Two concepts that cannot be separated are public drinking water and public health protection. In fact, an entire industry was built on the bond between these two notions. Drinking water systems, drinking water organizations, and, yes, even the dreaded drinking water regulations exist because safe drinking water and public health have an alliance that cannot be divided.

U.S. drinking water suppliers demonstrate their awareness of this tie everyday. The water they distribute to their customers is among the cleanest and safest in the world. But the country’s status as a public health leader didn’t happen by accident. Extensive regulations, guidelines, and water quality testing were the drive to the destination.

After years of complying with new regulations, however, it may seem more like the regulations are a burden than a blessing. Believe it or not, the U.S. Environmental Protection Agency (EPA) is not deliberately trying to hinder us with ever increasing regulations just for fun. The agency is doing what it’s been charged to do—making sure that public water systems provide safe drinking water to their customers.

“More than 260 million Americans rely on the safety of tap water provided by water systems that comply with national drinking water standards,” says Veronica Blette, special assistant to the director, EPA Office of Ground Water and Drinking Water (OGWDW).

Considering the multitude of people who depend on public drinking water supplies, making sure that it’s safe is a responsibility that cannot be taken lightly.

Health Effects Emerge

Within the past century, contaminated water was widespread and uncontrolled. Most people had no idea that such a situation might be a problem. For that matter, most people didn’t know there was a problem. After all, it was a time of prosperity. The Depression had ended. World War II was over, and the U.S. was fast becoming a world leader. It was the 1950s—a time when the living was easy.

Life was relaxed for drinking water treatment operators as well. Few regulations for drinking water existed. And, surprisingly, drinking water standards that had been set were only considered non-enforceable guidelines. The only exception was the coliform standard, and then, only when interstate commerce was involved.

Most water systems did disinfect their drinking water supplies. The U.S. Public Health Service (PHS) considered the use of chlorine as a disinfectant for public drinking water supplies to be a stroke of genius. This simple act was responsible for saving tens of millions of lives and would be recognized as one of the leading public health advances in the 20th century.

Concerns about chemical contamination, however, had not yet become a priority. That was likely because no one knew it was a health threat. The PHS had set guidelines for the maximum permissible concentrations for lead, fluoride, arsenic, selenium, and hexavalent chromium—all of which were naturally occurring.
During the 1950s and 1960s, chemical makers embarked upon a manufacturing heyday, and “better living through chemistry” became a reality. An abundance of new manmade chemicals was hitting the U.S. industrial and agricultural markets. Chemical manufacturers boasted that these modern miracles would rid us of pests, degrease our machinery, and, quite simply, infinitely improve the quality of life on this planet.

But as with all things that appear too good to be true, these new chemicals would soon show a dark side. Vast amounts of these chemicals were turning up in the nation’s water supplies. Uncontrolled factory discharge, unimpeded farm runoff, and unrestrained waste disposal were all creating a substantial mess.

By the time the 1970s rolled around, the sight and smell of grossly polluted waterways couldn’t be avoided. The chemicals that had once been peddled as modern marvels were now suspected as the cause of many emerging health problems.

Congress couldn’t escape the inquiring public prompting it to commission several studies about the nation’s water supplies. In 1972, the report, *Industrial Pollution of the Lower Mississippi River in Louisiana*, was released. It confirmed that chemicals were, indeed, in our water supplies. Researchers presented evidence that they had detected 36 chemicals in the treated water that systems along the Mississippi River were distributing to their customers.

The chemicals that the researchers found included synthetic organic chemicals (SOCs) and trihalomethanes (THMs). SOCs are organic, manmade chemicals that include pesticides and industrial chemicals. They are suspected to be cancer-causing agents and are considered toxicants. THMs are disinfection byproducts. They form when disinfection chemicals, such as chlorine, come in contact with organic material. They are also suspected to be cancer-causing agents. (See related article on page 34.)

Up until this time, researchers had lacked sophisticated laboratory techniques that would detect these chemicals. But technological advances were happening faster than they ever had. Analytical chemistry and measurement techniques could now reveal the chemicals that were polluting the waterways.

A number of other studies were creating even more fervor. Researchers had uncovered volatile organic chemicals (VOCs), inorganic chemicals, and
radionuclides in drinking water supplies. When drinking water consumers got hold of this news, they demanded something be done.

**EPA Established**

One of the most important events was the formation of EPA, which occurred in July 1970. Prior to the establishment of the EPA, the federal government was not structured to coordinate an all out assault on the pollutants that harm human health and degrade the environment.

Once EPA was formed, it was assigned the daunting task of repairing the damage already done to the natural environment and to establish new criteria to guide Americans in making a cleaner environment a reality.

