Appendix I

Human Health Addendum

I.1 Selected Waterborne Disease Outbreaks Documented by the Center for Disease Control and Prevention

The CDC routinely publishes reports of waterborne disease outbreaks as part of their *Mortality and Morbidity Weekly Report Surveillance Summaries*. These reports include incidents of waterborne disease contracted through exposure to contaminated recreational waters or consumption of contaminated drinking water, fish, or shellfish. EPA compiled reports from the *Surveillance Summaries* for etiologic agents that are known to be present in untreated wastewater; however, in doing so EPA does not intend to imply that all outbreaks listed in the following tables are related to untreated wastewater or CSO or SSO discharges. Outbreaks are indicated in **bold** when untreated wastewater was specifically identified by the CDC as contributing to the outbreak.

Table I.1 Selected Outbreaks from Exposure to Contaminated Drinking Water

Etiologic Agent	Cases	State(s)/Territory	Year	Type of Source Water
Salmonella typhii	**60**	**Virgin Islands**	**1985**	**Suspected cross connection between water and sewer line.[1]**
Giardia	12	Maine	1986	River[2]
Acute Gastrointestinal Illness (AGI)	36	New Mexico	1986	River[2]
Giardia	44	New York	1986	Lake[2]
Campylobacter	250	Oklahoma	1986	Lake[2]
Giardia	68	Vermont	1986	River[2]
AGI	71	New Hampshire	1987	Lake[2]
Giardia	513	Pennsylvania	1987	River[2]
AGI	1,400	Puerto Rico	1987	Community water supply.[2]
Shigella sonnei	**1,800**	**Puerto Rico**	**1987**	**Contamination of a reservoir with sewage following a rain event and power failure.[2]**
Norwalk-like virus	5,000	Pennsylvania, Delaware, and New Jersey	1987	For cases in Pennsylvania and Delaware, outbreak is due to commercially manufactured ice produced from a contaminated water well. The outbreak in New Jersey is also from ice from a contaminated water well.[2]
Cryptosporidium	13,000	Georgia	1987	River[2]
Giardia	90	Colorado	1988	River[2]
AGI	7	Colorado	1988	River[2]
Giardia	172	Pennsylvania	1988	Lake[2]
Norwalk-like virus (Setting: Resort)	**900**	**Arizona**	**1989**	**Outbreak due to "effluent from sewage treatment facility seeping directly into resort's well through cracks in the subsurface rock."[3]**
Giardia	19	Colorado	1989	River[3]
AGI	31	Idaho	1989	Untreated surface water from a lake.[3]
Giardia	308	New York	1989	Reservoir[3]
Giardia (Setting: Prison)	152	New York	1989	Treatment deficiencies for drinking water from a reservoir.[3]

Table I.1 continued

Etiologic Agent	Cases	State(s)/Territory	Year	Type of Source Water
Giardia	53	New York	1989	Lake[3]
E. coli O157:H7	**243**	**Missouri**	**1989**	**SSO contamination of municipal drinking water well. This outbreak resulted in four deaths.[3]**
Giardia	18	Alaska	1990	River[3] (Setting: Lodge)
AGI	109	Missouri	1990	Lake[3]
AGI	63	Pennsylvania	1990	Lake[3] (Setting: Inn)
Giardia	24	Vermont	1990	Lake[3] (Setting: Resort)
AGI	202	Puerto Rico	1991	Deficiency with penitentiary distribution system for drinking water taken from a river.[4]
AGI	9,847	Puerto Rico	1991	River[4]
AGI	250	Minnesota	1992	Lake[4]
Giardia	80	Nevada	1992	Lake[4]
Cryptosporidium	**3,000**	**Oregon**	**1992**	**Wastewater discharges and low flow in a river used for drinking water.[4]**
AGI	28	Pennsylvania	1992	River[4]
Cryptosporidium	27	Minnesota	1993	River[5]
Cryptosporidium parvum	103	Nevada	1993	Lake[5]
Cryptosporidium parvum	403,000	Wisconsin	1993	Treatment deficiencies and decline in raw water quality.[5]
Giardia lamblia	**20**	**Pennsylvania**	**1993**	**Well contaminated with sewage.[5]**
Giardia lamblia	18	New Hampshire	1994	Reservoir[5]
Giardia lamblia	36	New Hampshire	1994	Lake[5]
Giardia lamblia	304	Tennessee	1994	Reservoir[5]
Cryptosporidium parvum	134	Washington	1994	Well contaminated with wastewater.[5]
Giardia lamblia	10	Alaska	1995	Surface water contaminated by unknown source.[6]
Giardia lamblia	1,449	New York	1995	Lake[6]
Viral outbreak (small, round-structured virus)	148	Wisconsin	1995	Lake[6]
Shigella sonnei	**83**	**Idaho**	**1995**	**Sewage leak contaminated drinking water well.[6]**
Giardia intestinalis	50	New York	1997	Lake[7]
AGI	**123**	**New Mexico**	**1997**	**Sewage leak contaminated drinking water well.[7]**
Cryptosporidium parvum	**1,400**	**Texas**	**1998**	**Sewage spill contaminated drinking water wells.[7]**
AGI	6	Florida	1999	River/Stream[8]
AGI	4	Florida	1999	River/Stream[8]
AGI	46	Washington	1999	River/Stream[8]
E. coli O157:H7	5	California	2000	River/Creek[8]
Giardia intestinalis	27	Colorado	2000	River/Creek[8]
Giardia intestinalis	**12**	**Minnesota**	**2000**	**Well contaminated with sewage.[8]**
Giardia intestinalis	4	New Mexico	2000	River[8]
Norwalk-like virus	**123**	**West Virginia**	**2000**	**Well contaminated with sewage.[8]**

