

Health Risks and Economic Impacts of Beach Pollution

DISEASES CAUSED BY PATHOGENS IN BATHING WATERS

Polluted waters may contain disease-causing organisms called pathogens. The most common types of pathogens are those associated with human and animal waste, including bacteria, viruses, and protozoa. Swimmers in sewage-polluted water can contract any illness that is spread by fecal contact, including gastroenteritis, respiratory infection, and ear and skin infections (see Table 4). (Gastroenteritis, or stomach flu, is inflammation of the stomach and the small intestine, symptoms of which can include vomiting, diarrhea, stomachache, nausea, headache, and fever.)¹ Giardiasis, caused by the protozoa *Giardi lamblia*, is the most commonly reported intestinal disease in North America.² Most swimming-related illnesses last from a few days to several weeks, but in some cases pathogens may cause severe, long-term illness or even death. There is usually a delay of several days to two weeks between contact with contaminated water and expression of symptoms, and most people who get sick from swimming are not aware of the link. Sensitive populations such as children, the elderly, or those with a weakened immune system are particularly at risk for long-term effects. For example, diarrhea can be 10 times more likely to result in death in individuals over the age of 74 compared to those between the ages of 5 and 24.

The Centers for Disease Control and Prevention concluded that the incidence of infections associated with recreational water use has steadily increased over the past several decades.

Since 1971, the Centers for Disease Control and Prevention (CDCP), the EPA, and the Council of State and Territorial Epidemiologists have worked to maintain the Waterborne Disease and Outbreak Surveillance System for collecting and reporting waterborne diseases and outbreak-related data. Their most recent report, released in 2006, summarizes findings for January 2003–December 2004. During this survey period, 62 waterborne disease outbreaks were reported (see Table 5 and Figure 12). These outbreaks caused illness in 2,698 people, resulting in 58 hospitalizations and one death. The Centers for Disease Control and Prevention concluded that the incidence of infections associated with recreational water use has steadily increased over the past several decades. The increase is attributed to a combination of factors, such as the emergence of new pathogens, increased participation in aquatic activities, and better reporting.³

Because the CDCP relies on voluntary reporting of illnesses, the incidences may be much higher than those cases accounted for. Based on beach visitation rates and monitoring data, researchers have estimated that 689,000 to 4,003,000 gastrointestinal illness episodes and 693,000 respiratory illness episodes occurred each year between 2000 and 2004 at Southern California beaches.⁴ While these estimates are subject to a great deal of uncertainty, they provide insight into the potential for under-reporting of swimming-related illnesses.

In 2005, the first major report of the National Epidemiological Environmental Assessment of Recreational (NEEAR) Water Study examined the association between recreational freshwater quality and gastrointestinal illness as well as upper respiratory illness, rash, eye ailments, and earache after swimming at two beaches in the Great Lakes region.⁵ Both beaches are known to be affected by sewage discharges from waste treatment plants. In 2003, water samples were collected from each beach and tested for enterococcus using rapid and traditional culture-based methods. At one beach (Indiana Dunes National Lakeshore on Lake Michigan in Indiana), the NEEAR study found that the incidence of gastrointestinal illness was 10 percent among subjects who came in contact with the water, representing twice the number of illnesses reported by non-swimmers. At a second beach (on Lake Erie near Cleveland, Ohio) the rate of gastrointestinal illness among swimmers was as high as 14 percent. The illnesses correlated to the presence of enterococcus bacteria. Two additional freshwater beaches were added to the study in 2004: Silver Beach, near St. Joseph, Michigan, and Washington

Table 4. Details on the 62 Waterborne Disease Outbreaks Reported to CDCP: Jan 2003–Dec 2004

Associated Illnesses	Incidence	Etiologic Agents Identified:
Gastroenteritis	30 (48.4%)	
Dermatitis	13 (21.0%)	
Acute Respiratory Illness	7 (11.3%)	
Others: Amebic Meningoencephalitis, Meningitis, Leptospirosis, Otitis, Externa, Mixed Illnesses	12 (19.3%)	
		Bacterium 32.3% Parasite 24.2% Virus 9.7% Chemical or Toxin 4.8%

Table 5. Pathogens and Swimming-Associated Illnesses

Pathogenic Agent	Disease
Bacteria	
<i>Campylobacter jejuni</i>	Gastroenteritis
<i>E. coli</i>	Gastroenteritis
<i>Salmonella typhi</i>	Typhoid fever
Other salmonella species	Various enteric fevers (often called paratyphoid), gastroenteritis, septicemia (generalized infections in which organisms multiply in the bloodstream)
<i>Shigella dysenteriae</i> and other species	Bacterial dysentery
<i>Vibrio cholera</i>	Cholera
<i>Vibrio vulnificus</i>	Skin and tissue infection, death in those with liver problems
<i>Yersinia spp.</i>	Acute gastroenteritis (including diarrhea, abdominal pain)
<i>Aeromonas hydrophila</i>	Dysenteric illness, wound infections, gastroenteritis, septicemia
Leptospira	Leptospirosis
<i>Helicobacter pylori</i>	Chronic and severe inflammation of the stomach, increased likelihood of developing gastric cancer
<i>Legionella pneumoniae</i>	Fever, pneumonia
Viruses	
Adenovirus	Respiratory and gastrointestinal infections
Coxsackievirus (some strains)	Various, including severe respiratory disease, fever, rash, paralysis, aseptic meningitis, myocarditis
Echovirus	Various, similar to coxsackievirus (evidence is not definitive except in experimental animals)
Hepatitis	Infectious hepatitis (liver malfunction); also may affect kidneys and spleen
Norwalkvirus	Gastroenteritis
Poliovirus	Poliomyelitis
Reovirus	Respiratory infections, gastroenteritis
Rotavirus	Gastroenteritis
Calicivirus	Gastroenteritis
Polyomavirus	Cancer of the colon
Protozoa	
<i>Balantidium coli</i>	Dysentery, intestinal ulcers
<i>Acanthamoeba</i>	Eye infections
<i>Microsporidia</i>	Diarrhea

