Chapter 6

Human Health Impacts of CSOs and SSOs

In this chapter:

In addition to causing and contributing to the environmental impacts reported in Chapter 5, CSOs and SSOs can cause or contribute to human health impacts. Microbial pathogens and toxics can be present in CSOs and SSOs at levels that pose a risk to human health. Human health impacts occur when people become ill due to contact with or ingestion of water or shellfish that have been contaminated with microbial pathogens or toxics.

Although it is clear that CSOs and SSOs contain disease-causing pathogens and other pollutants, EPA found limited quantitative evidence of actual human health impacts attributed to specific CSO and SSO events. Factors such as under-reporting and incomplete tracking of waterborne illness, the presence of pollutants from other sources, and the use of non-pathogenic indicator bacteria in water quality monitoring often make it difficult to establish a cause-and-effect relationship between human illnesses and CSO and SSO discharges.

This chapter documents and expands the current understanding of human health impacts from CSOs and SSOs. The chapter first describes the pollutants commonly present in CSOs and SSOs that can cause human health impacts. The next sections discuss human exposure pathways; demographic groups and populations that face the greatest exposure and risk of illness; and ways in which human health impacts from CSOs and SSOs are communicated, mitigated, or prevented. The identification and tracking of illnesses associated with CSOs and SSOs are also discussed. Several examples of human health impacts are provided in the chapter.

6.1 What Pollutants in CSOs and SSOs Can Cause Human Health Impacts?

The principal pollutants present in CSOs and SSOs that can cause human health impacts are microbial pathogens and toxics. The presence of biologically active chemicals (e.g., antibiotics, hormones, and steroids) is also a concern but is less well understood at this time.

6.1.1 Microbial Pathogens

Microbial pathogens include hundreds of different types of bacteria, viruses, and parasites. Microbial pathogens of human and non-human origin are present in domestic and industrial wastewater. The presence of specific microbial pathogens in wastewater depends on what is endemic or epidemic in the local community and is often transient. Some microbial pathogens also have environmental sources. In general, microbial pathogens are easily transported by water. They can cause disease in aquatic biota and illness or even death in humans. The three major categories of microbial pathogens present in CSOs and SSOs are bacteria, viruses, and parasites. Fungi do not have a major presence in wastewater (WERF 2003b), and thus in CSOs and SSOs.

Bacteria

Bacteria are microscopic, unicelluar organisms. Two broad categories of bacteria are associated with wastewater: indicator bacteria and pathogenic bacteria. Indicator bacteria are common in human waste and are relatively easy to detect in water, but they are not necessarily harmful themselves. Their presence is used to indicate the likely presence of disease-causing, fecal-borne microbial pathogens that are more difficult to detect. Enteric (intestinal) bacteria have been used for more than 100 years as indicators of the presence of human feces in water and overall microbial water quality (NAS 1993). Enteric bacteria commonly used as indicators include total coliform, fecal coliform, *E. coli*, and enterococci. Further discussion of bacterial indicators is provided in Section 6.6.

Pathogenic bacteria are also common in human waste and are capable of causing disease. Human health impacts from pathogenic bacteria most often involve gastrointestinal illnesses. The predominant symptoms of pathogenic bacterial infections include abdominal cramps, diarrhea, fever, and vomiting. Pathogenic bacteria can also cause diseases such as typhoid fever, although this is not common in the United States. In addition to attacking the human digestive tract, the pathogenic bacteria present in CSOs and SSOs can cause illnesses such as pneumonia, bronchitis, and swimmer's ear. Common pathogenic bacteria, typical concentrations present in sewage (where available), and associated disease and effects are summarized in Table 6.1.

Viruses

Viruses are submicroscopic infectious agents that require a host in which to reproduce. Once inside the host, the virus reproduces and manifests in illness (EPA 1999c). More than 120 enteric viruses are found in sewage (NAS 1993). The predominant symptoms resulting from enteric virus infection include vomiting, diarrhea, skin rash, fever, and respiratory infection. Most waterborne and seafood-borne diseases throughout the world are caused by viruses (NAS 2000). Many enteric viruses, however, cause infections that are difficult to detect (Bitton 1999). A list of common enteric viruses, including typical

Table 6.1

Common Pathogenic Bacteria Present in Sewage

Infective dose is defined as the number of pathogens required to cause subclinical infection. Infective doses are typically given as ranges, as the actual infective dose depends on the pathogen strain and an individual's health condition.

Bacteria	Concentration in Sewage[a] (per 100mL)	Disease[b]	Effects[b]	Infective Dose[c,d]
Campylo-bacter	3,700 -100,000	Gastroenteritis	Vomiting, diarrhea	10^2 - 10^6
Pathogenic *E. coli*	30,000 - 10,000,000	Gastroenteritis	Vomiting, diarrhea, Hemolytic Uremic syndrome (HUS), death in susceptible populations	10^6 - 10^8
Salmonella	0.2 - 11,000	Salmonellosis	Diarrhea, dehydration	10^4 - 10^7
S. typhi		Typhoid fever	High fever, diarrhea, ulceration of the small intestine	10^3 - 10^7
Shigella	0.1 - 1,000	Shigellosis	Bacillary dysentery	10^1 - 10^2
Vibrio cholera		Cholera	Extremely heavy diarrhea, dehydration	10^3 - 10^8
Vibrio non-cholera	10 - 10,000	Gastroenteritis	Extremely heavy diarrhea, nausea, vomiting	10^2 - 10^6
Yersinia		Yersinosis	Diarrhea	10^6

[a] Details in Appendix I
[b] EPA 1999C
[c] Yates and Gerba 1998
[d] Lue-Hing 2003

concentrations present in sewage (where available), and associated disease and effects are summarized in Table 6.2. Infective doses are not reported; enteric viruses typically are very infectious.

Parasites

Parasites by definition are animals or plants that live in and obtain nutrients from a host organism of another species. The parasites in wastewater that pose a primary public health

Table 6.2

Common Enteric Viruses Present in Sewage

Enteric viruses are typically very infectious: 1-10 virus particles can cause infection.

Virus Group	Concentration in Sewage[a] (per 100mL)	Disease[b]	Effects [b]
Adenovirus	10 - 10,000	Respiratory disease, gastroenteritis, pneumonia	Various effects
Astrovirus		Gastroenteritis	Vomiting, diarrhea
Noraviruses (includes Norwalk-like viruses)		Gastroenteritis	Vomiting, diarrhea
Echovirus		Hepatitis, respiratory infection, aseptic meningitis	Various effects, including liver disease
Enterovirus (includes polio, encephalitis, conjunctivitis, and coxsackie viruses)	0.05 - 100,000	Gastroenteritis, heart anomalies, aseptic meningitis, polio	Various effects
Reovirus	0.1 - 125	Gastroenteritis	Vomiting, diarrhea
Rotavirus	0.1 - 85,000	Gastroenteritis	Vomiting, diarrhea

[a] Details in Appendix I
[b] EPA 1999C
[c] Yates and Gerba 1998
[d] Lue-Hing 2003

concern are protozoa and helminths (NAS 1993). Parasitic protozoa commonly present in sewage include *Giardia lamblia, Cryptosporidium parvum*, and *Entamoeba histolytica*. These protozoa cause acute and chronic diarrhea (NAS 1993). *Giardia* causes giardiasis, which is one of the most prevalent waterborne diseases in the United States (EPA 2001e).

Ranges of typical concentrations of protozoa in sewage and information on infective doses are summarized in Table 6.3. As shown, ingestion of a small number of parasitic protozoa is capable of initiating infection. Therefore, the presence of low levels of parasitic protozoa in wastewater is a greater health concern than are low levels of most pathogenic bacteria (NAS 1993).