One of the first things that the agency did was to conduct additional water quality studies that reached similar conclusions. These studies determined that the country’s natural resources, once thought indestructible, were vulnerable after all.

This revelation eventually led to the passage of several laws regarding environmental and public health. One of those new laws was the Safe Drinking Water Act (SDWA). Its passage, along with the Clean Water Act, enabled the U.S. to clean up its waterways and eventually have some of the safest drinking water in the world.

“We have cleaned up most of the ‘big dirties’ of the 1950s and 1960s,” says Kenneth Olden, director, National Institute of Environmental Health Sciences (NIEHS), adding that we can’t afford to become complacent when it comes to public health and that prevention is the most cost-effective and life-enhancing means we have to protect human health.

For 30 years, the SDWA has been protecting the nation’s drinking water supplies and, thus, preventing public health tragedies. When the SDWA became law in 1974, it required EPA to set enforceable standards for health-related drinking water contaminants. The act was reauthorized in 1986 and again in 1996.

“EPA establishes health-based standards, which state drinking water programs adopt and implement,” Blette explains.

She says that EPA’s strategy for ensuring safe drinking water over the next several years includes four key elements:

1. developing or revising drinking water standards that are based on sound science,
2. supporting states, tribes, and water systems in implementing standards and drinking water programs,
3. promoting sustainable management of drinking water infrastructure, and
4. protecting drinking water sources from contamination to ensure the safety of critical water infrastructure.

Setting a Standard

We rely on water to survive. We use water to digest food, absorb and transport nutrients, circulate blood supplies, build tissues, carry away waste, and maintain body temperature. But for water to maintain good health, it has to be safe from contaminants that can compromise wellbeing.

It should come as no surprise that researchers have linked exposure to some environmental hazards with specific diseases. According to the Centers for Disease Control and Prevention (CDC), one of the most well-known links is exposure to lead and decreased mental function in children. And many other links exist. That’s why EPA sets contaminant level limits.

Before it can set a standard, however, the 1996 SDWA Amendments require the agency to evaluate contaminants. It pays particular attention to those that:

- may have an adverse health effect, particularly on sensitive sub-populations,
- occur or are likely to occur in public water systems, and
- can be removed through treatment methods so that public health risks are reduced.

Only after this risk assessment period does EPA develop a regulation. But odds are the agency doesn’t work alone. EPA enlists other government agencies to help it create new standards.

“NIEHS provides data on the toxicity/carcinogenicity of drinking water contaminants, including disinfection byproducts, that EPA can use to set drinking water standards,” says Ronald Melnick, toxicologist, Division of Intramural Research Environmental Toxicology Program, NIEHS.

The institute also provides information about microbial and chemical contaminants because of concerns about their adverse health effects. He also notes that some microbial contaminants produce chemicals that are toxic to the liver and other organs.

Under Surveillance

According to NIEHS, epidemiology is the type of research upon which most health regulations are based because epidemiological studies are the best known, best understood, and most accepted tools in the environmental health sciences.

Epidemiological studies use surveillance techniques to track disease occurrence in people who have been exposed to a natural or manmade factor in the environment over a number of years. During that time, scientists look for relationships between a toxic substance and a health effect, comparing those exposed to the contaminant with those who have not been exposed.

In all, these kinds of studies supply researchers with solid data. But researchers must be aware that epidemiological studies have their limits. For example, significant barriers exist to conducting effective surveillance for waterborne microbial disease, such as the possibility of multiple routes of exposure, the fact that exposed people may not stay in one place, and the length of time between exposure and evident health effects.

Because of these limitations, investigators do not rely on just one research method.

Of Mice and Men

Scientists do not want illnesses to go untreated for years before they discover the cause, so they also use screening tests called animal assays. NIEHS notes that mice and men share many genetic characteristics, and most substances known to cause cancer in humans—including aflatoxin, asbestos, benzene and radon—also cause cancer in animals.

In a typical assay, mice and rats are exposed to various levels of a substance for two years and checked for changes in their development. To determine if changes have occurred, researchers ask questions such as:

- Do the animals have more cancers than normal?
- If cancers are found, are they types that are not usually found in these animals?
- Do the exposed animals have changes in their reproductive, cardiovascular, immune, or nervous systems?

This research not only helps EPA determine a toxic dose for a particular contaminant, it also helps them clarify whether a contaminant can be ingested at low levels and not cause a health effect. This information helps the agency establish a maximum contaminant level goal (MCLG).