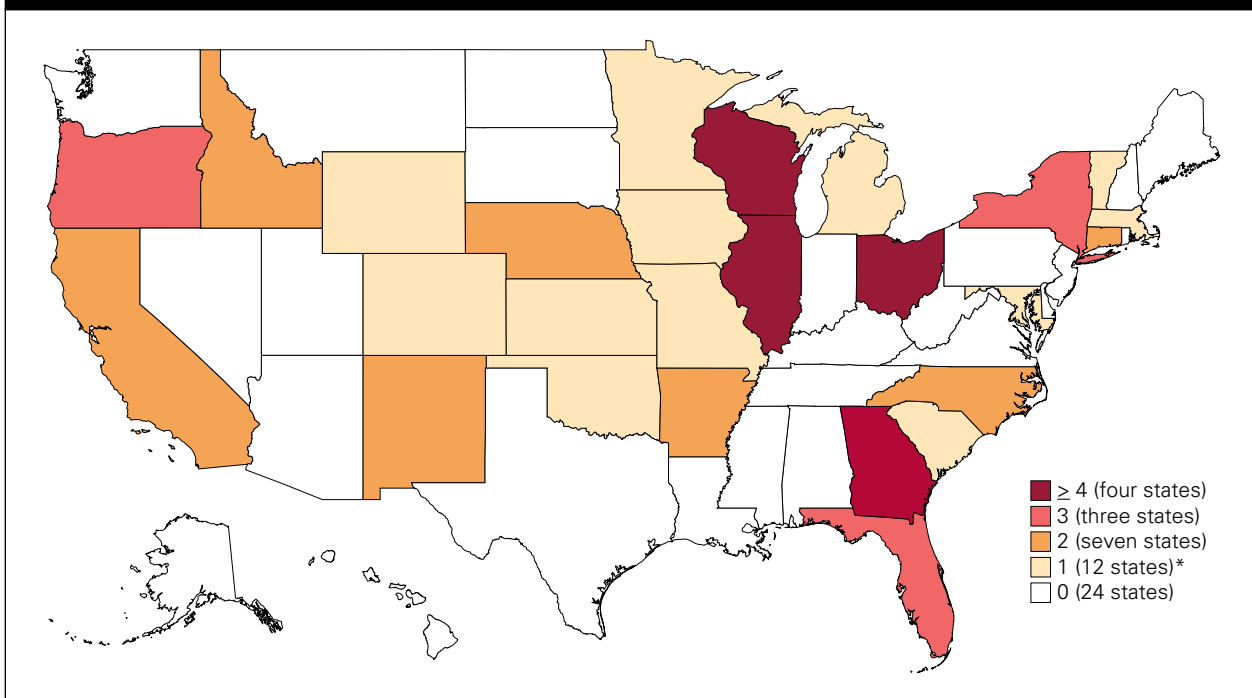
Testing the Waters 2009

Pathogenic Agent	Disease
Bacteria	
<i>Cayetanensis</i>	Abscess in liver or other organs
<i>Cryptosporidium</i>	Gastroenteritis
<i>Entamoeba histolytica</i>	Amoebic dysentery, infections of other organs
<i>Giardia lamblia</i>	Diarrhea (intestinal parasite)
<i>Isospora belli</i> and <i>Isospora hominis</i>	Intestinal parasites, gastrointestinal infection
<i>Toxoplasma gondii</i>	Toxoplasmosis
<i>Cyclospora</i>	Gastroenteritis

Park Beach in Michigan City, Indiana.⁶ Overall, enterococcus measured using the rapid test method was more strongly associated with illness at these four freshwater beaches than was enterococcus measured using the traditional culture-based method. The study also showed that children 10 years old and younger were especially susceptible to gastrointestinal illness following swimming exposure. The Centers for Disease Control and Prevention have noted that children under the age of nine have more reports of diarrhea and vomiting from exposure to waterborne pathogens than any other age group, with at least a twofold increase occurring over the summer swimming months.⁷

A large-scale 1995 epidemiological study investigated possible adverse health effects associated with swimming in ocean waters contaminated by urban runoff.⁸ The Santa Monica Bay Restoration Project study involved initial interviews with 15,492 beachgoers who bathed and immersed their heads, as well as follow-up interviews with 13,278, to ascertain the occurrence of certain symptoms such as fever, chills, nausea, and diarrhea. The study found an increase in risk of

Figure 12. Geographic Location of the Reported Disease Outbreaks⁹



Source: <http://www.cdc.gov/mmwr/preview/mmwrhtml/ss5512a1.htm>

Note: These numbers are largely dependent on reporting and surveillance activities in individual states and do not necessarily indicate the true incidence in a given state.

*Guam also reported one recreational water-associated outbreak in 2004.

illness associated with swimming near flowing storm drain outlets in Santa Monica Bay, compared with swimming more than 400 yards away. For example, swimmers near storm drains were found to have a 57 percent greater incidence of fever than those swimming farther away. This study also confirmed the increased risk of illness associated with swimming in areas with high densities of indicator bacteria. Illnesses were reported more often on days when water samples tested positive for enteric bacteria.

In a California study, the rates of reported health symptoms among surfers were compared in urban North Orange County and rural Santa Cruz County during two winters to determine the health impacts of exposure to urban runoff.¹⁰ The urban North Orange County surfers who were interviewed for the study reported almost twice as many symptoms as the rural Santa Cruz County surfers. There were numerous illnesses reported by the study participants, including respiratory disease, fever, nausea, gastrointestinal illness, sore throat, vomiting, and others. In both study years the risk of illness increased for all symptom categories by 10 percent for each 2.5 hours of weekly water exposure.