Helminths, or parasitic worms, include roundworms, hookworms, tapeworms, and whipworms. These organisms are endemic in areas lacking adequate hygiene. Very little documentation of waterborne transmission of helminth infection is available (NAS 1993). Helminth infections can be difficult to diagnose and often exhibit no obvious symptoms.

Indicator Bacteria and Microbial Pathogens in Sewage

Microbial pathogen concentrations in sewage vary greatly depending on the amount of illness and infection in the community served by the sewer system. The time of year can also be important, as some outbreaks of viral disease are seasonal. Average concentrations of indicator bacteria (e.g., fecal coliform) and other microbial pathogens (enteric viruses and protozoan parasites) shed by an infected person are shown in Table 6.4. These high concentrations illustrate that a single person shedding pathogenic organisms can cause a large pathogen load to be discharged to a municipal sewer system.

6.1.2 Toxics

As described in Section 4.1 of this report, toxics are chemicals or chemical mixtures that, under certain circumstances of exposure, pose a risk to human health. Individuals can suffer chronic health effects resulting from prolonged periods of ingestion or consumption of water, fish, and shellfish contaminated with a toxic substance. Generally, metals and synthetic organic chemicals are the

Table 6.3

Common Parasitic Protozoa Present in Sewage

Parasitic protozoa have very low infective doses, which makes their presence in CSO and SSO discharges an important public health concern.

Parasitic Protozoa	Concentration in Sewage[a] (per L)	Disease[b]	Effects[b]	Infective Dose[c]
Cryptosporidium	3 - 13,700	Crypto-sporidiosis	Diarrhea	1 - 150
Entamoeba	4 - 52	Amedbiasis (amoebic dysentery)	Prolonged diarrhea with bleeding, abscess of the liver and small intestine	10 - 20
Giardia	2 - 200,000	Giardiasis	Mild to severe diarrhea, nausea, indigestion	10 - 100

[a] Details in Appendix I
[b] EPA 1999C
[c] Yates and Gerba 1998

Table 6.4

Concentration of Indicator Bacteria and Enteric Pathogens Shed by an Infected Individual (Schaub 1995)

This table shows that a single infected person can shed a large number of pathogenic organisms.

Organism	Number per Gram of Feces
Fecal Coliform Bacteria	10^8 to 10^9
Enteric Viruses	10^3 to 10^{12}
Protozoan Parasites	10^6 to 10^7

toxic substances present in CSO and SSO discharges that can cause human health impacts. Metals and synthetic organic chemicals are introduced into sewer systems through a variety of pathways (Ford 1994). These include permitted industrial discharges, improper or illegal connections, improper drain disposal of chemical remnants, and urban runoff in areas served by CSSs. While the occurrence and concentration of specific toxics in CSOs and SSOs vary considerably from community to community and from event to event depending on site-specific conditions (see Tables 4.4 and 4.5), EPA found no evidence of human health impacts due to toxics in CSO and SSO discharges.

Metals

The metals most commonly identified in wastewater include cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc (AMSA 2003a). In CSSs, storm water can also contribute metals. EPA's Nationwide Urban Runoff Program (NURP) identified copper, lead, and zinc in 91 percent of urban storm water samples collected (EPA 1983a). That is, all three metals were present in 91 percent of samples. Other metals commonly detected in urban runoff include arsenic, cadmium, chromium, and nickel. The NURP Program focused on end-of-pipe samples and therefore did not consider receiving water impacts.

Metals are a human health concern for two reasons. First, metals are persistent in the environment. This creates an increased chance of long-term human exposure once metals are introduced to a waterbody. Second, metals such as arsenic, cadmium, lead, and mercury bioaccumulate in the human brain, liver, fat, and kidneys, causing detrimental effects. Other impacts that can be caused by metals include dermatitis, hair loss, gastrointestinal distress, bone disease, and developmental illnesses.

Synthetic Organic Chemicals

The synthetic organic chemicals that have been identified in CSOs and SSOs include chlorinated aromatic hydrocarbons such as polychlorinated biphenyls (PCBs), chlorinated hydrocarbons such as pesticides, and polycyclic aromatic hydrocarbons. Synthetic organic chemicals can be ingested by drinking contaminated water or by eating contaminated fish that have bioaccumulated the chemical. Synthetic organic chemicals can also be absorbed through the skin. Their effects on humans range from skin rash to more serious illnesses including anemia, nervous system and blood problems, liver and kidney problems, reproductive difficulties, and increased risk of cancer.

6.1.3 Biologically Active Chemicals

Recent research efforts have begun to consider the presence of biologically active chemicals—antibiotics, caffeine, hormones, human and veterinary drugs, and steroids—in wastewater (Kümmerer 2001). For the most part, these chemicals have not undergone extensive analysis for environmental fate and transport, human health impacts, or ecological impacts. Concerns about the presence of these biologically active chemicals focus on abnormal physiological processes and reproductive impairments, increased incidence of cancer, development of antibiotic-resistant bacteria, and potential increased toxicity of chemical mixtures. Human health effects, however, are largely unknown (Kolpin et al. 2002).

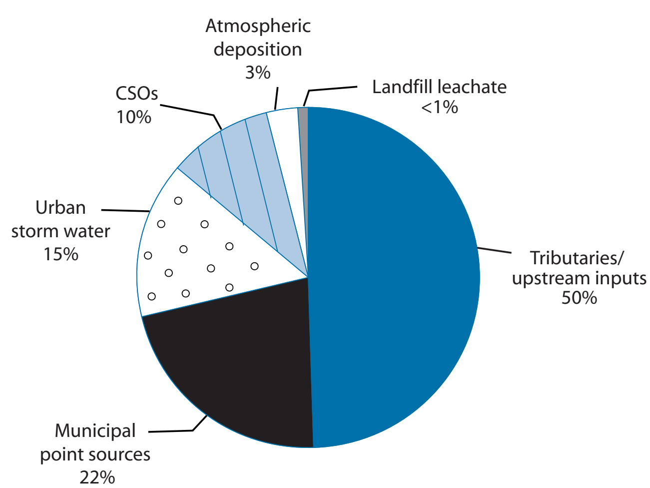
Little is known about the effectiveness of conventional wastewater treatment processes in the removal of these biologically active chemicals. The relative concentrations of these chemicals in CSOs and SSOs are also unknown.

6.2 What Exposure Pathways and Reported Human Health Impacts are Associated with CSOs and SSOs?

Humans may be exposed to the pollutants found in CSOs and SSOs through several pathways. The most common pathways include recreating in waters receiving CSO or SSO discharges, drinking water contaminated by CSO

Sources of Synthetic Organic Chemicals Deposition: NY/NJ Harbor

The New York-New Jersey Harbor Estuary Program sponsored studies to estimate pollutant loads, including loads of synthetic organic chemicals to New York Harbor. As shown, the studies identified six sources of PCB inputs to the harbor. Application of a mass balance water quality food chain model for PCBs indicated that discharges of PCBs to the lower estuary from municipal point sources and CSOs are significant in causing PCB levels in striped bass to exceed the FDA standard for fish consumption (NYNJHEP 1996).



or SSO discharges, and consuming or handling fish or shellfish that have been contaminated by CSO or SSO discharges. Other pathways include direct contact with discharges, occupational exposure, and secondary transmission.

During wet weather events, CSO- and SSO-impacted waterbodies typically receive microbial pathogens and toxics from a variety of other sources including municipal and industrial wastewater discharges, urban storm water runoff, and agricultural nonpoint source discharges. These "interferences" can complicate the identification of specific cause-and-effect relationships between individual CSO or SSO discharges and human health impacts.