MCLGs are the level of a contaminant for which no adverse health effects are expected to occur. EPA considers MCLGs to be non-enforceable goals because they only consider the public health risks of a contaminant and exclude other limiting factors such as whether a system has the equipment to detect a particular contaminant, the available technology to treat for it, and how much it will cost to remove it from the water. Most MCLGs are set at zero.

When EPA sets the maximum contaminant level (MCL)—the enforceable standard—it includes limiting factors in its final decision but considers a contaminant’s health effects first. The agency uses two contaminant health-effect classifications: acute and chronic.

“Acute effects occur within hours or days of the time that a
Microbial Pathogens

Microbial pathogens in drinking water have serious, acute health effects. (See the article "A Lesson in Microbiology" in the Winter 2004 On Top.) Pathogens are disease-causing microorganisms that include bacteria, such as:

- **Coliform bacteria** are common in the environment and are generally not harmful. However, the presence of these bacteria in drinking water is usually a result of a problem with the treatment system or the pipes that distribute water and indicates that the water may be contaminated with germs that can cause disease.

- **Fecal coliform** and **E.coli** are bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Microbes in these wastes can cause short-term effects, such as diarrhea, cramps, nausea, headaches, or other symptoms.

- **Cryptosporidium** is a parasite that enters lakes and rivers through sewage and animal waste. It causes cryptosporidiosis, a mild gastrointestinal disease. However, the disease can be fatal for people with weakened immune systems. EPA and CDC have prepared advice for those with severely compromised immune systems who are concerned about Cryptosporidium.

- **Giardia lamblia** is a parasite that enters lakes and rivers through sewage and animal waste and causes gastrointestinal illness (e.g. diarrhea, vomiting, cramps).

- **Turbidity**—the cloudiness of water—has no health effects, but it can interfere with disinfection and provide a medium for microbial growth. Turbidity may indicate the presence of disease-causing organisms. These organisms include bacteria, viruses, and parasites that can cause symptoms such as nausea, cramps, diarrhea, and associated headaches.

*Photo Source: The Philadelphia Water Department, http://www.phillywater.org*
person consumes a contaminant,” says Jenny Bielanski, drinking water utilities team leader, EPA’s OGWDW. “People can suffer acute health effects from almost any contaminant if they are exposed to extraordinarily high levels, as in the case of a spill.

“In drinking water, microbes such as bacteria and viruses are the contaminants with the greatest chance of reaching levels high enough to cause acute health effects,” she notes. “Most people’s bodies can fight off these microbial contaminants the way they fight off other germs, and these acute contaminants typically don’t have permanent effects.

“Nonetheless, when high enough levels occur, they can make people ill and can be dangerous or deadly for a person whose immune system is already weak due to HIV/AIDS, chemotherapy, steroid use, or another reason,” Bielanski warns. “EPA has released several rules in the past few years that are aimed at tightening standards for microbial contaminants, and the agency is working to finalize additional rules over the next several months.

“Chronic effects occur after people consume a contaminant at levels over EPA’s safety standards for many years,” she explains. “Drinking water contaminants that can have chronic effects are chemicals such as disinfection byproducts, solvents, and pesticides; radionuclides, such as radium; and minerals, such as arsenic. Examples of the chronic effects of drinking water contaminants are cancer, liver or kidney problems, or reproductive difficulties.”

But there are situations where water systems do not have feasible methods for measuring for contaminants at particularly low concentrations. In these instances, EPA designates a treatment technique (TT) rather than an MCL.

A TT is an enforceable procedure or level of technological performance that public water systems must follow to ensure control of a contaminant. Examples are the Surface Water Treatment Rule that uses disinfection and filtration as the TT, and the Lead and Copper Rule that specifies optimized corrosion control procedures.

After determining an MCL or TT, EPA must complete an economic analysis to determine whether the benefits of that standard justify the costs. If not, EPA may adjust the MCL for a particular class or group of systems to a level that “maximizes health risk reduction benefits at a cost that is justified by the benefits.” EPA may not adjust the MCL if the benefits justify the costs.

EPA has already set limits for many microbial and chemical contaminants but has not established an exhaustive list. It adds new contaminants regularly. To track down contaminants that may be a public health risk, the agency relies on the contaminant candidate list (CCL) to develop new standards. The CCL is a list of contaminants that are not currently regulated but have a significant public health concern. EPA published the first CCL in 1998 that included 50 chemical and 10 microbial contaminants. Since then, as required by the 1996 SDWA amendments, EPA has added new contaminants every five years.

Because contaminants have many varying qualities, they are grouped into four categories: microbial pathogens, organics, inorganics, and radionuclides.

