Microbial Pollutants in Our Nation’s Water
Environmental and Public Health Issues
Cover: Escherichia coli. The strain E. coli O157:H7 is responsible for the illness of 10,000 to 20,000 Americans each year.

Source: CDC

Photo of petri dish: ©1998 Jack M. Bodzack/Visuals Unlimited
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About the American Society for Microbiology

The American Society for Microbiology (ASM) is the largest single life science society, composed of over 42,000 scientists, teachers, physicians, and health professionals. The ASM’s mission is to promote research and research training in the microbiological sciences and to assist communication between scientists, policymakers, and the public to improve health, economic well-being, and the environment. The ASM and its members work to identify and support research efforts that can appropriately address infectious diseases including waterborne microbial infections. The goal of this booklet is to provide background information on the problem and to emphasize the critical role of research in responding to environmental and public health issues which currently confront policymakers.

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Control of water pollution in the United States over the past two decades has focused on chemical risks, overshadowing the significant risks associated with microbial pollutants. Waterborne microorganisms pose increasingly greater threats to public health, due to changing patterns in water use, increased water pollution, the nation’s aging water treatment systems, and outmoded risk assessment protocols. Action should be taken to address microbial water quality issues through a coordinated research and policymaking effort by all agencies and institutions involved.

The alarming lack of focus on microorganisms is apparent in the Environmental Protection Agency’s (EPA) major initiative to study the nation’s watersheds. Current indicators of watershed health do not include microbial contaminants of public health concern and only minimally address indicator coliform bacteria, which are not useful for assessing risks due to viruses and protozoa. In fact, the major water quality data available include no microbiological data, but rather focus on toxic chemicals, such as zinc, and “conventional pollutants,” such as ammonia. Similar omissions are obvious in the current Clean Water Act. The Act needs to be changed to include more emphasis on microbial threats, as well as a greater emphasis on rigorous risk assessment to address the biological, physical, and chemical integrity of our waterways. However, current evidence indicates that microbial pollutants in water, when compared to chemicals, pose far greater risks to communities.

Health Risks from Microbial Pollutants

Microbial pollutants of water are a major source of health and economic problems.

The Centers for Disease Control and Prevention (CDC) estimates that each year in the United States up to 900,000 cases of illness and possibly 900 deaths occur as a result of waterborne microbial infections. Disease-causing microorganisms found in water include many different types of bacteria, such as E. coli O157:H7; protozoa, such as Cryptosporidium and Giardia; and viruses, such as hepatitis A. Diseases caused by waterborne organisms vary from diarrhea to respiratory distress to heart disease.
Water contaminated with pathogenic microorganisms results not only in human suffering but also in significant economic losses. Even a mild case of diarrhea costs an estimated $280 in lost work productivity and over-the-counter medicines. More severe episodes can cost $8,000 per person for medical diagnosis and treatment. In 1993, the Cryptosporidium outbreak in Milwaukee cost that community well over $55 million. The 1997 Pfiesteria bloom in the Chesapeake Bay region caused $43 million in economic losses. Many waterborne pathogens can cause chronic diseases with costly long-term effects, such as degenerative heart disease and stomach cancer. For these and other reasons, individuals and industries want to locate in communities with adequate and safe water supplies, placing the current crisis over microbial pollutants firmly within national economic concerns.

Children, the elderly, and other groups are at higher risk from microbial pollutants in water.

Some population groups are more likely than others to suffer serious illness and death from waterborne diseases, including children, the elderly, pregnant women, and those with compromised immune systems. These groups presently represent 20-25 percent of the U.S. population, and they are rapidly increasing in size. Among children, rotaviruses hospitalize many due to serious diarrheal disease. In the United States, more than 70 percent of the diarrheal-related deaths occur among the rapidly growing age group of 55 or older. The number of immunocompromised individuals is increasing as a result of AIDS, cancer, and organ transplantation. Whereas Cryptosporidium causes a self-limiting diarrhea in normal healthy individuals, in AIDS and cancer patients it can be untreatable and persistent, even fatal.