6.2.1 Recreational Water

In the United States, millions of people use natural waters (e.g., oceans, lakes, rivers, and streams) each year for a variety of recreational activities. The National Survey on Recreation and the Environment, conducted by the U.S. Forest Service and NOAA, describes nationwide participation in 50 categories of outdoor recreation activities (Leeworthy 2001). The survey estimates the percentage of the population, 16 years of age or older, participating in water-based recreation activities. Participation in more than one activity in a single water-based recreation category is possible (e.g., respondents may report both sailing and canoeing). Data from the most recent version of the survey (the period of July 1999 to January 2001) are presented in Table 6.5.

A number of studies have documented the risks of gastroenteritis among people recreating in water contaminated with microbial pathogens (NAS 1993; Wade et al. 2003). Recreational exposure generally comes from contaminants suspended in the water column entering the body via oral ingestion. Exposure can also occur through the eyes, ears, nose, anus, genitourinary tract, or dermal cuts and abrasions (Henrickson et al. 2001). Contact with and ingestion of ocean water near wastewater or storm drain outfalls have resulted in increases in reported respiratory, ear, and eye symptoms by ocean swimmers and surfers (Corbett et al. 1993; Haile et al. 1999).

As described in Chapter 5, 25 percent of the beaches inventoried in EPA's National Health Protection Survey of Beaches under the BEACH Program had at least one advisory or area closing during the 2002 swimming

Table 6.5

Participation in Water-Based Recreation in U.S. between July 1999 and January 2001

The National Survey on Recreation and the Environment estimates nationwide participation in various outdoor recreation activities, including water-based recreation. Participation in more than one activity is possible.

U.S. Population (16 and Older)	Boating/Floating [a]	Fishing	Swimming [b]
Percent participating	36%	34%	61%
Number in millions	77	72	131

[a] Includes sailing, canoeing, kayaking, rowing, motor-boating, water skiing, personal watercraft use, wind surfing, and surfing.
[b] Includes swimming in freshwater or saltwater, snorkeling, scuba, and visiting a beach.

season. Elevated bacteria levels were cited as the primary cause for 75 percent of these beach advisories or closures. CSOs were reported to be responsible for 1 percent of reported closings and advisories, and 2 percent of advisories and closures that had a known cause. SSOs (including sewer line breaks) were reported to be responsible for 6 percent of all reported advisories and closings, and 12 percent of advisories and closing that had a known cause (EPA 2003a).

Reported Human Health Impacts

A review of CDC Surveillance Summaries identified 74 waterborne disease outbreaks linked to open recreational waters (i.e., rivers, streams, beaches, lakes, and ponds) from 1985 to 2000. A waterborne disease outbreak is defined by CDC as two or more people experiencing similar illness after exposure to a waterborne pathogen. A total of 5,601 cases of illness were attributed to these 74 waterborne disease outbreaks (CDC 1988, 1990, 1992, 1993, 1996a, 1998, 2000, 2002).

The source of the pathogens causing these waterborne disease outbreaks was not identified in CDC's reports. These waterborne disease outbreaks, however, were caused by the types of microbial pathogens found in CSOs and SSOs. Figure 6.1 shows that *Shigella*, which is present in CSOs and SSOs, caused the largest number of recreational water-associated outbreaks having a known cause.

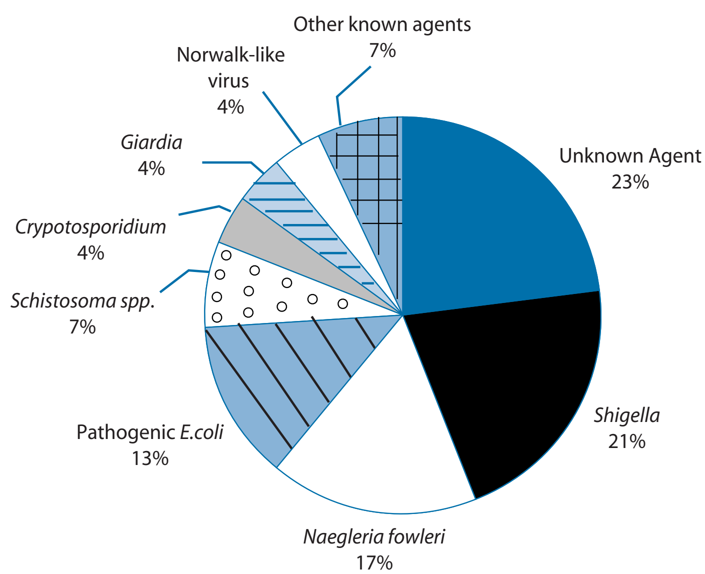
Additional information from CDC Surveillance Summaries on outbreaks linked to recreational exposure in fresh or marine waters contaminated with microbial pathogens is presented in Appendix I.

CDC Surveillance Summaries also identify outbreaks linked to swimming pools or hot tubs. For swimming pools and hot tubs, 191 recreational waterborne disease outbreaks with 14,836 cases of illness were reported to CDC between 1985 and 2000 (CDC 1988, 1990, 1992, 1993, 1996a, 1998, 2000, 2002). This is 265 times the

Figure 6.1

Microbial Pathogens Linked to Outbreaks in Recreational Waters, 1985 - 2000

Shigella was the most commonly identified cause of waterborne disease outbreaks linked to recreational waters between 1985 and 2000. *Shigella* has a relatively low infective dose of 10-100 and is typically found in wastewater in concentrations of 0.1-1,000 per 100 mL of sewage.



number of illnesses reported for open recreational waters.

Estimated Illnesses at Recognized Beaches

In developing this Report to Congress, EPA found an absence of direct cause-and-effect data relating the occurrence of CSO and SSO discharges to specific human health impacts. Lacking comprehensive data, EPA was able to implement an alternate approach to estimate the annual number of illnesses caused by recreational exposure to CSO and SSO discharges at a small subset of the nation's swimming areas—that is, those recreational beaches recognized by state authorities ("recognized beaches"). EPA's illness estimate was based on existing environmental and recreational use databases. Data limitations made it impossible to develop a comprehensive estimate of illness at all swimming areas at this time, but EPA believes that a significant number of additional illnesses occur in exposed swimmers at many inland and unrecognized beaches.

EPA's estimation of illness at recognized beaches was limited to gastrointestinal illness. EPA employed a multi-step process, including the following:

- Number of recognized beaches using specific management approaches;
- Number of CSO and SSO events impacting recognized beaches;
- Number of individuals exposed annually;
- Average concentration of fecal coliform bacteria at affected beaches;
- Rate of infection for exposed population; and
- Total annual number of gastrointestinal illnesses.

The number of highly credible gastrointestinal illnesses (HCGI) resulting from human exposure to SSOs and CSOs at recognized beaches was estimated by combining information on the number of exposed swimmer days, the concentration of indicator bacteria to which swimmers are exposed, and the Cabelli/Dufour dose-response functions for marine and fresh waters. First, EPA calculated the total number of illnesses caused by CSOs and SSOs, and then attributed them separately to CSO illnesses or SSO illnesses according to the ratio of CSO to SSO events in the BEACH Survey. A more detailed presentation of EPA's methodology is included in Appendix J.

Results from the analyses are presented in Table 6.6. The range shown reflects differences in how compliance rates with beach advisories were estimated. The lower bound uses a compliance rate of 90 percent, and the upper bound uses a compliance rate of 36 percent. As shown, CSOs and SSOs are estimated to cause between 3,448 and 5,576 illnesses annually at the recognized beaches included in this analysis. This estimate captures only a portion of the likely number of annual illnesses attributable to CSO and SSO contamination of recreational waters.

Table 6.6

Estimated Illness Resulting from Recreational Exposure to CSOs and SSOs at Select Beaches

This table shows the portion of the estimated number of annual illnesses attributable to exposure to CSO and SSO contaminated water at state-recognized beaches in the U.S. and its territories.