Swimmers who contract a waterborne illness may also pass the disease on to household members, multiplying the effect of the polluted water. While swimming-related illnesses are usually not life-threatening, they can take a substantial toll in terms of convenience, comfort, and the well-being of the people affected.

Climate change is expected to increase the incidence of diseases contracted by swimmers. The bacterium *Vibrio cholerae*, which causes cholera, is an example of a pathogen that presents an increased threat to humans as a result of climate change. Extreme weather events and warmer waters can foster growth of the bacterium—one study found that *V. cholerae* was nearly 20 times more likely to occur at a temperature of 19° C or higher than at lower temperatures.¹¹ In 2005, cases of illness due to *V. cholerae* occurred in association with Hurricane Katrina.¹² Increased freshwater runoff, high in nutrients and low in salinity, also may favor the growth of *V. cholerae*. As one study of Chesapeake Bay concluded, “increased climate variability, accompanied by higher stream flow rates and warmer temperatures, could favor conditions that increase the occurrence of *V. cholerae* in Chesapeake Bay.”¹³

Table 6. Possible Influence of Climate Change on Climate-Susceptible Pathogens¹⁴

Pathogen	Climate-Related Driver	Possible Influence of Climate Change	Likelihood of Change	Basis for Assessment
<i>Vibrio</i> Species	Rising temperature	Increasing ambient temperatures associated with growth in pre-harvest and post-harvest shellfish (in absence of appropriate post-harvest controls) and increasing disease	Very likely	Likelihood of climate event is high, and evidence supports growth trend in ambient waters; adaptive (control) measures (refrigeration) would reduce this effect for post-harvest oysters
		Increasing temperature associated with higher environmental prevalence and disease	Extremely likely	Likelihood of climate event is high, and evidence supports environmental growth trend
		Increasing temperature associated with range expansion	Very likely	Likelihood of climate event is high, and evidence collected to date supports trend; more data needed to confirm
	Changes in precipitation	Increasing precipitation and freshwater runoff leads to depressed estuarine salinities and increases in some <i>Vibrio</i> species	About as likely as not	Likelihood of climate event is probable, but additional research is needed to confirm pathogen distribution patterns
	Sea level changes	Rising sea level or storm surge increases range and human exposure	Likely	Likelihood of climate event is probable
<i>Naegleria fowleri</i>	Rising temperature	Increasing temperature associated with expanded range and conversion to flagellated form (infective)	More likely than not	Likelihood of climate event is high, but more research is needed to confirm disease trend

Pathogen	Climate-Related Driver	Possible Influence of Climate Change	Likelihood of Change	Basis for Assessment
<i>Cryptosporidium</i>	Rising temperature	Expanded recreational (swimming) season may increase likelihood of exposure and disease	About as likely as not	Likelihood of climate event is high, but there is insufficient research on this relationship
	Changes in precipitation	Increasing precipitation associated with increased loading of parasite to water and increased exposure and disease	Very likely	Likelihood of climate event is probable, and research supports this pattern; adaptive measures (water treatment and infrastructure) would reduce this the effect
<i>Giardia</i>	Rising temperature	Expanded recreational (swimming) season may increase likelihood of exposure and disease	About as likely as not	Likelihood of climate event is high, but there is insufficient research on this relationship
	Changes in precipitation	Increasing precipitation associated with increased loading of parasite to water and increased exposure and disease	Very likely	Likelihood of climate event is probable, and research supports this pattern; but adaptive measures (water treatment and infrastructure) would reduce this effect
	Shifts in reservoir host ranges or behavior	Increasing temperature associated with shifting range in reservoir species (carriers) and expanded disease range	About as likely as not	Likelihood of climate event is high, but there is insufficient research on this relationship

THREATS TO SWIMMERS FROM HARMFUL ALGAL BLOOMS

Harmful algal blooms (HABs), which are known as “red tides” when they occur in marine waters, are a growing problem in surface waters where nutrient-rich pollution can spur algal growth. Several species of phytoplankton, including *Karenia brevis*, *Alexandrium tamarense*, and *Pseudo-nitzschia australis*, produce potent toxins that can make people sick if they are exposed to contaminated water or if they eat contaminated fish or shellfish. These toxic organisms are a natural part of the phytoplankton community, but when conditions are right, they experience a rapid growth in numbers, resulting in a “bloom.” HABs can last for days, weeks, or months, and cause serious and potentially life-threatening human illnesses that have a slew of symptoms, including diarrhea, nausea, vomiting, abdominal cramping, chills, diminished temperature sensation, muscular aches, dizziness, anxiety, sweating, seizures, numbness and tingling of the mouth and digits, and paralysis, as well as cardiovascular and respiratory symptoms (Table 7).¹⁵ Approximately 10 percent of all foodborne disease outbreaks in the United States are caused by eating seafood contaminated by algal toxins.¹⁶ Toxins produced by harmful algae can aerosolize and cause respiratory distress even in beach visitors who do not enter the water.

Although the most common type of poisoning related to toxic blooms comes from eating contaminated shellfish, there are also instances in which such blooms have directly affected fishermen and swimmers and other recreational users of near shore marine and riverine waters. Toxic outbreaks of such organisms as *Pfiesteria piscicida*, which was first discovered in North Carolina in 1991, have been found to be associated with fish kills and with skin and neurological damage as well as memory loss.¹⁷ There were also instances in 1996 in which red tide algal blooms of *Gymnodinium brevis* on the west coast of Florida resulted in respiratory illness in beachgoers.