[1]Center for Disease Control (CDC). 1988. Water-Related Disease Outbreaks, 1985. *Morbidity & Mortality Weekly Report Surveillance Summaries*. 37 (SS-2): 16-17.

[2] CDC. 1990. Waterborne-Disease Outbreaks, 1986-1988. *Morbidity & Mortality Weekly Report Surveillance Summaries.* 39 (SS-1): 1-13.

[3] CDC. 1991. Waterborne-Disease Outbreaks, 1989-1990. *Morbidity & Mortality Weekly Report Surveillance Summaries.* 40 (SS-3): 1-21.

[4] CDC. 1993. Surveillance for Waterborne-Disease Outbreaks - United States, 1991-1992. *Morbidity & Mortality Weekly Report Surveillance Summaries* 42 (SS-5): 1-22.

[5] CDC. 1996. Surveillance for Waterborne-Disease Outbreaks - United States, 1993-1994. *Morbidity & Mortality Weekly Report Surveillance Summaries* 45 (SS-1): 1-33.

[6] CDC. 1998. Surveillance for Waterborne-Disease Outbreaks - United States, 1995-1996. *Morbidity & Mortality Weekly Report Surveillance Summaries* 47 (SS-5): 1-34.

[7] CDC. 2000. Surveillance for Waterborne-Disease Outbreaks - United States, 1997-1998. *Morbidity & Mortality Weekly Report Surveillance Summaries* 49 (SS-4): 1-35.

[8] CDC. 2002. Surveillance for Waterborne-Disease Outbreaks - United States, 1999-2000. *Morbidity & Mortality Weekly Report Surveillance Summaries* 51 (SS-8): 1-28.

Table I.2 Selected Outbreaks from Exposure to Contaminated Recreational Waters

Etiologic Agent	Number of cases	Location	Date	Type of Recreational Water
AGI	**21**	**New York**	**1982**	**Diving in waters known to be contaminated with human sewage caused outbreak among New York City Police scuba divers.**
Shigella sonnei and *boydii*	68	California	1985	Lake[2]
Norwalk-like virus	41	California	1986	Lake[2]
Leptospira	8	Hawaii	1987	Stream[2]
Shigella sonnei	130	South Carolina	1987	Lake[2]
Shigella sonnei	22	Georgia	1988	Lake[2]
Shigella sonnei	138	Pennsylvania	1988	Lake[2]
AGI	300	Vermont	1988	Lake – Recreational Area[2]
AGI	36	Vermont	1988	Lake – Swimming Area[2]
AGI	24	Minnesota	1988	Lake[2]
AGI	22	Maine	1989	Lake[3]
AGI	17	New Jersey	1989	Lake[3] (Setting: Park)
AGI	26	New Jersey	1989	Lake[3] (Setting: Swimming Area)
AGI	18	Minnesota	1990	Lake[3]
Shigella sonnei	7	New York	1990	Lake[3]
Shigella sonnei	9	Oregon	1990	Lake[3]
AGI	60	Pennsylvania	1990	Lake[3]
Shigella sonnei	68	North Carolina	1990	Lake[3]
AGI	244	Washington	1990	Lake[3]
AGI	79	Wisconsin	1990	Lake[3]
Leptospira	6	Illinois	1991	Pond[4]
Adenovirus	595	North Carolina	1991	Pond linked to outbreak of pharyngitis.[4]
E.coli	80	Oregon	1991	Lake[4]
Shigella sonnei	203	Pennsylvania	1991	Lake[4]
Shigella sonnei	23	Rhode Island	1991	Lake[4]
Giardia	4	Washington	1991	Lake[4]
AGI	15	Maryland	1992	Creek[4]
Giardia	43	New Jersey	1993	Lake[5]
Giardia	12	Maryland	1993	Lake[5]
Shigella sonnei	160	Ohio	1993	Lake[5]
Giardia	6	Washington	1993	River[5]
Shigella sonnei	35	Minnesota	1994	Lake[5]
Shigella sonnei	242	New Jersey	1994	Lake[5]
Cryptosporidium parvum	418	New Jersey	1994	Lake[5]
E. coli	166	New York	1994	Lake[5]
E. coli	12	Illinois	1995	Lake[6]
AGI	12	Minnesota	1995	Lake[6]