Source	Lower Bound	Upper Bound
SSOs	2,269	3,669
CSOs	845	1,367
CSO/SSOs	334	540
Total	**3,448**	**5,576**

6.2.2 Drinking Water Supplies

Public water systems regulated by EPA, states, and tribes provide drinking water to 90 percent of Americans (EPA 2002e). Approximately 65 percent of the population served by these systems receive water primarily taken from surface water sources such as rivers, lakes, and reservoirs. The remaining 35 percent drink water that originated as groundwater (EPA 1999d).

Reported Human Health Impacts

People can contract waterborne diseases through consumption of municipal drinking water, well water, or contaminated ice. Because drinking water is directly ingested, and it is generally ingested in larger quantities than recreational water that is accidentally ingested, drinking water is an important pathway of exposure. From 1985 to 2000, 251 outbreaks and 462,169 cases of waterborne illness related to contaminated drinking water were reported to CDC (CDC 1988, 1990, 1992, 1993, 1996a, 1998, 2000, 2002). The vast majority of these cases of illness are from a 1993 cryptosporidiosis outbreak in Milwaukee, Wisconsin, which affected an estimated 403,000 people; the CDC did not specifically identify untreated wastewater as contributing to the Milwaukee outbreak.

As shown in Appendix I, EPA identified a subset of 55 of these 251 outbreaks linked to drinking source water contaminated with human sewage or to drinking water taken

SSOs linked to Drinking Water Contamination: Cabool, MO

Between December 15, 1989, and January 20, 1990, residents of and visitors to Cabool, Missouri, experienced 243 cases of diarrhea and four deaths (Swerdlow et al. 1992). The CDC conducted a household survey and concluded that persons drinking municipal water were 18.2 times more likely to develop diarrhea than persons using private well water (Geldreich et al. 1992). Observations suggested that Cabool's SSS was prone to excessive storm water infiltration and therefore was unable to convey all of the wastewater to the treatment facility. As a result, frequent capacity-related SSOs occurred, spilling sewage onto the ground surface in areas over drinking water distribution lines and near water meter boxes. During the outbreak, the water distribution system was under construction, allowing untreated sewage to contaminate the drinking water system (Geldreich et al. 1992).

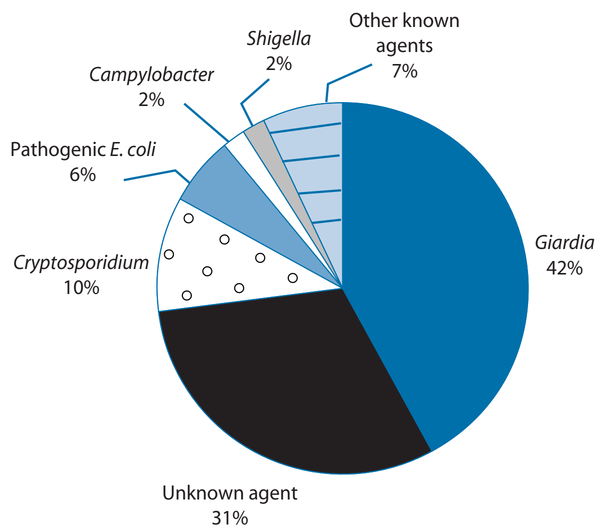


Figure 6.2

Microbial Pathogens Causing Outbreaks Linked to Drinking Water 1985 - 2000

Giardia was responsible for 42 percent of the outbreaks of waterborne disease linked to drinking water.

from rivers, streams, or lakes. Of these, EPA identified 11 outbreaks accounting for 7,764 cases of waterborne illness that CDC linked to drinking water contamination with sewage. Only one of these outbreaks was linked directly to CSOs or SSOs. The outbreaks were caused, however, by the types of microbial pathogens found in CSOs and SSOs. As shown in Figure 6.2, *Giardia*, which is present in significant concentrations in CSOs and SSOs, caused the largest number of outbreaks linked to drinking water. A summary of these outbreaks is provided in Appendix I.

Proximity of CSO Outfalls to Drinking Water Intakes

As described in Chapter 5 and documented in Appendix F, EPA geo-referenced more than 90 percent of all CSO outfalls. EPA compared the locations of these CSO outfalls to drinking water intakes. Only drinking water systems that serve a community on a year-round basis and that use surface water as the primary source of water were considered in this analysis. Approximately 7,519 such systems operate in the United States, of which 6,631 (85 percent) have been

Drinking Water Contaminated by Sewage: Brushy Creek, TX

In July 1998, a lighting strike and the subsequent power outage caused 167,000 gallons of raw sewage to flow into Brushy Creek in Texas (TDH 1998). The sewage contaminated municipal drinking water wells that supplied the community of Brushy Creek. Although the wells are not in direct contact with surface waters (the wells are more than 100 feet deep and encased in cement), drought conditions at the time are thought to have caused water from Brushy Creek to be drawn down into the aquifer and into the wells through a geologic fissure. It is estimated that 60 percent of Brushy Creek's population of 10,000 were exposed to *Cryptosporidium* and approximately 1,300 residents became ill with cryptosporidiosis. Residents of Brushy Creek were supplied water from the contaminated wells for approximately eight days (TDH 1998).

geo-referenced to the NHD and are included in this analysis.

All of the drinking water systems within one mile of any CSO outfall were selected for further analysis. As shown in Table 6.7, EPA identified seven states with outfalls located within one mile upstream of a drinking water intake. Phone interviews were conducted with both the NPDES permit-holder and drinking water authority in the identified areas to confirm the location of the CSO outfall, the status of the CSOs (active/inactive), and the location of the drinking water intake. In many cases, the NPDES permit-holder reported that the CSO was inactive, as a result of sewer separation or other CSO controls.

EPA identified and confirmed 59 active CSO outfalls within one mile of a drinking water intake. One NPDES-permit holder reported that receiving water modeling found that the drinking water intake (located within one mile, but on the opposite side of the river) was not affected by the CSO. Interviews with drinking water authorities found, where a primary drinking water intake was located within one mile of an active CSO, each drinking water authority was aware of the CSO. Further, in all cases, lines of communication existed between the drinking water authority and the NPDES permit-holder. In many cases the drinking water authority indicated adjustments are made to the treatment process during wet weather.

This assessment indicates that CSO's generally do not pose a major risk of contamination to most public drinking water intakes. However, to understand the relationship between a discharge point and a downstream drinking water intake the transport and fate of the discharge between the two points must be modeled under the range of real world flow conditions for that stream reach. Such modeling is beyond the scope of this report.

6.2.3 Fish and Shellfish

Fish and shellfish are widely consumed in the United States and are a valued economic and natural resource (NYNJDEP 2002a). In 1995,

Table 6.7

Association of CSO Outfalls with Drinking Water Intakes

EPA identified 59 CSO outfalls in seven states with outfalls located within one mile upstream of a drinking water intake.

EPA Region	State	Number of CSO Outfalls within 1 mile upstream of a drinking water intake
1	ME	7
2	NY	7
3	PA	19
3	WV	9
4	KY	7
5	IN	3
5	OH	7
	Total:	**59**

Note: EPA was unable to confirm data for an additional 14 outfalls in two states (PA and WV); these outfalls are not included in this table.

the most recent year for which data are available, 77 million pounds of clams, oysters, and mussels were harvested in the coastal United States (NOAA 1997). Shellfish grown in contaminated waters concentrate microbial pathogens and can have higher concentrations than the waters in which they are found. Viable pathogens can be passed on to humans by eating whole, partially cooked, or raw contaminated shellfish.