When the Water’s Bad, Seniors Must Take Care
Immune System Hard Put to Deal With Bacteria
## Acute and Chronic Health Effects Associated with Waterborne Microorganisms

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Sources of Microbial Pollutants

As water moves through a watershed, where it collects and drains into rivers, lakes, and groundwaters, it often carries unseen microbial pollutants. Most waterborne disease-causing microorganisms come from animal and human fecal wastes, which invariably contain a wide variety of viruses, bacteria, and protozoa. Other microorganisms, such as Legionella and Pfiesteria, occur naturally in waters and can multiply in response to environmental changes such as influxes of fertilizer. Whereas Legionella may become a problem in hospital plumbing, Pfiesteria is an issue in rivers and estuaries.

Human Fecal Wastes

Our rivers, lakes, and oceans are used for the disposal of human wastes—including human feces, which are laden with microorganisms. A small drop of fecal matter can contain millions of these microorganisms. Waste treatment systems are supposed to render these wastewaters safe for release back into the environment, but conventional wastewater treatment does not always adequately reduce the number of pathogens. Thus, the wastewaters released could still contain enough pathogenic microorganisms to threaten human health. In addition, communities dealing with combined sewer overflows are at risk from high concentrations of microbial pollutants.
There are approximately 25 million septic tanks in the United States, receiving 175 billion gallons of wastewater that could contaminate ground and surface waters with viruses and other pathogens. Current evidence indicates virus contamination (i.e., rotaviruses, hepatitis A virus, and coxsackieviruses) from fecal sources in 20 percent of the groundwaters tested nationwide. Viruses can move through the septic tank system—from the toilet to adjacent surface waters—within 18 hours.

### Agricultural and Animal Wastes

Microbial pollution of the environment also comes from animals. Cattle can excrete millions of *E. coli* O157:H7, Cryptosporidium, Giardia, and other microbes. Chicken wastes can carry the pathogenic bacteria *Salmonella* and *Campylobacter*. Most management of animal wastes has not been directed at the control of microbial pollutants, but it is mandatory that the health risks from these potential pathogens receive the same attention as those from human wastes.

In the United States, 1.37 billion tons of animal manure are produced annually, equivalent to 5 tons for every person in this country.

Animal wastes carry parasites, fungi, and bacteria in concentrations as high as a billion organisms per gram.

In areas of intensive livestock production, animal wastes often are the leading suspected cause of blooms of toxic microbes such as *Pfiesteria piscicida*.

Sources of microbial water pollutants and their associated risks.
Human Exposure to Microbial Pollutants

Numerous unseen pathogens can readily enter potable and recreational waters as well as the nation’s food supply.

Surface Water and Groundwater Supplies

Both surface water and groundwater can transmit microbial pollutants, and outbreaks continue to occur. Unfortunately, exposure by this route may become more important in the future—unless some key contributing factors are addressed immediately: improper treatment and disposal of wastewaters, aging water treatment and distribution systems, mismanagement of animal wastes, and the current lack of an integrated regulatory approach.

Improperly treated drinking water can be an important route of exposure to human pathogens.

Groundwater has historically been assumed to be safe without treatment to kill the microorganisms. It was assumed that passage through soil would filter out these pathogens. However, the majority of waterborne outbreaks have resulted from use of untreated groundwater that has become contaminated. The potential for public health problems is large: more than 100 million Americans rely on groundwater for drinking, and only half of our communities disinfect water prior to distribution. In rural and nonincorporated areas, almost none of the water is treated.

Infectious disease outbreaks indicate that there are watersheds and communities at higher risk from contaminated water. Part of the problem is that many of the nation’s rivers serve both as receiving waters for sewage and as sources of potable water, enabling the spread of microorganisms from an infected individual to an entire community through what is known as the “fecal-oral route.” Wastewaters should be, and often are, treated for control of microorganisms prior to discharge, but this does not always occur or happens only seasonally. The intensive treatment of waste and potable waters necessary to destroy all microbial pollutants does not occur in all treatment systems. Thus, microbes can survive and enter our homes.

