerabilities. This approach is comparable to the Hazard Analysis and Critical Control Point (HACCP) framework that is used in the United States for food production and supply. A report by the Awwa Research Foundation (now the Water Research Foundation) evaluated application of the HACCP framework for distribution system protection at two water utilities. However, this regulatory approach does not easily fit within the current SDWA framework of contaminant-by-contaminant regulation (AwwaRF, 2006). More information on the Australian guidelines can be found at their Web site (see "The Internet as a Resource").

### European Union

The European Union (EU) is a voluntary economic alliance consisting of several European countries. The Drinking Water Directives (DWDs) for drinking water quality developed by the EU must be adopted by the individual countries in order to remain an EU member state. Comparable to regulations established by USEPA, the enforceable drinking water standards developed by the EU member states must be at least as strict as the limits established in the DWD. The member states can regulate additional parameters beyond the parameters in the DWD, but cannot adopt stricter standards. The DWD, Council Directive 98/83/EC, addresses the quality of water intended for human consumption and lists 48 parameters that must be monitored and tested regularly. The European Commission started a review of Directive 98/83/EC in 2003 with a large public consultation. Member states report back to the European Commission every three years with their monitoring results. Generally, the WHO guidelines for drinking water are used as the basis for the DWD standards. More information the EU standards can be found at their Web site (see "The Internet as a Resource").

### World Health Organization

The World Health Organization (WHO) is a specialized agency within the United Nations with the primary responsibility of protecting international public health. The WHO produces international guidelines for drinking water quality that are used as the basis for regulation and standard setting by both developing and developed countries. Every country considers a broad range of environmental, social, cultural, and economic factors when determining which guidelines to adopt as their own standards. The 2004 *Guidelines for Drinking Water Quality* introduced the concept of Water Safety Plans, which shifts the regulatory focus from control of the drinking water at the end of the treatment plant or at the tap toward managing drinking water quality from the watershed, through the treatment plant, and through the distribution system. More information on the WHO guidelines can be found at their Web site (see "The Internet as a Resource").

## *OUTLOOK FOR THE FUTURE*

The SDWA is the starting point for U.S. drinking water regulations. With competing legislative priorities in Congress, it is not likely that the SDWA will be significantly amended anytime soon. The risk management and regulatory development process used by USEPA

will continue to evolve as more research is conducted and more contaminants are evaluated as potential candidates for regulation. As analytical methodologies continue to improve the ability to measure extremely low levels of contaminants, previously undetected contaminants will likely be found in some drinking water supplies. These emerging contaminants may generate public concern because of the uncertainty of their impact on public health at these low levels. Emerging contaminants such as endocrine disruptors, pharmaceuticals, and personal care products will need to be addressed through USEPA's regulatory development processes, using both the SDWA and other environmental statutes, such as the Clean Water Act (CWA) and Food Quality Protection Act (FQPA). States and PWSs will continue to be challenged by more regulations with more inherent complexities that will continue to stress limited resources. The public will continue to be interested in the safety of their drinking water, based on their own growing interest and the stories that will appear in the media.

The U.S. population will continue to grow. Currently, most population growth is projected to be in the southern half of the United States where water quantity and water quality problems will continue to increase. Utilities, regulators, and the public must remain vigilant in protecting existing source waters; finding new sources of water; and raising enough capital to build the appropriate transmission, treatment, and distribution facilities. The future will pose many challenges to keeping water safe and secure.

## THE INTERNET AS A RESOURCE

Since the mid-1990s, the Internet has become an increasingly valuable resource for information on drinking water regulations. But one must be careful, because as with many issues, information overload can occur. In 2008, more than 8 million hits resulted when "drinking water regulations" was searched on Google™.

Many government Web sites are now the most direct source for copies of *Federal Register* notices, guidance documents, background documentation, NDWAC reports, and other information. The starting point for any research on U.S. drinking water regulations is the USEPA's Office of Ground Water and Drinking Water Web site (water.epa.gov/drink/index.htm). This Web site is a virtual treasure trove of drinking water regulatory information and has links to electronic copies of *Federal Register* notices dating back to May 1996.

Copies of *Federal Register* notices can also be found on the Government Printing Office's Web site (www.gpoaccess.gov/fr/). Dating back to 2000, the table of contents can be searched, but he publication date of the specific *Federal Register* notice is needed in order to search the table of contents.

Background documentation, such as the economic analysis (EA) and the technology and cost (T&C) documents, can be found through a federal government clearinghouse Web site (www.regulations.gov). For example, searching by the docket number greatly simplifies the search for background documentation on a proposed drinking water regulation. Without the docket number, searching through this Web site can be challenging.