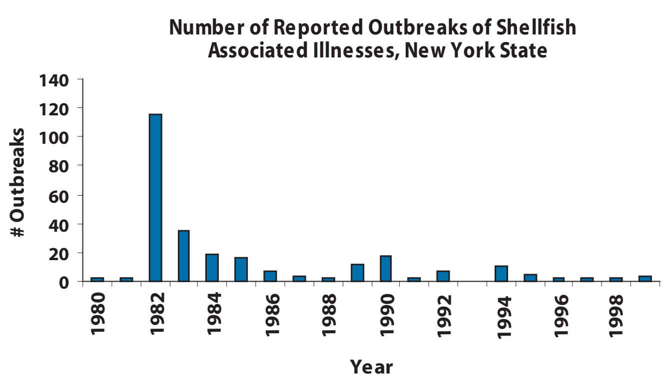
Reported Human Health Impacts

The World Health Organization reported that seafood is involved in 11 percent of all disease outbreaks from food ingestion in the United States (WHO 2001). The most common illness associated with eating sewage-contaminated raw shellfish and fish is gastroenteritis (CERI 1999).

A review of CDC Surveillance Summaries identified eight waterborne disease outbreaks linked to the consumption of contaminated fish or shellfish for the period 1985-2000. These outbreaks resulted in 995 cases of illness (CDC 1990, 1995, 1996b, 1997). More information on these outbreaks is provided in Appendix I. In most cases, the contaminated fish or shellfish were exposed to or grown in sewage-contaminated water. Waste dumped overboard by boaters and improperly treated sewage were the most commonly cited sources of fish and shellfish contamination.

Shellfish-Associated Illness: New York State

The New York State Department of Health compiled data on shellfish-associated illness (most commonly gastroenteritis) recorded in New York State from 1980 to 1999 (NYNJHEP 2002b). The incidence of reported illness has dropped markedly since its peak in 1982. The study was able to trace most of the outbreaks in 1982 to Rhode Island shellfish. The study noted that it is often difficult to identify the source of the shellfish that induced the outbreak. Decreases in shellfish-associated disease are attributed to a number of factors including: improvements in wastewater treatment leading to reductions in concentrations of waterborne microbial pathogens; more restrictions on shellfish harvesting in contaminated areas; and more public awareness of the risks associated with consuming raw shellfish. The study also noted that although shellfish beds are carefully monitored for pathogenic contamination, the levels of toxic contaminants in shellfish, including impacts from marine algal toxins, need additional study.



Direct links to CSO and SSO events as a cause of contamination were not made.

6.2.4 Direct Contact with Land-Based Discharges

Many SSOs discharge to terrestrial environments including streets, parks, and lawns. CSSs and SSSs can also back up into buildings, including residences and commercial establishments. These land-based discharges present exposure pathways that are different than those pathways associated with typical discharges to water bodies. Exposure to land-based SSOs and building backups typically occurs through dermal contact. The resulting diseases are often similar to those associated with exposure through drinking or swimming in contaminated water, but may also include illness caused by inhaling microbial pathogens (CERI 1999).

Reported Human Health Impacts

In general, very few outbreaks associated with direct contact with land-based SSOs have been documented. Land-based SSOs tend to leave visible evidence of their occurrence, such as deposits of sanitary products and other wastes commonly flushed down a toilet. The presence of these items often acts as a deterrent to direct contact with the SSO. Further, municipal response to land-based SSOs often includes cleaning the impacted area by washing the sewage into a nearby manhole or storm drain and disinfecting as needed. This review identified one confirmed outbreak resulting from direct contact with a discharge of untreated sewage in Ocoee, Florida. This event resulted in 39 cases of hepatitis A (Vonstille 1993).

6.2.5 Occupational Exposures

Many occupational settings occasionally expose personnel to microbial pathogens. These include restaurants and food processing, agriculture, hospitals and healthcare, emergency response, and wastewater treatment.

Wastewater treatment plant workers and public works department personnel operate and maintain wastewater treatment facilities and respond to CSO or SSO events. In doing so, they may be exposed to microbial pathogens present in CSOs and SSOs. Police, firefighters, rescue divers, and other emergency response personnel also face exposure to CSOs and SSOs. Depending on the context in which the overflow event occurs, exposure can occur through inhalation, ingestion, and dermal contact. Adherence to good personal hygiene and the appropriate use of personal protective equipment are important in minimizing the potential for injury or illness.

Reported Human Health Impacts

Comprehensive epidemiologic research on waterborne illness associated with occupational exposure to untreated wastewater is lacking. Some researchers believe that wastewater workers may experience increased numbers of bacterial, viral, and parasitic infections without exhibiting signs or symptoms of illness. These are called "sub-clinical" infections (AFSCME 2003). One study concluded that the lowest rates of illness are found among workers employed in wastewater treatment for less than five years, the highest rates in workers with five to 10 years of exposure, and lower rates again in workers with 15 years or more of exposure (Dowes et al. 2001). An explanation for this is that workers build immunity to many of the microbial pathogens present in the work environment over the course of their employment, and those who become very ill no longer work in the plant. This phenomenon is also known as the "healthy worker effect."

In general, the effect of microbial pathogens, other than hepatitis A, on wastewater workers has been given little attention, and "there have been few epidemiologic studies conducted among sewage workers in the U.S. to determine the actual prevalence and types of infections" (AWR 2001).

One confirmed waterborne disease outbreak through occupational exposure was identified from the review of CDC Surveillance Summaries. In 1982, 21 cases of gastrointestinal illness were identified among 55 police and fire department scuba divers training in sewage-contaminated waters (CDC 1983). The divers developed gastrointestinal disease more than four times as frequently as nondiving firefighters, the control group in the study. Although the causes of illness in many divers were not identified, gastrointestinal parasites were found in 12 divers: *Entamoeba histolytica* in five divers, and *Giardia lamblia* in seven divers.

6.2.6 Secondary Transmission

An individual who contracts an infection from exposure to a waterborne microbial pathogen may, in turn, infect other individuals, regardless of whether symptoms are apparent in the first individual. This is commonly referred to as "secondary transmission." The rate of secondary transmission depends largely on the particular microbial pathogen. Illnesses caused by secondary transmission are not included in CDC Surveillance Summaries, which list only primary illnesses.

Reported Human Health Impacts

Secondary transmission statistics obtained from a variety of waterborne and non-waterborne disease outbreaks are shown in Table 6.8 (NAS 1998). As presented, the secondary attack ratio represents the ratio of secondary cases to primary cases.

6.3 Which Demographic Groups Face the Greatest Risk of Exposure to CSOs and SSOs?

Several demographic groups face increased risk of exposure to the pollutants in CSOs and SSOs because they are more likely to spend time in locations impacted by such discharges. These groups include people recreating in CSO- and SSO-impacted waters, subsistence fishers, shellfishers, and wastewater workers. The sections that follow describe exposure risks for each of these groups in greater detail. This information is

Table 6.8

Examples of Secondary Transmission from Waterborne and Non-Waterborne Disease Outbreaks (NAS 1998)

An individual who contracts an infection may, in turn, infect other individuals. This table shows for every two individuals infected with Norwalk virus, one to two individuals can become infected via secondary transmission.

Microbial Pathogen	Secondary Attack Ratio	Source of Outbreak
Cryptosporidium	0.33	Contaminated apple cider
Shigella	0.28	Child day care center
Rotavirus	0.42	Child day care center
Giardia	1.33	Child day care center
Unspecified virus causing viral gastroenteritis	0.22	Contaminated drinking water
Norwalk virus	0.5 - 1.0	Contaminated recreational water

presented based on the availability of literature documenting each group's potential for exposure, rather than on the relative sensitivity of each population to the pollutants in CSO and SSO discharges.

6.3.1 Swimmers, Bathers, and Waders

Swimming in marine and fresh water has been linked directly to diseases caused by the microbial pathogens found in wastewater (Cabelli et al. 1982). For example, a 1998 study comparing bathers and non-bathers found that 34.5 percent of gastroenteritis and 65.8 percent of ear infections reported by participants were linked to bathing in marine waters contaminated with sewage. The percentage of people who lost at least one day of normal activity due to contacting one of the illnesses studied ranged from 7 to 26 percent (Fleisher et al. 1998).