The current lack of an integrated regulatory approach threatens the nation’s water supply.

Despite the Safe Drinking Water Act (SDWA) that was reauthorized in 1996, the United States cannot assume that its drinking water is always safe. Partly to blame is the lack of coordination among agencies and institutions responsible for public health. New initiatives by the EPA, the CDC, the U.S. Department of Agriculture (USDA), and the National Academy of Sciences (NAS) are intended to take a closer look at microbial water contaminants, largely under directives. However, the absence of consistent, nationwide standards, regulations, and legislation regarding microbial pollutants is an obstacle to guaranteeing safe drinking water to all consumers.

Responsibility for the nation’s water quality is fragmented among numerous federal, state, county, and local governmental groups, all with different methods and standards. At the federal level, the EPA oversees microbial quality of community drinking water, and most states enforce testing requirements. The Food and Drug Administration (FDA) regulates bottled drinking water, but, although required to meet the same standards, most states do not require testing. The CDC surveys outbreaks of waterborne disease. Monitoring of our nation’s waters is divided further among the U.S. Geological Survey (USGS— inland), the National Marine Fisheries Service (NMFS— coastal), the FDA (shell fishing waters), the National Oceanic and Atmospheric Administration (NOAA—oceans), and the individual states and municipalities—all without adequate coordination.
Amidst the confusion, there is too much opportunity for inconsistencies or even omissions. For example, many homes have filtering devices for tap water, but these devices do not yet adequately ensure that the water is indeed safe to drink. Increasing demands on the nation’s water supplies have led to reuse of wastewater following treatment (to date, largely for nonpotable uses such as irrigation). We do not know whether reuse contributes to increased risk from drinking water, and for some states reuse is not yet an issue, but potential hazards from reused water must be investigated. Currently, no federal laws govern water reuse, leaving each state to address treatment needs, water quality, and health and safety issues.

Recreational Waters

Coastal states and communities rely on beautiful beaches and waterways to attract tourists. Unfortunately, exposure to microbial pollution in recreational waters has caused outbreaks of gastrointestinal disease; respiratory, ear, eye, and skin infections; meningitis; and hepatitis. Exposure to toxin-producing algae can cause respiratory problems, making even a stroll on the beach risky under these conditions. Over recent years, hundreds of beaches have been closed. During 1996, nearly 3,700 beach closings and advisories were issued at ocean, bay, and Great Lake beaches in the United States. Of the closings, 83 percent were due to excessive levels of bacteria. Such closures put residents, visitors, and local economies at risk. Still, most states have not yet developed comprehensive monitoring programs to protect these natural resources. Only 33 percent have followed guidelines developed by the EPA on microbial quality of waters used for swimming and fishing.

Foods

Prior to 1990, pathogens were rarely found, or looked for, in fresh fruits and vegetables in the United States. Since then, however, there have been multiple outbreaks of Salmonella-caused illness tied to imported produce. During the winter season, most produce consumed in the United States now comes from Mexico and Latin America. Because of inadequate wastewater treatment, irrigation waters used in many of these countries are laden with microbial pathogens. As a result, there have been outbreaks of hepatitis A from contaminated lettuce and strawberries and of Cyclospora from raspberries.
The water-to-food connection also impacts the American seafood industry: fish and shellfish can acquire pathogens from contaminated waters, a growing problem in this country. Sadly, about 42 percent of our estuary-water area is contaminated by municipal, industrial, and agricultural wastes. As a result, bacteria, viruses, and toxic dinoflagellates are the major causes of fish- and shellfish-associated disease in humans. (Chemicals cause only 1 percent of all fish-associated disease outbreaks.) Recently, fish harvested in waters near the nation’s capital were deemed unsafe for human consumption because of high numbers of the dinoflagellate Pfiesteria, associated with major fish kills in the mid-Atlantic and southeastern United States. Pfiesteria has been postulated to cause an ulcerative fish disease and serious neurological effects in humans.

