

Chapter 2

Health Concerns at Beaches

2.1 What are pathogens and bacterial indicators?

This section includes background information about pathogens and bacterial indicators to allow a better understanding of the BEACH Act's requirements for water quality standards and criteria.

Pathogens

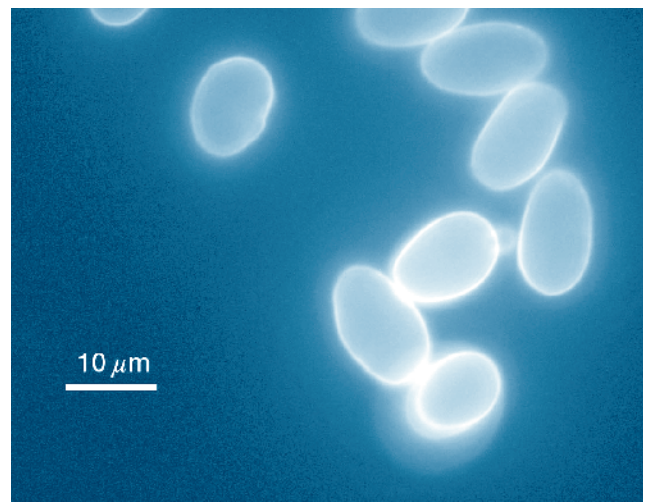
A *pathogen* is defined as any disease-producing microorganism (Dorland's Illustrated Medical Dictionary, 2000). Microorganisms are ever-present in all terrestrial and aquatic ecosystems. Many types are beneficial, functioning as agents for chemical decomposition, food sources for larger animals, and essential components of the nitrogen cycle and other biogeochemical cycles. Some microorganisms reside in the bodies of animals and aid in the digestion of food; others reside on the skin, providing protection against pathogens. Still others are used commercially for medical purposes, such as providing antibiotics.

The small subset of microorganisms that cause human diseases are known as human pathogens. If taken into the body, they can cause gastrointestinal illness, other medical problems, or even death. The source of human pathogens is usually the feces of humans and other warm-blooded animals. For recreational waters, there are three groups of gastrointestinal pathogens of concern—bacteria, viruses, and protozoans.

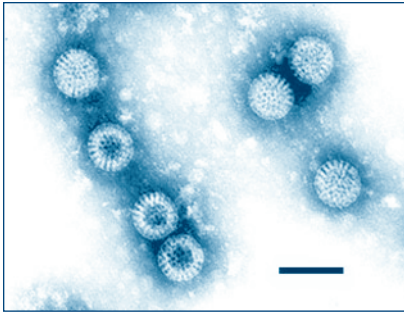
- **Bacteria** are unicellular organisms that lack an organized nucleus and contain no chlorophyll (Chapra 1997). They contain a single chromosome and typically reproduce by binary fission, during which a single cell divides to form two new cells. A primary bacteria source of concern at beaches is feces from people and other warm-blooded animals, including fecal waste associated with farming and the discharge

of domestic sewage. Feces can contain many types of bacteria found in waterbodies, including the coliform group, streptococcus, lactobacillus, staphylococcus, and clostridia. It is important to understand, however, that most bacteria are not pathogenic or disease-causing.

- **Protozoans** are unicellular organisms with a nucleus that reproduce by fission and occur primarily in the aquatic environment. Pathogenic protozoans, which constitute almost 30 percent of the 35,000 known species of protozoans, are found in the feces of people and other warm-blooded animals (Mitchell et al. 1988, cited in NCSU 1997). They can exist in the environment as cysts that hatch, grow, and multiply after ingestion, causing associated illness. Encystation of protozoans facilitates their survival by protecting them from harsh conditions like high temperature and salinity. Two protozoan species of major concern as waterborne pathogens are *Giardia lamblia* and *Cryptosporidium parvum* (Academic Press 2003).



Giardia lamblia. (H.D.A. Lindquist. USEPA)



Rotavirus. (F.P. Williams. USEPA)

- **Viruses** are a group of infectious agents that require a host in which to live and reproduce. They are composed of a sequence of nucleic acids—either DNA or RNA, depending on the virus—that is covered by a protein shell for protection. The most significant virus group affecting water quality and human health grows and reproduces in the cells of the gastrointestinal tract of people and infected animals. These enteric viruses are excreted in feces, and they include hepatitis A, rotaviruses, caliciviruses (noroviruses), adenoviruses, enteroviruses, and reoviruses.