Many variables influence the exposure of people to pathogens in recreational water. These factors include whether people swim or wade, the type of pathogens present at the time of exposure, the route of exposure (ingestion or skin contact), and individual susceptibility to waterborne disease (WSDH 2002).

6.3.2 Subsistence and Recreational Fishers

Subsistence and recreational fishers and their families tend to consume more fish and shellfish than the general population, and men tend to consume more fish and shellfish than women (Burger et al. 1999). Further, in areas conducive to fishing, people with lower education levels or lower income levels consume more fish and shellfish, as it is often an inexpensive source of protein (Burger et al. 1999).

Cultural preferences influence the amount and frequency of fish as well as shellfish consumption and the methods for preparing and serving fish and shellfish. For example, a study of two Native American groups in Puget Sound in Washington found that these groups consumed fish at much higher rates than the general public and at rates greater than those recommended by EPA (Toy et al. 1996). Asians and Pacific Islanders generally consume fish at much higher rates than the general United States population (Sechena et al. 1999). In addition, cooking methods and consumption rates of parts of the fish that tend to concentrate toxins (e.g., skin, head, organs, and fatty tissue) can increase the risk of human health impacts from consuming contaminated fish and shellfish (e.g., Wilson et al. 1998; WDNR 2003).

Fish and shellfish advisories target recreational and subsistence fishers. Despite warnings and advisories, however, many fishers consume their catch. May and Burger (1996) found that a majority of urban and suburban recreational fishers ignored warnings issued by the New York State Department of Health and the New Jersey Department of Environmental Protection.

6.3.3 Wastewater Workers

Wastewater workers are more likely to come into contact with untreated wastewater than the general public, but there is insufficient data to determine whether wastewater workers or their families face an increased risk of illness as a result of this exposure. Although there is disagreement regarding the benefits of additional immunization above those recommended by CDC for the adult general population (i.e., diptheria and tetanus), WERF (2003b) asserts that wastewater workers should be vaccinated for both Hepatitis A and B.

6.4 Which Populations Face the Greatest Risk of Illness from Exposure to the Pollutants Present in CSOs and SSOs?

Certain demographic groups, including pregnant women, children, individuals with compromised immune systems, and the elderly, may be at greater risk than the general population for serious illness or a fatal outcome resulting from exposure to the types of pollutants present in CSOs and SSOs. Specific characteristics of these demographic groups that make them particularly susceptible to these illnesses are discussed in more detail in the following sections. These sensitive groups represent almost 20 percent of the U.S. population (Gerba et al. 1996). Also, tourists and travelers may be more prone to waterborne illnesses than local residents (EPA 1983b). EPA research has found that when exposed to pathogens found in local sewage, local residents have been shown to develop fewer symptoms than non-residents or visitors.

6.4.1 Pregnant Women

During pregnancy, women appear to be at greater risk of more serious disease outcomes from exposure to the types of enteric viruses found in CSOs and SSOs (Reynolds 2000). Waterborne diseases contracted during pregnancy may result in transfer of the illness to the child either *in utero*, during birth, or shortly after birth (Gerba et al. 1996).

6.4.2 Children

The incidence of several waterborne infectious diseases caused by the types of pollutants present in CSO and SSO discharges is significantly greater in infants and children than in the general population (Laurenson et al. 2000). Factors contributing to the susceptibility of children include children's naturally immature immune systems and child-associated behaviors that result in abnormally high ingestion rates during recreational exposure to contaminated water (Laurenson et al. 2000). For example, children frequently splash or swim in waters that would be considered too shallow for full-body immersion by adults (EPA 2001b).

6.4.3 Immunocompromised Groups

People with compromised immune systems, such as those with AIDS, organ transplant recipients, and people undergoing chemotherapy, are more sensitive than the general public to infection and illness caused by the types of pollutants present in CSO and SSO discharges (Gerba et al. 1996). Using Wisconsin death certificate data, Hoxie et al. (1997) analyzed cryptosporidiosis-associated mortality in AIDS patients following the 1993 Milwaukee outbreak that affected an estimated 403,000 people. The researchers found that AIDS was the underlying cause of death for 85 percent of post-outbreak cryptosporidiosis-associated deaths among residents of the Milwaukee area. Further, the researchers found that AIDS mortality increased significantly in the six months immediately after the outbreak, then decreased to levels lower than expected, and then returned to expected levels. This suggests that some level of premature mortality was associated with the outbreak.

6.4.4 Elderly

The elderly are at increased risk for waterborne illness due to a weakening of the immune system that occurs with age (Reynolds 2000). Studies have found that people over 74 years old, followed by those between 55 and 74, and then by children under 5, respectively experience the highest mortality from diarrhea as a result of infection by waterborne or foodborne illness (Gerba et al. 1996). Studies of a giardiasis outbreak in Sweden that occurred when untreated sewage contaminated a drinking water supply found people over 77 years old faced an especially high risk of illness (Ljungstrom and Castor 1992).

6.5 How are Human Health Impacts from CSOs and SSOs Communicated, Mitigated, or Prevented?

A variety of programs are in place to reduce human health impacts associated with exposure to microbial pathogens and toxics. These programs generally involve preventive measures enacted by public health officials, including: communication efforts to warn the public about risk and threats; and monitoring, reporting, and tracking activities. This section is focused on agencies, activities, and programs designed to communicate, mitigate, or prevent potential human health impacts from exposure to CSOs and SSOs.

6.5.1 Agencies and Organizations Responsible for Protecting Public Health

Numerous agencies and organizations have responsibilities for monitoring, tracking, and notifying the public of potential human health impacts. These include federal and state agencies, local public health officials, owners and operators of municipal wastewater collection and treatment facilities, and non-governmental organizations.

Federal Agencies

EPA administers a national water quality standards program that establishes criteria to support designated uses including recreation, drinking water supply, and shellfish harvesting. EPA also administers a national safe drinking water program with a goal that, by 2005, 60 percent of the population served by community drinking water systems will receive their water from systems with active source water protection programs (EPA 1997b). In developing source water protection programs, EPA specifically encourages suppliers to consider CSOs, sewer system failures, and wet weather municipal effluent point source discharges as sources of microbial contamination. Further, drinking water intakes and their designated protection areas are identified as "sensitive areas" under the CSO Control Policy. The elimination, control, or relocation of CSO outfalls that discharge to sensitive areas are to be given high priority in the development and implementation of CSO LTCPs (EPA 1994a).

As discussed earlier in Section 5.5.2 of this report, EPA's BEACH program conducts an annual survey of the nation's swimming beaches. The program was created to reduce health risks to swimmers due to contact with contaminated water by working to improve monitoring and public notification procedures at beaches.

CDC's National Center for Infectious Diseases works to prevent illness, disability, and death caused by infectious diseases. Waterborne disease prevention is a priority for this program. Working with EPA, CDC coordinates national reporting of waterborne illness outbreaks through its Outbreak Surveillance System. This system compiles state-reported outbreaks to characterize waterborne outbreaks epidemiologically (e.g., to investigate the agents, reasons for the outbreak, and adequacy of various treatment methods) and to strengthen the public health community's ability to respond. Outbreak summaries are produced biennially. With the cooperation of state health departments and other national partners, CDC's Division of Parasitic Diseases and Division of Bacterial and Mycotic Diseases are responsible for the investigation, surveillance, and control of specific groups of diseases, including many pathogens linked to waterborne illness.