**Organics Chemicals**

Organics that cause the most worry include:
- trihalomethanes (THMs), which form when chlorine in treated drinking water combines with naturally occurring organic matter;
- pesticides, including herbicides, insecticides, and fungicides; and
- volatile organic chemicals (VOCs), which include solvents, degreasers, adhesives, gasoline additives, and fuel additives. Some of the common VOCs are benzene, trichloroethylene (TCE), styrene, toluene, and vinyl chloride.

Some of the possible health effects of organic chemicals include cancer, central nervous system disorders, liver and kidney damage, reproductive disorders, and birth defects.

**Inorganic Chemicals**

Inorganics include toxic metals, such as arsenic, barium, chromium, lead, mercury, and silver. These metals can get into drinking water from natural sources, industrial processes, and materials used in plumbing systems.

Toxic metals are regulated because they can cause acute poisoning, such as lead or copper poisoning. But they do have chronic health effects, including cancer.

Nitrate is an inorganic contaminant that requires special attention because of its health effects on infants. It is found in mineral deposits, fertilizers, sewage, and animal wastes. Nitrate has been associated with methemoglobinemia or “blue baby syndrome.”

Methemoglobinemia is a condition that causes an infant’s hemoglobin, which carries oxygen, to be converted to methemoglobin, which cannot carry oxygen. Without oxygen, symptoms of cyanosis usually appear. Babies with cyanosis have bluish mucous membranes and may also have digestive and respiratory problems. When methemoglobin levels reach 20 to 30 percent or above, anoxia occurs. Anoxia is a condition characterized by the absence of oxygen supply to an organ or a tissue. At methemoglobin levels around 50 to 70 percent, brain damage or death is likely.

Once diagnosed, however, methemoglobinemia is readily reversed. However, if anoxia has occurred, oxygen-deprived organs or tissues may be permanently damaged.

**Radionuclides**

Alpha emitters, beta/photon emitters, and combined radium 226/228, come from minerals that give off radiation. Some people who drink water containing these radioactive emitters in excess of EPA’s standard over many years may have an increased risk of getting cancer.

Radon gas is another radioactive material. It can dissolve and accumulate in underground water sources, such as wells, and in the
air in your home. Breathing radon can cause lung cancer. It is considered to be more dangerous in air than in water. However, drinking water that contains radon presents a risk of developing cancer.

**SWP Programs Reduce Risks**

If all of these contaminants can enter drinking water supplies, what can be done to stop them? Source water protection programs are the key to keeping water secure. They help safeguard public health, and they reduce the overall treatment challenges and costs. (See article on page 41.)

“While treatment installed to address regulated contaminants may also remove unregulated contaminants, when one considers the number of pesticides, herbicides, and other organic pollutants that are used in agriculture and industry, it is clear that preventing contamination of sources of drinking water makes good public health, economic, and environmental sense,” says Blette.

“Congress required that every state carry out assessments for every water system under their jurisdiction to characterize the susceptibility of drinking water to potential sources of contamination,” she explains. “These assessments have largely been completed. States, water utilities, and local communities should now use this new information to develop strategies for ensuring that their drinking water is safe from contamination from chemical and microbial pollutants.

“All water contains some impurities that are picked up as water dissolves or absorbs the substances with which it comes into contact. So there is no such thing as naturally pure water.”

**Reriterating the Link**

The public health concerns of providing safe drinking water are the reasons that this industry exists. Those concerns drive the need for new regulations, and subsequently, new treatment technologies. They also power the need for sustainable infrastructure, skilled operators, and educated drinking water industry leaders.

If there were no concern about drinking water straight from the source, there would be no reason to protect the public’s well being in the first place. Drinking water systems could simply pump water in and out. The industry would consist of a few pipe manufacturers, construction companies, and possibly some firms that deal with water’s aesthetics. The rest of us would be doing other things.

But that is not the case. As new chemicals and microbes emerge, drinking water contaminants will continue to change. The public health effects of those contaminants will continue to be the motivation of the drinking water industry’s evolution. Researchers will need to find better ways to detecting contaminants, engineers will need to develop new treatment technologies, and regulators will need to monitor source water for contaminants. The challenge, however, will be in protecting the public from those contaminants from drinking water before they reach consumers.

*For more information about how EPA establishes regulations, visit the agency’s Web site at: [www.epa.gov/safewater/index.html](http://www.epa.gov/safewater/index.html). To read CDC’s view of safe drinking water priorities, visit their Web site at [www.cdc.gov/health/water.htm](http://www.cdc.gov/health/water.htm). NIEHS’s safe drinking water Web site is online at [www.niehs.nih.gov](http://www.niehs.nih.gov).*

**References:**