While red tides are a natural phenomenon, they are exacerbated by human impacts such as nutrient overloads into coastal waters, which spur their growth. The incidence of HABs has increased over the past 30 years, particularly along the New England coastline (see Figure 13).¹⁸ Analyzing data over a 50-year period from the southwest coast of Florida, researchers at the University of Miami determined that *K. brevis* red tides are occurring with greater frequency, closer to shore, and during more months of the year. They attribute this phenomenon to greater inputs of nutrients into coastal

Table 7. Algae and Their Threats to Human Health

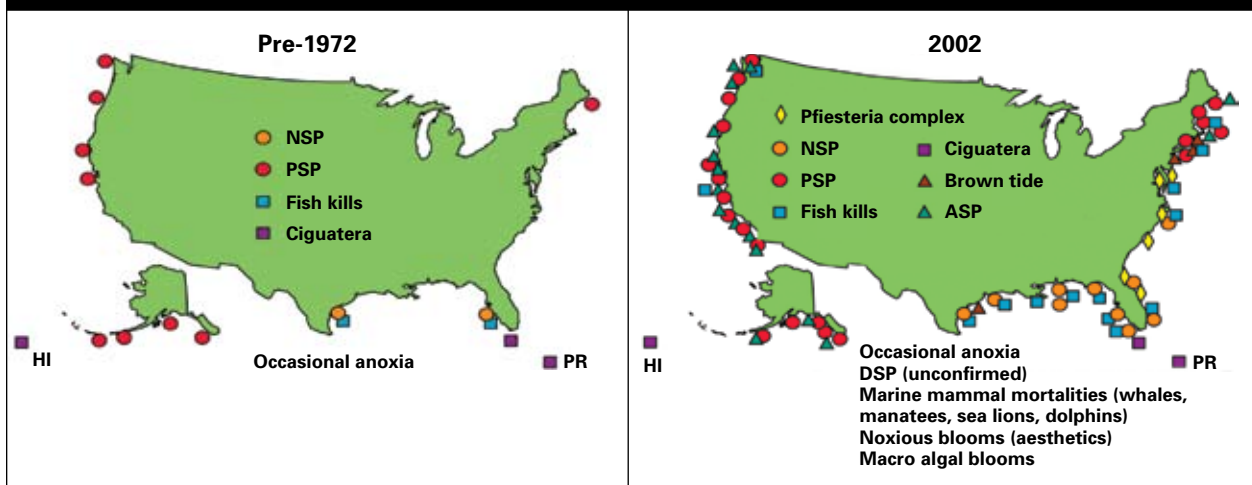
Algal Blooms	Health Risk
Cyanobacteria (mainly <i>Microcystis</i> and <i>Anabaena</i>)	Severe dermatitis, burning or itching of the skin, erythematous wheals, redness of lips and eyes, sore throat, asthma symptoms, dizziness
<i>Karenia brevis</i> (and other marine algae)	Irritation of the skin, eyes, nose, and throat, coughing, shortness of breath
<i>Pfiesteria piscicida</i>	Headache, confusion, skin rash, eye irritation, respiratory irritation
<i>Alexandrium tamarense</i>	Paralytic Shellfish Poisoning: tingling, numbness, and burning of the perioral region, ataxia, giddiness, drowsiness, fever, rash, and staggering; respiratory arrest in more severe cases
<i>Pseudo-nitzschia australis</i>	Amnesic Shellfish Poisoning: nausea, vomiting, abdominal cramps, and diarrhea; in more severe cases dizziness, headache, seizures, disorientation, short-term memory loss, respiratory difficulty, and coma

waters due to increased agricultural runoff and sewage discharges in the watershed over that time period.¹⁹ *K. brevis* red tides are also becoming more common elsewhere in the Gulf of Mexico. For example, along the Texas coast, red tide blooms occurred in all but one year between 1995 and 2002.²⁰ In August and September of 2007, red tides occurred off the coast of Delaware, the first documented occurrence of *K. brevis* north of Cape Hatteras, North Carolina.²¹

Climate change may be contributing to the increases in frequency, intensity, and duration of harmful algal blooms that have occurred on a global scale in the past few decades.²² The blooms are influenced by weather patterns, ocean temperature, and nutrients in the water. For example, heavy rains lead to increased runoff, and this runoff, especially nutrient-rich fertilizers from agriculture, is linked to the proliferation of harmful algal blooms. In the Gulf Coast, for instance, precipitation and runoff have both increased significantly over the past 100 years.²³

As is the case with pathogens, warmer waters may also result in expanded ranges of some harmful algae species.²⁴ For instance, shellfish toxicity from harmful algae in Puget Sound occurs in late summer and early fall when temperatures are warmest. Given that temperatures in the Puget Sound are expected to increase, so too will the window of time during which these harmful algae bloom.²⁵ Climate change might already be expanding the range of a few new toxic species of algae into the Chesapeake Bay estuary and causing others to bloom earlier. For example, a toxic alga normally associated with Florida and the Gulf Coast, *Alexandrium monilatum*, was believed to have been responsible for killing whelks

Figure 13. Expansion of HAB Problems in the United States²⁶



Abbreviations: NSP: Neurotoxic Shellfish Poisoning, PSP: Paralytic Shellfish Poisoning, ASP: Amnesic Shellfish Poisoning, and DSP: Diarrhetic Shellfish Poisoning

(a species of sea snail) in the York River in Virginia in 2007. This bloom represented a potential shift northward for this particular alga. Also, a large bloom of a toxic alga normally found in the Caribbean Sea, *Cochlodinium polykrikoides*, killed young fish and oysters in the lower Chesapeake Bay in August 2007.²⁷

Land use and development practices along coastlines and in watersheds can lead to increased runoff into water bodies and result in a greater number of red tide events. Man-made alterations to hydrology, such as dredging and filling, can slow water circulation and thus impede the ability of the water body to cleanse itself of harmful algae. Filter-feeding shellfish serve as natural cleansers of phytoplankton, so human activities that diminish shellfish populations reduce an ecosystem's capacity to naturally cleanse itself of toxic algae.