Bacterial indicators

Bacterial indicators¹ are used to measure fecal contamination in environmental waters and the potential pres-

ence of a diverse group of hard-to-detect pathogenic organisms. A bacterial indicator organism provides evidence of the presence or absence of fecal waste and the potential presence of pathogenic organisms that survive under similar physical, chemical, and nutrient conditions. An ideal indicator organism should have as many of the following characteristics as possible: be easily detected using simple laboratory tests; generally not be present in unpolluted waters; appear in concentrations that can be correlated with the extent of contamination; and have a die-off rate similar to the die-off rate of the pathogens of concern (Sloat and Ziel 1992, Thomann and Mueller 1987).

Most disease-causing microbes exist sporadically, often at very low concentrations, and are difficult and expensive to detect. Indicator organisms, therefore, have been used for more than a century to help identify where fecal contamination has occurred and to indicate where disease-causing microbes might be present. These organisms generally do not cause illness directly; however, they have characteristics that make them good indicators that fecal contamination has occurred and that harmful pathogens might be in the water (Thomann and Mueller 1987, Wilhelm and Maluk 1999). Figure 2.1 shows the relationship of various bacterial indicator organisms.

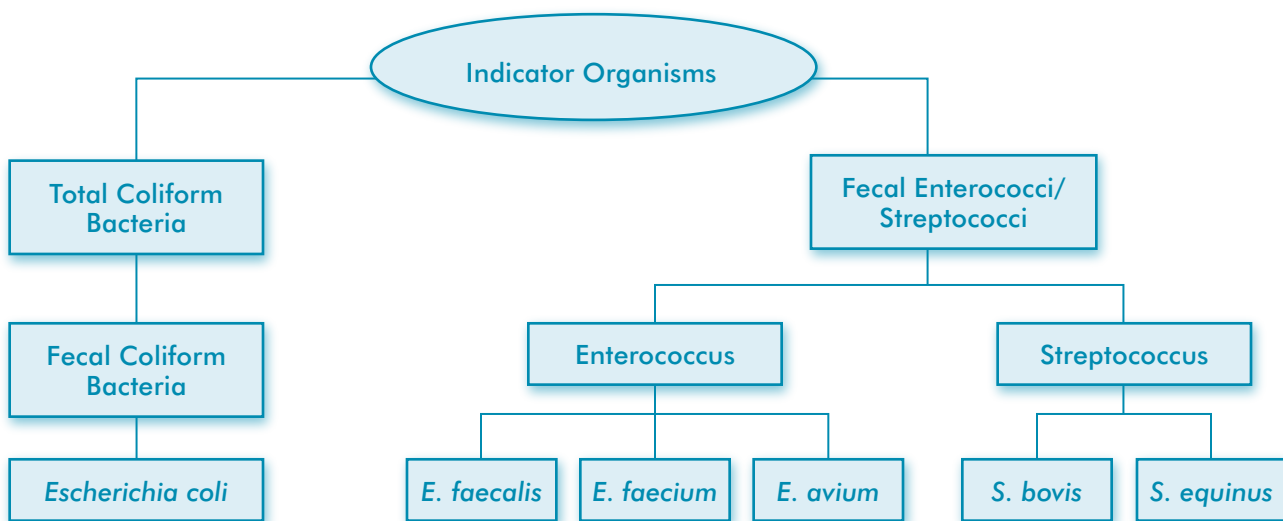


Figure 2.1. Relationship between bacterial indicator organisms

¹ This report uses the term *bacterial indicators* because it is the term more commonly used by microbiologists. The CWA defines a pathogen indicator as a substance that indicates the potential for human infectious disease. EPA interprets the term pathogen indicators, as used in the BEACH Act, to refer to any indicators for pathogens, which include bacterial indicators.