NOAA works to protect and preserve U.S. living marine resources through scientific research, fisheries management, enforcement, and habitat conservation. As detailed in Section 5.3.2 of this report, NOAA is currently working with Interstate Shellfish Sanitation Conference (ISSC), EPA, and FDA to develop an information resource on shellfish safety. This data system will house shellfish growing area monitoring, survey, and classification data.

FDA administers the National Shellfish Sanitation Program, an effort intended to standardize the inspection and monitoring of shellfish growing areas and shellfish packing/shucking facilities. Working with EPA, FDA publishes guidance on the safety attributes of fish and fishery products, including acceptable levels of organic and inorganic compounds such as mercury and PCBs.

USGS plays an active role in monitoring and reporting the quantity and quality of the nation's water resources. USGS helps to assess water quality problems and sources of pollution, including CSOs and SSOs, by studying how pathogens and other agents of waterborne disease interact with the environment and by monitoring and reporting the quality of the nation's water resources.

State Agencies

State public health agencies track communicable diseases, perform outbreak investigations, and issue warnings to the public. These agencies integrate and compile findings from local efforts, and they provide coordination with other state and federal agencies and programs. This coordination includes providing data on waterborne illness and investigations to CDC.

State environmental agencies conduct water quality monitoring and assessment programs and require monitoring to be conducted by others, such as local sanitation districts, public water systems, regional planning agencies, and recreational facilities. State environmental or natural resource agencies also monitor fish and shellfish. These monitoring programs provide data for management decisions at the state level in response to environmental and public health concerns. In addition to monitoring, state agencies perform sanitary surveys to identify problems that could affect the safety of the drinking water supply. A sanitary survey is a physical inspection of the

Coastal Beach Monitoring Program: Connecticut

The State of Connecticut has a comprehensive monitoring program for its coastal waters, with standards and guidelines set by the state. The state collects and analyzes samples taken at four coastal state parks on Long Island Sound. At least 18 municipalities in the state's four coastal counties monitor their own beaches, following the ocean and bay beachwater-quality monitoring protocol established by the Connecticut Departments of Public Health and Environmental Protection. In 2002, Connecticut set aside a $226,000 grant to integrate monitoring at municipal beaches into a state-administered sampling and public notification plan for the entire state. The beach grant funded a courier service to bring municipal beach samples to the Department of Public Health lab, where the state analyzes the samples free of charge.

Beach Monitoring and Public Notification Program: Rhode Island

The Rhode Island Health Department requires every licensed beach to sample its water and test for the presence of fecal coliform bacteria. The Rhode Island water quality standard for recreation is 50 MPN per 100 ml of salt water and 200 MPN per 100 ml of fresh water. Results are posted on the department's website, along with advisories on waterborne illness and beach closures and openings. Public notification of beach closures is accomplished in several ways, including the use of color-coded flags at beaches, press releases, and notices on the department website. The website also supports on-line reporting by the public of suspected beach-related illnesses.

water treatment and distribution system and a review of operation and maintenance practices.

States also implement notification programs to warn citizens about human health impacts associated with recreation at contaminated beaches and consumption of contaminated water, fish, or shellfish.

Local Agencies

Local public health agencies, regional planning authorities, and the owners and operators of wastewater collection and treatment facilities have distinct responsibilities to protect public health. Working with state oversight, city and county health departments often maintain separate divisions for tracking communicable diseases and for environmental health. The communicable disease divisions of these departments generally have responsibility for cataloging, investigating, and reporting cases of "reportable illness" to the appropriate state agency. The environmental health divisions generally have responsibility for monitoring, analysis, and posting of recreational waters, where needed. Owners and operators of municipal wastewater collection and treatment facilities have their own responsibilities, many of which are stipulated as NPDES permit requirements, including notifying the public when SSOs occur and reporting SSOs to state regulatory and public health agencies. Communities with CSSs are required to implement public notification programs as part of implementing the NMCs.

6.5.2 Activities to Protect Public Health from Impacts of CSOs and SSOs

The principal activities undertaken to protect the public from the impacts of CSOs and SSOs can be grouped into three areas: exposure pathway monitoring, public notification, and research. These activities protect public health by identifying possible sources of pathogens, reducing public exposure through notification and

Local Public Health Activity: Orange County, CA

In California, the Orange County Health Care Agency's Ocean Water Protection Program has a mission to ensure that all public recreational waters meet bacteriological water quality standards for full body contact recreation activities, such as swimming, surfing, and diving. Staff collect water samples at approximately 150 locations along the shoreline of Orange County for laboratory analysis for indicator bacteria. Results of the analysis are reviewed by program specialists who determine if action needs to be taken to protect the public. Staff are available to respond on a 24-hour basis to investigate reports of contamination incidents, including SSOs, affecting Orange County's public beaches.

Local Public Health Activity: Allegheny County, PA

The Allegheny County Health Department in Pennsylvania implemented a public notification program designed to warn recreational users of health risks in CSO-impacted waters in the Pittsburgh area. The program includes publishing advisories in local newspapers and producing public service announcements on local television stations to educate the public about health risks associated with CSO discharges. The department also installed orange warning flags that read "CSO" at 30 locations near CSO outfalls. The flags are raised to warn recreational users whenever CSO discharges cause or contribute to elevated bacteria levels.

use restriction, when necessary, and continuing research by public health experts to better protect public health in the future. More detail on each activity is presented below.

Exposure Pathway Monitoring

Exposure pathway monitoring programs focus on recreational waters, public drinking water systems, and fish and shellfish in order to reduce the risk of human health impacts from exposure to contaminated water and food.

Recreational waters are typically monitored using indicator bacteria to detect the presence of or the potential for microbial pathogen contamination. If the bacteria levels in a given water sample exceed the state standard for recreational waters, advisories are posted or the waterbody is closed. For example, EPA's 2002 BEACH Program found that 91 percent of surveyed beaches had some type of water quality monitoring program. Though the frequency of monitoring varied, 63 percent of the beaches were monitored at least once per week (EPA 2003a).

Public water systems are governed by National Primary Drinking Water Standards, also known as primary standards (EPA 2003f). Primary standards are legally enforceable standards that protect public health by limiting the levels of specific contaminants in drinking water. To protect the health of those being served, public water systems have monitoring requirements. Contaminants monitored are as follows (EPA 2002f):

- Microorganisms including indicator organisms, enteric viruses, and parasitic protozoa;
- Disinfectants including chlorine, chlorine dioxide, and chloramine;
- Disinfection byproducts including bromate, chlorite, haloacetic acids, and trihalomethanes;
- Inorganic chemicals including metals, nitrate, and nitrite;
- Organic chemicals including a broad list of agricultural and industrial products; and
- Radionuclides.

If monitoring shows the drinking water is contaminated, the owner or operator of the public water system is required to shut down the system and/or direct the public to take precautions, such as boiling water.

Fish and shellfish monitoring is administered jointly by state agencies, EPA, NOAA, and FDA. Bacteriological monitoring is used to assess the potential presence of microbial pathogens in shellfish harvesting areas. States, U.S. territories, and authorized tribes have primary responsibility for protecting residents from the health risks of consuming contaminated, noncommercially caught fish. This is accomplished by issuing of fish consumption advisories. These advisories inform the public when high concentrations of contaminants have been found in local fish. They also include recommendations to limit or avoid eating certain fish species from specific waterbodies or waterbody types.

Public Notification

Public notification programs provide information to communities regarding the occurrence of CSO and SSO events and ongoing efforts to control discharges.

Public notification programs include posting temporary or permanent signs where CSOs and SSOs occur, coordinating with civic and environmental organizations, and distributing fact sheets to the public and the media. Notices in newspapers are used to publicize CSO or SSO discharges in some states. Radio and television announcements may be appropriate for CSOs and SSOs with unusually severe impacts. Distribution of information on websites is rapidly gaining wider use. Additional information on reporting and public notification is presented in Chapter 8 of this Report to Congress and in the technology descriptions included as Appendix L.