Efforts to deal with red tides have focused on mitigating the effects of these events, primarily through improved systems to monitor for harmful algal blooms, educate and communicate the risks to the general population, and learn more about the causes of harmful algal blooms and how they affect humans and aquatic life. Other techniques to prevent HABs involve restricting the movement of harmful algal species via the shellfish market and ship ballast water. For example, ballast water may be heated or chemically treated to prevent the introduction of invasive species, and trade may be restricted in shellfish from areas experiencing red tides. Strong efforts need to be made to control nutrient pollution from nonpoint sources (e.g., agricultural runoff and septic tank runoff) as well as from point sources (e.g., sewage treatment and aquaculture facilities) to reduce the number of red tide events.²⁸

WATER QUALITY STANDARDS

Current federal standards for recreational water quality are based on the concentration of fecal indicator bacteria, usually enterococcus and *E. coli*. They are called indicator bacteria because, although they may not be directly harmful to humans, they indicate the likely presence of fecal contamination, are relatively easy to test for, and are typically found in the presence of harmful pathogens. Testing for the full range of pathogens found in beachwaters is difficult, partly because if they are present they are often found at very low concentrations.

Under the Clean Water Act, the EPA is required to develop water quality criteria for pollutants based on their impact on human health and aquatic life. States then create limits, or standards, for these pollutants using the EPA recommended water quality criteria or other criteria that the EPA deems as protective. In 1986, the EPA developed criteria for testing recreational waters using *E. coli* and enterococci bacteria as pathogen indicators in Great Lakes (fresh) waters, and enterococci as indicators in marine and fresh waters, based on prior scientific research on their effectiveness (see Table 8).²⁹

As of 2000, only 11 states had adopted the 1986 criteria. Recognizing the need for consistent water quality criteria at recreational beaches, Congress passed the Beach Environmental Assessment and Coastal Health (BEACH) Act in 2000, amending the Clean Water Act to improve beachwater quality monitoring programs and processes for notifying the public of health risks from contamination at beaches. Under the BEACH Act, states were required to adopt standards based on the EPA's 1986 criteria for pathogen indicators.³⁰ In addition, the EPA was required to complete studies on the human health effects of pathogens in coastal recreational waters and to develop new criteria and methods for detecting pathogens by 2005.³¹ The EPA is now conducting additional epidemiological studies, setting new water quality criteria, and validating rapid test methods as a result of a settlement of an enforcement action brought by NRDC to enforce the BEACH Act requirements.

Table 8. Beachwater Quality Standards Required by the BEACH Act

Water Type	Indicator	Standard	
		For Multiple Samples ^a	For a Single Sample ^b
Marine	Enterococcus	35 per 100 ml	104 per 100 ml
Fresh	Enterococcus	33 per 100 ml	61 per 100 ml
	<i>E. coli</i>	126 per 100 ml	235 per 100 ml

a Geometric mean of at least five samples over a 30-day period.

b For designated beach areas.

The gastrointestinal illness rates predicted by the fecal indicator bacteria concentrations set by the EPA in 1986 have been confirmed throughout the world.³² However, the acceptable illness rate for full-body water contact that was used when setting the standards is high. Under the levels set by the EPA in the 1986 criteria, 19 out of 1,000 people swimming in ocean waters and 8 out of 1,000 swimmers in fresh waters just meeting these standards will become ill. Put another way, if a family of four were to swim once per week in the summer (June, July, and August) in ocean waters that just meet the EPA's standard, one member of the family would probably become ill.

According to a 2007 report by the U.S. Government Accountability Office (GAO), the current water quality criteria have other significant limitations.³³ The GAO concluded that the current indicators may not identify all health risks. For instance, the GAO pointed out that standards were developed primarily to address the risk of contracting gastroenteritis, but not necessarily to address rashes, earaches, pinkeye, respiratory infections, or very serious illnesses such as hepatitis and encephalitis (inflammation of the brain). An epidemiological study at four Great Lakes beaches noted that rates of gastrointestinal illness correlated with enterococcus levels, but other illnesses known to be associated with swimming did not.³⁴

The ability to test for pathogens instead of fecal indicator bacteria would strengthen the link between health standards and illness. While quantifying the concentrations of the multitude of pathogenic bacterial and viral species in recreational waters is difficult and expensive, the technologies for molecular methods are advancing and the possibility of directly detecting the relative presence of microbes has been demonstrated.^{35,36} Molecular methods take advantage of the fact that fecal indicator bacteria and pathogens themselves have unique genetic sequences that can be detected. Quantitative polymerase chain reaction (qPCR) is an example of a molecular method for quantifying very small amounts of specific sequences of RNA or DNA. Because molecular methods do not involve culturing live cells, there is a possibility that water quality standards could be developed for species that are not easily cultured. However, most molecular methods do not differentiate between live and dead cells, which is particularly problematic when measuring for water quality in waters that receive disinfected sewage. Also, molecular methods are susceptible to interference from chemicals, which could cause an underestimation of health risk.³⁷

If a family of four were to swim once per week in June, July, and August in ocean waters that just met the EPA's current bacteria standard, one member of the family would probably become ill.

Another potential problem with the EPA's bacterial indicator is that the underlying epidemiological studies used to develop pathogen indicators have been based primarily on exposure to human feces-dominated point-source contamination coming from pipes. In many coastal areas, diffuse, nonpoint sources—including urban runoff, septic system discharges, and animal waste—can be larger sources of pathogens in recreational waters. The EPA is now conducting studies at stormwater impacted beaches to address this concern.