Table 2.1. Waterborne Pathogens (adapted from Metcalf and Eddy, 1991)

Pathogen	Disease	Effects
Bacteria		
<i>Escherichia coli</i> (enteropathogenic)	Gastroenteritis	Vomiting, diarrhea, and death in susceptible populations
<i>Helicobacter pylori</i>	Gastritis	Diarrhea. Peptic ulcers are a long-term sequela.
<i>Legionella pneumophila</i>	Legionellosis	Acute respiratory illness
<i>Leptospira</i>	Leptospirosis	Jaundice, fever (Weil's disease)
<i>Pseudomonas</i>	Infections in immuno-compromised individuals	Urinary tract infections, respiratory system infections, dermatitis, soft tissue infections, bacteremia, and a variety of systemic infections
<i>Salmonella typhi</i>	Typhoid fever	High fever, diarrhea, ulceration of the small intestine
<i>Salmonella</i>	Salmonellosis	Diarrhea, dehydration
<i>Shigella</i>	Shigellosis	Bacillary dysentery
<i>Vibrio cholerae</i>	Cholera	Extremely heavy diarrhea, dehydration
<i>Yersinia enterocolitica</i>	Yersinosis	Diarrhea
Protozoans		
<i>Balantidium coli</i>	Balantidiasis	Diarrhea, dysentery
<i>Cryptosporidium</i>	Cryptosporidiosis	Diarrhea
<i>Entamoeba histolytica</i>	Ameobiasis (amoebic dysentery)	Prolonged diarrhea with bleeding, abscesses of the liver and small intestine
<i>Giardia lamblia</i>	Giardiasis	Mild to severe diarrhea, nausea, indigestion
<i>Nagleria fowleri</i>	Amoebicmeningoencephalitis	Fatal disease; inflammation of the brain
Viruses		
Adenovirus (31 types)	Respiratory disease	Eye infections, diarrhea
Astroviruses	Gastroenteritis	Vomiting, diarrhea
Enteroviruses (67 types, e.g., polio, echo, and Coxsackie viruses)	Gastroenteritis	Diarrhea. Heart anomalies and meningitis are long-term sequela and are very rare.
Hepatitis A and E	Infectious hepatitis	Jaundice, fever
Noroviruses (Norwalk- and Sapporo-like viruses)	Gastroenteritis	Vomiting, diarrhea
Reovirus	Gastroenteritis	Vomiting, diarrhea
Rotavirus	Gastroenteritis	Vomiting, diarrhea

2.2 What are the health concerns at beaches?

Various studies and reports have documented the adverse health effects that might result from human exposure to fecally contaminated waters. The main route of exposure to disease-causing organisms in recreation waters is contact with polluted water while swimming.²

In waters that contain fecal contamination, bathers could potentially contract all the waterborne diseases spread by the fecal-oral route (Henrickson et al. 2001). These illnesses include diseases resulting from exposure to various pathogens, such as

- Bacteria that can cause cholera, salmonellosis, shigellosis, and gastroenteritis
- Viruses that can cause diseases like infectious hepatitis, gastroenteritis, and intestinal diseases
- Protozoans that can cause diseases like amoebic dysentery, cryptosporidiosis, and giardiasis

These and other diseases that can result from contact with water contaminated with introduced or naturally occurring pathogens are summarized in Table 2.1.

When people become ill as a result of contact with contaminated water, one common illness is gastroenteritis. Gastroenteritis is the inflammation of the gastrointestinal tract, usually caused by a microorganism. It can involve chills, nausea, diarrhea, and sometimes fever.

People can also contract diseases that affect the eyes, ears, skin, and upper respiratory tract. Infection might result when pathogenic microorganisms come into contact with abrasions in the skin, or ruptures in delicate membranes in the ear or nose, resulting from swimming exposures.

Epidemiology studies

The relationship between water quality and human health has been studied for many years. EPA began studies to quantify the relationship between the quality of bathing water and the resultant health effects in 1972. Studies in the 1970s and 1980s examined the differences in symptomatic illness between swimming and nonswimming beachgoers at marine

and freshwater bathing beaches. The studies found the following (USEPA, 1999):

- Swimmers who bathe in water contaminated with sewage are at greater risk than nonswimmers of contracting gastroenteritis.
- The swimming-associated illness rate increases as the quality of the bathing water degrades.
- The illness rate in marine swimmers is greater than that in freshwater swimmers when indicator densities are equivalent in marine waters and freshwaters.
- Most swimming-related illnesses are of undetermined etiology (cause).³