Shellfish may be even more problematic. Outbreak data from New York show that emerging viruses such as Norwalk and other small round structured viruses are responsible for a majority of shellfish-associated diarrheal illnesses. The Vibrio bacterium is a growing problem in Florida, where almost 90 percent of fatal cases of V. vulnificus septicemia are due to consumption of raw Gulf Coast oysters. Some oyster-related cases of cholera caused by V. cholerae also occur each year.

Sadly, about 42 percent of our estuary-water area is contaminated by municipal, industrial, and agricultural wastes.
Oversight of Water Safety

Microbial pollution of water in the United States is a growing crisis in environmental and public health that is not being addressed nationally through scientific research and risk assessment.

Despite increased awareness of the importance of safe water supplies in the United States, there are reasons to be alarmed about the future of this essential resource:

- Regulatory responsibilities for the microbial quality of water with respect to public health are fragmented among several federal agencies and between state and local levels. Water quality and treatment standards for control of microorganisms vary widely as a result.

- During the last two decades, the regulatory focus has been primarily on chemical pollutants and has neglected methods, sources, and risk assessments for addressing the more threatening microorganisms.

- Indicator systems such as coliform bacteria currently used to assess microbial risks are out-of-date in regard to many of the microorganisms threatening our water supply.

- Any effective risk assessment demands an adequate database of information on exposure and outcomes. This database does not exist.

To scientifically evaluate pollutants and to develop protective public policies, risk assessment is the accepted approach. This approach, however, is no better than the database on which we subsequently build public health strategies. A usable database must include information about sources, occurrence, concentrations, frequency, survival, and transport of specific microorganisms in the environment. A great deal of basic research, field study, and statistical surveying needs to be done to build a sound microbial pollutants database.

The ongoing identification of new waterborne pathogens mandates the development of innovative indicators and methods of assessing microbial pollutants in water. Indicators should include surrogates for testing removal of large parasites and small viral particles. Molecular detection methods developed in recent years, such as the polymerase chain reaction, have greater sensitivity, showing much more contamination of water than previously recognized. Additional research is needed to assess the pathogenicity to humans of microorganisms detected by these new methods. The intensive, multidisciplinary effort needed will require a consortium of academic, industry, and government scientists and policy-makers working together.
A National Initiative Is Needed

There is a critical need for an integrated, national initiative on the microbial quality of water and on risk assessment as related to public health. Because water quality problem-solving should address entire watersheds and aquifers, a national effort is necessary to overcome bureaucratic, institutional, and political obstacles. The current state of fragmentation and inaction can be overcome only by active participation of various government agencies, academic researchers, and industry. The initiative should provide resources for research and development, training of a workforce, and outreach education on strategies and programs. It should include creation of a comprehensive database of pertinent information.

Recommendations for Action

1. Establish a task force of the EPA, CDC, National Institute for Environmental Health Sciences (NIEHS), and other federal agencies—as well as universities and other key nongovernment groups—to outline a national initiative with the goal of protecting the public from waterborne pathogens. This task force should be charged to:
   - Provide the framework for an integrated National Assessment of Microbial Pollutants in Water, to gauge risks through coordination of studies done by various agencies and groups.
   - Coordinate risk assessment efforts with national guidelines for states, towards the development of consistent, effective regulations and standards.
   - Guide reauthorization and implementation of the Clean Water Act and the SDWA.

2. Initiate an independent scientific assessment to address the microbial safety of the nation’s waters to:
   - Determine the appropriate and necessary human and financial resources needed for research, development, and implementation of water protection programs focused on waterborne microbes.
   - Identify the education and training programs needed to improve surveillance of our waters and our human population for outbreaks.
   - Determine which programs and methods must be developed or expanded for sufficiently monitoring the microbial quality of water.
   - Delineate occurrence and health effects databases needed to establish appropriate water safety policies, as related to microbial pathogens.

If implemented, these recommendations will lead to a more balanced approach to addressing and controlling microbial contamination of our nation’s waters, thus contributing to sustainable and safe waters for our future use.
REFERENCES