A single gram of dog feces is estimated to contain 23 million bacteria,³⁸ and waterfowl feces contains similar amounts.³⁹ There is a widely held belief in the beachwater quality community that since the standards currently in use were developed by studying beachwater that was contaminated with human sewage, then only human fecal contamination makes humans sick and fecal matter from other animals is not pathogenic. For example, some states will leave a beach that is exceeding water quality standards open if source tracking reveals the source of indicator bacteria to be animals, because they believe the water is safer for swimming than it would be if the source of indicator bacteria were humans. However, EPA has analyzed this issue and has concluded that “both human and animal feces in recreational waters continue to pose threats to human health.”⁴⁰ In addition, the results thus far of an epidemiological study at Doheny Beach in Southern California, which is impacted by gull fecal matter, indicate that human illness rates from nonhuman fecal contamination may be similar to illness rates from human sources of fecal contamination.⁴¹ Drinking water contaminated with animal waste killed seven and hospitalized nearly 100 people with bloody diarrhea and vomiting in Walkerton, Ontario, in 2000.⁴²

Geographic differences in climate conditions, such as the amount of UV exposure, and temperature, for example, may affect the life cycle of pathogens and their impact on human health. As a result, pathogens can behave in different ways in tropical waters than in temperate waters. The current standards fail to capture the variability in the potential for

pathogens to regrow, persist, and die off, or to address variability in indicator/illness relationships.⁴³ The EPA is now conducting research to attempt to address these concerns.

Standards could include requirements about sampling locations and times. Recent studies establish that ambient concentrations of bacteria in dynamic aquatic environments can vary radically within short distances and time spans.⁴⁴ Also, since human viruses are generally more resistant to sunlight than the indicator organisms that are measured, sampling is best conducted in the early morning hours.⁴⁵

TIMELINESS OF ANALYSIS METHODS

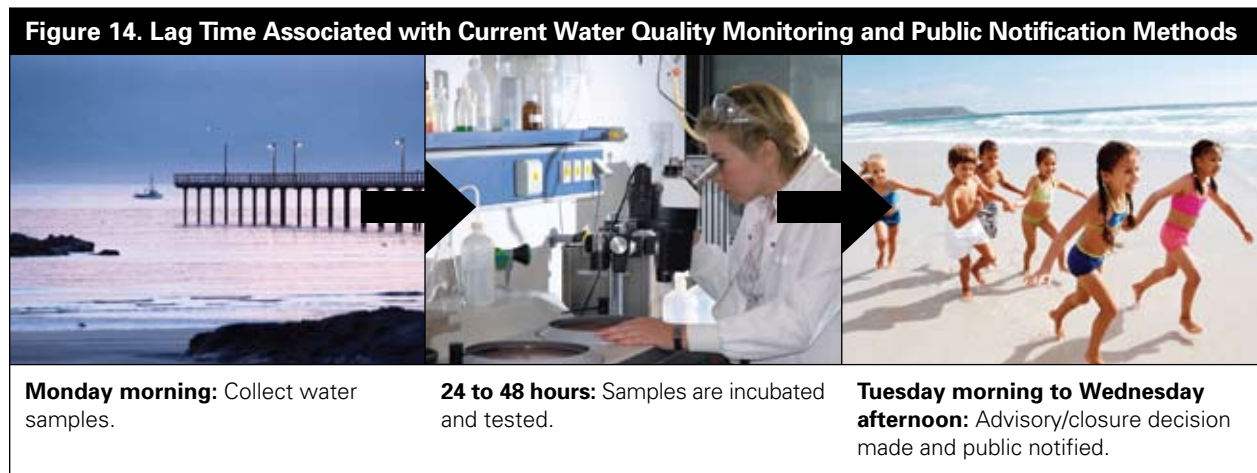
Perhaps the most significant challenge associated with current fecal indicator bacteria standards is that current approved detection methods for fecal indicator bacteria require a long incubation period, usually producing results in 24 hours. This lag time between when pathogen-contaminated waters are sampled and when the public is notified creates a window of time in which swimmers may be exposed to contaminated water (see Figure 14). In addition, it results in beaches being closed on days when the beachwater may meet standards.

The limitations of frequently used methods for monitoring beachwater quality to protect public health were illustrated by one local beach manager who demonstrated that at a particular beach, advisories and closings based on monitoring results were issued inaccurately 100 percent of the time.⁴⁶ Samples taken when the beach was under advisory or closed due to the previous day's monitoring results showed that the beachwater quality met standards on the days that the beach was under advisory or closing in every case.

The EPA included rapid detection technologies as part of its freshwater epidemiological surveys conducted in the Great Lakes in 2004. The study concluded that the use of faster indicators of recreational water quality would result in the ability to make decisions about recreational water quality on the day of sample collection and could thereby lower gastrointestinal illnesses in beach communities.⁴⁷ The economic benefit of faster testing and earlier posting was found to be about \$202,000 per year for two Great Lakes beaches. Racine, Wisconsin, is one city that has been testing and piloting different rapid detection technologies since 2006 with the goal of obtaining EPA approval.⁴⁸

The EPA has been conducting research for several years on the use of rapid test methods to determine beachwater quality, particularly using qPCR methods, including how the qPCR results correlate with other test methods of determining fecal indicator bacteria concentrations, whether qPCR detects all strains of fecal indicator bacteria, and whether the methods can be used to correlate the amount of indicator present with illness rates in swimmers.