Research

Several research activities are expected to improve the ability of public health programs to protect humans from impacts associated with CSOs, SSOs, and other sources of pollution. Two examples are provided below.

EPA's National Epidemiological and Environmental Assessment of Recreational (NEEAR) Water Study is intended to develop a better understanding of water pollution at beaches, recreational use of beaches, and public health. As part of the BEACH Program, this effort seeks to improve beach monitoring by linking real-time monitoring results with meaningful risk-based guidelines.

EPA's Office of Research and Development has completed the first in a planned series of studies to estimate the urban contribution to the total *Cryptosporidium* and *Giardia* loads to receiving waters (EPA 2003f). It is hoped that the studies will provide a basis for designing source water protection programs.

6.6 What Factors Contribute to Information Gaps in Identifying and Tracking Human Health Impacts from CSOs and SSOs?

Systematic data on human health impacts as a result of exposure to CSOs and SSOs are not readily available. The chief factors that account for the absence of direct cause-and-effect data

Monitoring Identifies SSS as Source of Drinking Water Contamination: Braun Station, TX

In 1984, public drinking water for the community surrounding Braun Station, Texas, was drawn from an artesian well that was not filtered but was chlorinated prior to distribution. At the time, well water was not routinely sampled in this region of Texas. Community complaints, however, convinced authorities to begin testing. Fecal coliform level as high as 2,600/100 mL were measured in untreated well water samples. Subsequent dye tests indicated that the community's SSS was leaking into the well water. When attempts to identify the exact site of contamination were not successful, an alternative water source was provided to the community (D'Antonio et al. 1985).

are underreporting of waterborne disease and the reliance of water quality monitoring activities on indicator bacteria instead of microbial pathogens. Both factors are discussed below.

6.6.1 Underreporting

Reporting and tracking of outbreaks of waterborne disease are difficult under the best circumstances. Underreporting stems from a number of causes. CDC's waterborne disease outbreak surveillance system depends on states to report outbreaks, and this reporting is often incomplete. Existing local systems for tracking these outbreaks often lack sufficient information on the cause of the outbreak to establish whether CSOs and SSOs are suspected source.

Factors that affect the likelihood that outbreaks will or will not be detected, investigated, and reported include (adapted from CDC 2000):

- Public awareness about illness symptoms, environmental conditions that might precipitate an outbreak, and where to report symptoms;
- The frequency with which people experiencing illnesses related to exposure to contaminated water seek medical care from the same provider;
- The adequacy of laboratory infrastructure to fully investigate outbreaks;
- The compatability of local reporting requirements for specific waterborne diseases with data tracking systems employed by the CDC; and
- The integration of state and local reporting and investigation protocols for waterborne disease outbreaks.

Large outbreaks are more likely to be noticed and reported than smaller outbreaks. Nevertheless, the source and exposure pathway of the 1993 Milwaukee cryptosporidiosis outbreak, the largest documented in U.S. history, remained unidentified for more than two weeks (CDC 1996a). This outbreak, affecting an estimated 403,000 people, was detected only "when increased sales of antidiarrheal medicines were observed and reported to the local public health agency" (Frost et al. 1995).

6.6.2 Use of Indicator Bacteria

Indicator bacteria are used to evaluate human health risks from contaminated water without sampling for every possible microbial pathogen. As described in Section 6.1.1, indicator bacteria are relatively easy to detect and are used to indicate the likely presence of fecal-borne microbial pathogens. There is ongoing scientific debate regarding the use of indicators and their ability to predict human health impacts. Some specific criticisms of the use of indicator bacteria are as follows:

- A single indicator organism may be insufficient to establish water quality standards. EPA's current water quality criteria are targeted toward protecting people participating in recreational activities from acute gastrointestinal illness (EPA 2002g).

- Current bacterial detection methods are subject to false positives and false negatives (Griffin et al. 2001).
- Coliform bacteria can survive and replicate in waters and soils under certain environmental conditions. Their presence is not always due to recent fecal contamination. In addition, all current bacteria indicators are shed by animals. Their occurrence in the environment does not always indicate that human pathogens are present or that contamination was due to a human source (Griffin et al. 2001).
- Indicator bacteria do not directly indicate the presence of viruses, which survive longer in marine waters and have a low infective dose (Seyfried et al.1984; Freeman 2001; Schvoerer et al. 2001).

Bacteriophages have shown merit for use as an alternative to indicator bacteria to identify human health risks. Specifically, *Bacteroides fragilis* bacteriophages have been found to be more resistant to chlorine than current indicator bacteria and are thought to be good indicators of enteric viruses. *Bacteriodes* also show potential for use as an indicator of recent fecal contamination (Griffin et al. 2001).

Although EPA recognizes the limitations of indicator bacteria, they continue to be used to assess potential human health risk because:

- Indicator bacteria area simple and inexpensive to measure (Griffin et al. 2001).
- Studies show that *E. coli* and enterococci exhibit a strong relationship to swimming-associated gastrointestinal illness (Fattal et al. 1987; Cheung et al. 1990; EPA 2002g).
- Indicator bacteria are present where fecal contamination occurs; they are always present in feces and at higher levels than most enteric pathogens (Griffin et al. 2001).

EPA continues to encourage states and authorized tribes to use *E. coli* or enterococcci as the basis of their water quality criteria for protecting recreational waters.

6.7 What New Assessment and Investigative Activities are Underway?

Several local government agencies are implementing innovative programs to identify risks and to track the types of illness associated with the pathogens present in CSO and SSO discharges. Select examples are provided in this section.

6.7.1 Investigative Activities

Monitoring, modeling, and other investigative activities are useful tools in reducing human exposure to pathogens, identifying waterborne and foodborne disease outbreaks, and assessing illness patterns. Some innovative investigative programs intended to reduce human health impacts and risk are described below.

- In Texas, the Austin-Travis Health and Human Services Department has a predictive model for recreational water quality at the Barton Springs pool. If the Barton Creek watershed receives more than one inch of rainfall, the pool is closed until monitoring determines it is safe to reopen (Staudt 2002).
- New York City has an advanced rainstorm modeling system that predicts the estimated amount of fecal matter that will contaminate beaches after a measurable rainfall. This information is used to make decisions on beach closures and is shared with all area beaches and neighboring states (Luke 2002).
- Orange County, California, maintains a passive reporting system for illnesses from recreational waters. Between 1998 and 2002, Orange County received 110 ocean and bay bather illness reports and one illness report from a freshwater lake (Mazur 2002).
- Boston, Massachusetts, operates a waterborne surveillance project that monitors *Cryptosporidium* and *Giardia* illnesses from drinking water. The program uses fixed populations within the city (schools, nursing homes, prisons) as control groups (Gurba 2002).
- San Diego County, California Department of Environmental Health and a group called Surfers Tired of Pollution conducted a self-reported ocean illness survey. Between August 1, 1997, and December 31, 1999, 232 illnesses were reported. The county plans a second survey (Clifton 2002).
- The Douglas County, Nebraska Health Department compares reported illnesses with a computer model that provides epidemiologic analysis for 1- to 10-year periods. Reported illnesses are compared with projected baselines and trends to determine if an outbreak is occurring (Kurtz 2002).
- New York City has an active outbreak monitoring procedure. The Department of Health tracks reports of giardiasis and cryptosporidiosis by visiting labs in New York City on a weekly basis and making sure all samples testing positive for the pathogens are reported. The Department of Health receives weekly tallies of diarrheal medicine sold in the area and has a clinical lab monitoring system to track the number of stool samples tested. Finally, the city monitors hospital emergency rooms for the number of people complaining of diarrhea and vomiting (Seeley 2002).