In 1995, researchers with assistance from the Santa Monica National Estuary Program, launched a large-scale study in the Santa Monica Bay area to assess both the effectiveness of bacterial indicators in predicting health risks to bathers and the relative health risk associated with bathing near storm drains. In this study, approximately 15,000 beachgoers who bathed and immersed their heads were interviewed. Approximately 13,000 of the beachgoers were contacted for follow-up interviews designed to assess the occurrence of symptoms such as fever, chills, nausea, and diarrhea. The study found that there is a significant correlation between swimming in water with high densities of indicator bacteria and the incidence of adverse health effects. In addition, the study indicated that people who swim in front of flowing storm drains are twice as likely to exhibit adverse health effects as people who swim 400 yards away from such storm drains (Haile et al. 1996).

A review of studies conducted during the past several decades has provided the following overall conclusions (Prüss 1998):

- An exposure-response relationship exists between bacterial indicator counts in recreational waters and gastrointestinal symptoms in bathers.
- There is no demonstrated relationship between bacterial indicator counts and symptoms not related to the gastrointestinal tract (such as eye, nose, ears, and skin symptoms).

² The terms *swimming* and *bathing* are used in this report to encompass recreational activities (such as swimming, bathing, water skiing, surfing, and kayaking) where ingestion of, or immersion in, the water is likely. States and territories typically identify these uses in their water quality standards as "primary contact recreation."

³ The illnesses can be identified, but the specific pathogen (i.e., bacterium, virus, or protozoan) often is not identified unless there is a specific outbreak investigation.



E. coli, a bacterial indicator organism that correlates with adverse effects in freshwater. (Rocky Mountain Laboratories, NIAID, NIH)

- The relative risk of swimming in contaminated waters ranged from one to three times above the risk associated with swimming in uncontaminated waters.
- The indicators showing the best correlation with adverse health effects were enterococci (marine water and freshwater) and *Escherichia coli* (freshwater).

Illness Outbreak Reports

Another source of information about adverse human health effects is reports of waterborne disease outbreaks. In 1971 EPA, the Centers for Disease Control and Prevention (CDC), and the Council of State and Territorial Epidemiologists initiated a surveillance system for reporting the occurrence and causes of waterborne outbreaks in the United States. This system resulted in a series of annual reports on waterborne disease outbreaks.

These reports are an important source of information about human health problems in our nation's recreational waters. A recently published article titled "Outbreaks associated with recreational water in the United States" summarizes these reports from the past 30 years (Craun et al. 2005). In the article, the authors review the causes of outbreaks associated with recreational water during 1971–2000 and note the following:

- A bacterial or protozoan etiology was identified in three-quarters of the outbreaks; 23 percent of the outbreaks were of undetermined etiology. The most frequently identified agents were *Cryptosporidium* (15 percent), *Pseudomonas* (14 percent), *Shigella* (13 percent), *Naegleria* (11 percent), *Giardia* (6 percent), and toxigenic *E. coli* (6 percent). Outbreaks attributed to *Shigella*, *E. coli* O157:H7, and *Naegleria* were primarily associated with swimming in fresh waters such as lakes, ponds, and rivers. In contrast, outbreaks caused by *Cryptosporidium* and *Giardia* were primarily associated with treated water in swimming and wading pools.
- An important source of contamination for both treated and untreated recreational waters was the bathers themselves. Contamination from sewage discharges and wild or domestic animals were also important sources for untreated waters. A contributing factor in swimming-pool outbreaks was inadequate attention to maintenance, operation, disinfection, and filtration.
- Although not all waterborne outbreaks are recognized or reported, the national surveillance of these outbreaks has helped identify important sources of contamination of recreational waters and the etiologic agents. This information can be useful in making prevention recommendations and setting research priorities that might lead to improved water quality guidelines.

These reports provide insight into the health effects and, to some degree, the causes of human illnesses. Unfortunately, the reporting has limitations. For example, it is difficult to detect and document illness outbreaks in the population. People who acquire an illness from bathing in contaminated water do not always associate their illness with swimming. The symptoms might arise after leaving the beach and might be attributed to other causes, such as food poisoning. As a result, disease outbreaks often are inconsistently recognized (Craun et al. 2005). Disease surveillance reports also cannot accurately determine the incidence of disease among bathers.

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