Another promising rapid test method is immunomagnetic separation/adenosine triphosphate (IMS/ATP), which exploits the unique properties of the surfaces of target cells (e.g., enterococcus or *E. coli*) to capture and tag the cells and count their concentrations in a given sample. The use of IMS/ATP techniques for detecting microbes in surface



waters has not been studied as much as the use of qPCR, but it is being used in epidemiological studies this year. One of the challenges of IMS/ATP is that strains of indicator bacteria for which antibodies do not yet exist are not detected.⁴⁹

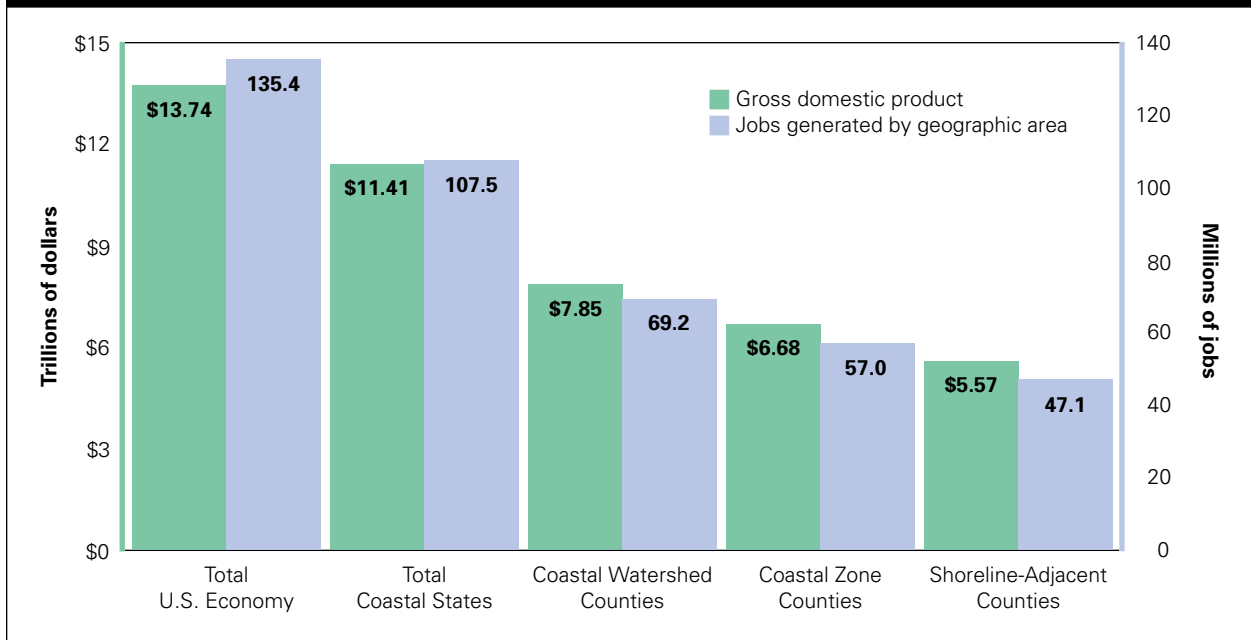
In 2009, more epidemiological studies using rapid test methods are being conducted at beaches in many areas, including California, Florida, and Puerto Rico.

Beachwater quality generally depends on many complex factors, but for some beaches, predictions of beachwater quality can be calculated fairly accurately based on a few physical measurements of daily conditions. Some states have taken advantage of this and have created computer beachwater quality models that rely on data from physical measurements such as rainfall levels, wind speed and direction, tides, wave heights, and currents. These models prepare rapid predictions of beachwater quality and allow for beaches to be closed or placed under advisory the day that bacterial levels are expected to be high, rather than 24 hours after samples with high bacteria concentrations are taken. Because the water quality at many beaches is adversely impacted by stormwater runoff, another, less sophisticated means of protecting public health is to preemptively close beaches or issue advisories when indicator bacteria levels are expected to be high after rainfall events. These preemptive rainfall advisories can be based on rainfall intensity or some other rain-related factor. States should always provide adequate warnings to swimmers when there has been a sewage spill.

THE ECONOMIC IMPACTS OF BEACH POLLUTION

Beaches, rivers, and lakes are the number one vacation destination for Americans; about one-fourth of the population goes swimming in our waterways every year.⁵⁰ Americans take more than 1.8 billion trips annually—or an average of approximately six trips per person per year—to fish, swim, boat, or just relax. In 2007, the nation’s shoreline-adjacent counties contributed \$5.5 trillion toward the nation’s gross domestic product and 47 million jobs (Figure 15).⁵¹ One report estimates that by 2010 more than 70 million individuals will visit ocean beaches annually—an increase of 50 percent above the figure for the year 2000. By 2010, Americans will spend almost 1 billion days by the beach each year.⁵² Economic activity directly associated with the ocean contributed more than \$138 billion to the U.S. economy in 2004.⁵³ Approximately 85 percent of all U.S. tourism revenue is received in coastal states.⁵⁴

Figure 15. The Value of the Coastal Economy (2007)



Polluted water puts these revenues at risk. A 2007 study by the National Oceanic and Atmospheric Administration (NOAA) found that an increase in water quality in Long Beach, California, to the healthier standards of Huntington City Beach would create \$8.8 million in economic benefits over a 10-year period.⁵⁵ A similar 2006 study compared the 1996 water quality of the Chesapeake Bay to the quality it would have had if legislation to clean the waters had never been passed. The study estimated that the water quality improvements increased annual boating, fishing, and swimming revenue between \$357.9 million and \$1.8 billion.⁵⁶

The property value of houses and land near waters is also threatened by pollution. An American Housing Survey found that, all other things being equal, a location within 300 feet of a waterbody increases the value of a home by up to 28 percent.⁵⁷ The New Jersey Department of Environmental Protection included beaches when recently conducting a study on the value of certain natural features in the state.⁵⁸ Assuming that people are willing to pay to be close to environmental features that are attractive to them, the study analyzed the effect of proximity to beaches on actual residential housing prices. The study focused on seven local housing markets located in Middlesex, Monmouth, Mercer, and Ocean counties, which are representative of the state as a whole. Results showed that in four of the seven markets, sale prices for homes within 300 feet of a beach were between \$81,000 and \$194,000 higher than homes more than 300 feet away.⁵⁹