Other useful government Web sites include:

- Office of Management and Budget (OMB); www.whitehouse.gov/omb/inforeg_default
- U.S. Geological Survey (USGS); http://water.usgs.gov/
- U.S. Department of Health and Human Services, Centers for Disease Control and Prevention (CDC); www.cdc.gov/healthywater/drinking/index.html
- U.S. Department of Homeland Security (DHS), Office of Infrastructure Protection; www.dhs.gov/xabout/structure/gc_1185203138955.shtm

- U.S. Department of Agriculture (USDA) Rural Development Utilities Programs, Water and Environmental Programs; www.usda.gov/rus/water
- The following drinking water associations can also be a useful source of information:
  - American Water Works Association (AWWA); www.awwa.org
  - Association of State Drinking Water Administrators (ASDWA); www.asdwa.org. Web sites for state drinking water programs can generally be found by searching on the state name followed by "drinking water".
  - Association of Metropolitan Water Agencies (AWMA); www.amwa.net
  - National Rural Water Association (NRWA); www.nrwa.org
  - National Association of Water Companies (NAWC); www.nawc.com
  - Water Research Foundation; www.waterresearchfoundation.org

Government Web sites (outside of the United States) that are useful sources of information on international drinking water standards include:

- Health Canada; www.hc-sc.gc.ca/ewh-semt/water-eau/drink-potab/index-eng.php
- European Union; http://ec.europa.eu/environment/water/water-drink/index_en.html
- World Health Organization; www.who.int/water_sanitation_health/dwq/en
- Australia; www.nhmrc.gov.au/publications/synopses/eh19syn.htm

## DISCLAIMER

This chapter does not necessarily reflect the views and policies of USEPA nor does the mention trade names or products constitute endorsement or recommendation for their use.

## ABBREVIATIONS

| | |
|---|---|
| ADWG | Australian Drinking Water Guidelines |
| AIP | agreement in principle |
| AMWA | Association of Metropolitan Water Agencies |
| ARRA | American Recovery and Reinvestment Act |
| ASDWA | Association of State Drinking Water Administrators |
| ATSDR | Agency for Toxic Substances and Disease Registry |
| AWOP | area-wide optimization program |
| AWWA | American Water Works Association |
| AwwaRF | Awwa Research Foundation, now known as the Water Research Foundation |
| BCA | benefit–cost analysis |
| CCL | Contaminant Candidate List |
| CCR | Consumer Confidence Report |
| CDC | Centers for Disease Control and Prevention |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| CI | critical infrastructure |

| | |
|---|---|
| CWA | Clean Water Act |
| CWSS | Community Water System Survey |
| DBP | disinfection by-product |
| DBPR | Disinfection By-Product Rule |
| DHS | Department of Homeland Security |
| DWA | Drinking Water Advisory |
| DWD | Drinking Water Directive |
| DWSRF | Drinking Water State Revolving Fund |
| EA | economic analysis |
| EO | Executive Order |
| ERP | emergency response plan |
| EU | European Union |
| FACA | Federal Advisory Committee Act |
| FBRR | Filter Backwash Recycling Rule |
| FIFRA | Federal Insecticide, Fungicide, and Rodenticide Act |
| FQPA | Food Quality Protection Act |
| HA | Health Advisory |
| HACCP | Hazard Analysis and Critical Control Points |
| HRRCA | health risk reduction cost analysis |
| ICR | Information Collection Rule |
| IESWTR | Interim Enhanced Surface Water Treatment Rule |
| IOC | inorganic chemical |
| IRIS | Integrated Risk Information System |
| IUP | intended use plan |
| GPRA | Government Performance and Results Act |
| GWR | Ground Water Rule |
| LCR | Lead and Copper Rule |
| LT1ESWTR | Long Term 1 Enhanced Surface Water Treatment Rule |
| LT2ESWTR | Long Term 2 Enhanced Surface Water Treatment Rule |
| M&R | monitoring and report |
| MAC | maximum acceptable concentration |
| MCL | maximum contaminant level |
| MCLG | maximum contaminant level goal |
| M/DBP | microbial/disinfection by-product |
| MRDL | maximum residual disinfectant level |
| MRDLG | maximum residual disinfectant level goal |
| MTBE | methyl-*tert*-butyl-ether |
| NAS | National Academy of Sciences |
| NAWC | National Association of Water Companies |
| NDWAC | National Drinking Water Advisory Council |
| NHMRC | National Health and Medical Research Council |

| | |
|---|---|
| NIPP | National Infrastructure Protection Plan |
| NIRS | National Inorganic and Radionuclide Survey |
| NPDWRs | National Primary Drinking Water Regulations |
| NRC | National Research Council |
| NRMMC | Natural Resource Management Ministerial Council |
| NRWA | National Rural Water Association |
| OIRA | Office of Information and Regulatory Affairs |
| OMB | Office of Management and Budget |
| PNR | Public Notification Rule |
| PWSS | public water system supervision |
| RED | Registration Eligibility Decision |
| SAB | Science Advisory Board |
| SDWA | Safe Drinking Water Act |
| SDWIS–FED | Safe Drinking Water Information Systems–Federal |
| SMCL | secondary maximum contaminant level |
| SOC | synthetic organic chemical |
| SSP | sector-specific plan |
| SWTR | Surface Water Treatment Rule |
| T&C | technology and cost |
| TCR | Total Coliform Rule |
| TCRDSAC | Total Coliform Rule/Distribution System Advisory Committee |
| TON | threshold odor number |
| TT | treatment technique |
| TTHMs | total trihalomethanes |
| TWG | Technical Work Group |
| UCM | unregulated contaminant monitoring |
| UCMR | Unregulated Contaminant Monitoring Rule |
| USDA | U.S. Department of Agriculture |
| USEPA | U.S. Environmental Protection Agency |
| USGS | U.S. Geological Survey |
| USPHS | U.S. Public Health Service |
| VA | vulnerability assessment |
| VOC | volatile organic chemical |
| WHO | World Health Organization |

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