Researchers concluded that higher property values are associated with proximity to beaches and open water, and that people are willing to pay more to be closer to these attractive environmental features. Similarly, property values in close proximity to water increase with water quality improvements. Along Maryland's western shore of the Chesapeake Bay, localized improvements in fecal coliform counts so that state standards are met would increase waterfront property values by approximately 6 percent.⁶⁰

In addition to harming people, pathogen pollution causes ecological impacts, which in turn have economic impacts.⁶¹ Each year, 4 million visitors augment the 90,000 inhabitants of the Florida Keys; its reefs are the biggest diving destination in the world.⁶² A 2003 study estimates that reef-related sales in Broward County, Florida, contribute more than \$2 billion to the economy and provide more than 35,000 jobs.⁶³ Yet coral reefs are adversely impacted by a combination of rising temperatures, increasing nutrients, and pathogen pollution from sources such as untreated or inadequately treated sewage. Diseases killing coral, sponges, and other marine life were first identified about 30 years ago, and most were unknown just 10 years ago.⁶⁴ Fecal contamination from sewage in the Florida Keys is thought to be a major source of disease in coral. Elkhorn coral (*Acropora palmata*) was once the most common coral in the Caribbean; more than 90 percent has died since 1980.⁶⁵ In 2006, the species was listed on the U.S. Endangered Species List.⁶⁶ Scientists in Queensland, Australia—using an epidemiological technique first used to link smoking to lung cancer in the 1960s—have uncovered a causal link between agricultural pollution, low coral biodiversity, and poor recolonization of the reef.⁶⁷ Hard coral biodiversity was found to be almost twice as high on the reefs far from agricultural areas as on the reefs close by. Upsetting the nutrient balance of the oceans can stimulate the growth of algae. Algal growth on reefs may damage coral by taking over habitat space that would otherwise be occupied by coral.⁶⁸

Explosive growth of toxin-producing algae, or harmful algal blooms, occurs in many coastal states. These events also create substantial economic costs in terms of their impact on public health (lost work days and medical costs), commercial fisheries, recreation and tourism, and monitoring and management. A 2006 report estimates that harmful algal blooms cost the United States \$82 million a year.⁶⁹ Over the last several decades, algal blooms in the United States have caused more than \$1 billion in cumulative economic loss.⁷⁰

Polluted beaches cause a loss to those who had planned to visit the beach and swim in the water that in turn costs local economies in the form of lost tourist dollars and jobs. Coastal tourism, attributable in part to clean beaches, generates substantial revenues for state and local governments. Economists estimate that a typical swimming day is worth \$30.84 to each individual.⁷¹ Depending on the number of potential visitors to a beach, this “consumer surplus” loss can be quite significant. For example, one study estimated economic losses as a result of closing a Lake Michigan beach due to pollution as ranging between \$7,935 and \$37,030 per day.⁷²

While beach closings may be necessary to protect swimmers, they are no substitute for efforts to clean up our waters. In fact, the Lake Michigan study estimated that even a perfectly implemented beach closing policy would result in considerable economic losses and reduce predicted illnesses by only 42 percent.⁷³ Another study, performed in Orange County, California, evaluated the economic burden of several individual illnesses that can be contracted from swimming

in polluted recreational marine waters. For the two beaches studied, researchers estimated the cumulative public health cost from lost wages and medical care to treat the more than 74,000 incidents of illness annually by calculating a cost for each illness (Table 9). The total annual burden was \$3.3 million, excluding personal out-of-pocket expenses associated with having a prescription filled after a doctor visit or the costs of self-medication.⁷⁴

Coastal industries like commercial fin fishing and shell fishing are also affected by beach pollution. In 2006, the U.S. commercial fishing industry (including processors and retailers) generated more than \$44 billion in income and supported more than 1.5 million jobs.⁷⁵ According to the National Oceanic and Atmospheric Administration's National Marine Fisheries Service, U.S. fishermen in the 50 states brought 9.3 billion pounds of commercial fish and shellfish to market in 2007, with a total annual value of \$4.2 billion.⁷⁶ This value increases more than tenfold, to an estimated \$44 billion, in the retail marketplace.⁷⁷ In 2006, 13.6 million individuals participated in recreational angling, thus contributing \$82 billion directly to the economy and generating more than 500,000 jobs.⁷⁸

Harmful algal blooms, spurred by nutrients delivered by stormwater and other sources, can close shellfish beds for prolonged periods. In the spring and summer of 2005, shellfish beds from Maine to Cape Cod that represented more than 35 percent of the nation's clam harvest were closed due to the worst toxic algal bloom in New England since 1972. The problem was so bad that the governor of Massachusetts asked the Small Business Administration to declare an "economic injury disaster" for the state's fishermen and related businesses.⁷⁹

Some areas either do not monitor their beaches or do not close them when water quality fails to meet standards. This can result in lower short-term losses for businesses in the area, but it also means that those who get sick will incur medical costs and lost workdays as a result. Cleaning up the sources of pollution so that beachwater does not pose a health risk is the optimal solution. In the meantime, protecting public health will require improved beachwater monitoring and closing of beaches when contamination is detected or suspected, rather than allowing people to swim and get sick. Given the large number of people using beaches and the substantial income from coastal tourism, the cost of monitoring programs is reasonable.

Table 9. Cost Estimates for Illnesses Associated with Polluted Water Due to Lost Wages and Medical Care

Type of Illness	Cost Per Illness
Gastrointestinal Illness	\$36.58
Acute Respiratory Disease	\$76.76
Per Ear Ailment	\$37.86
Per Eye Ailment	\$27.31

Source: Ryan H. Dwight, Linda M. Fernandez, Dean B. Baker, Jan C. Semenza, and Betty H. Olson, "Estimating the Economic Burden from Illnesses Associated with Recreational Coastal Water Pollution: A Case Study in Orange County, California," in *Journal of Environmental Management*, 76 (2): 95–103, 2005, p.1–9.

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