Table I.2 continued

Etiologic Agent	Number of cases	Location	Date	Type of Recreational Water
E. coli	6	Minnesota	1995	Lake[6]
E. coli	2	Minnesota	1995	Lake[6]
AGI	17	Pennsylvania	1995	Lake[6]
Shigella sonnei	70	Pennsylvania	1995	Lake[6]
E. coli	8	Wisconsin	1995	Lake[6]
Shigella sonnei	39	Colorado	1996	Lake[6]
Shigella sonnei	81	Colorado	1996	Lake[6]
Cryptosporidium parvum	3	Indiana	1996	Lake[6]
AGI	4	Indiana	1996	Lake[6]
E. coli	6	Minnesota	1996	Lake[6]
AGI	32	Oregon	1996	Lake[6]
E. coli	8	Missouri	1997	Lake[7]
Schistosoma spindale	2	Oregon	1997	Lake[7]
AGI	650	Maine	1998	Lake[7]
E. coli	5	Minnesota	1998	Lake[7]
Norwalk-like virus	30	Ohio	1998	Lake[7]
Cryptosporidium parvum	8	Pennsylvania	1998	Lake[7]
AGI	41	Washington	1998	Lake[7]
AGI	248	Washington	1998	Lake[7]
Norwalk-like virus	18	Wisconsin	1998	Lake[7]
Leptospira	375	Illinois	1998	Outbreak among triathletes exposed to a lake.[7]
Shistosomes	2	Oregon	1999	Lake[8]
E. coli O121:H19	11	Connecticut	1999	Lake[8]
AGI	25	Illinois	1999	Lake[8]
Giardia intestinalis	18	Massachusetts	1999	Swimming at a pond.[8]
Norwalk-like virus	168	New York	1999	Lake[8]
E. coli O157:H7	36	Washington	1999	Lake[8]
E. coli O157:H7	5	Wisconsin	1999	Lake[8]
E. coli O157:H7	5	California	1999	Lake [8]
AGI	2	Florida	2000	Lake[8]
AGI	4	Florida	2000	Lake - Summary states that this outbreak occurred from an outdoor spring.[8]
AGI	32	Maine	2000	Lake/pond[8]
Cryptosporidium parvum	220	Minnesota	2000	Lake[8]
Shigella sonnei	15	Minnesota	2000	Lake/pond[8]
Shigella sonnei	25	Minnesota	2000	Lake[8]
Leptospira	21	Guam	2000	Lake[8]
Schistosomes	6	California	2000	Pond[8]
Schistosomes	4	California	2000	Pond[8]
Schistosomes	2	Oregon	1999	Lake [8]

[1] CDC. 1983. Epidemiologic Notes and Reports: Gastrointestinal Illness among Scuba Divers – New York City. *Morbidity & Mortality Weekly Report* 32 (44): 576-577.

[2] CDC. 1990. Waterborne-Disease Outbreaks, 1986-1988. *Morbidity & Mortality Weekly Report Surveillance Summaries* 39 (SS-1): 1-13.

[3] CDC. 1991. Waterborne-Disease Outbreaks, 1989-1990. *Morbidity & Mortality Weekly Report Surveillance Summaries* 40 (SS-3): 1-21.

[4] CDC. 1993. Surveillance for Waterborne-Disease Outbreaks - United States, 1991-1992. *Morbidity & Mortality Weekly Report Surveillance Summaries* 42 (SS-5): 1-22.

[5] CDC. 1996. Surveillance for Waterborne-Disease Outbreaks - United States, 1993-1994. *Morbidity & Mortality Weekly Report Surveillance Summaries* 45 (SS-1): 1-33.

[6] CDC. 1998. Surveillance for Waterborne-Disease Outbreaks - United States, 1995-1996. *Morbidity & Mortality Weekly Report Surveillance Summaries* 47 (SS-5): 1-34.

[7] CDC. 2000. Surveillance for Waterborne-Disease Outbreaks - United States, 1997-1998. *Morbidity & Mortality Weekly Report Surveillance Summaries* 49 (SS-4): 1-35.

[8] CDC. 2002. Surveillance for Waterborne-Disease Outbreaks - United States, 1999-2000. *Morbidity & Mortality Weekly Report Surveillance Summaries* 51 (SS-8): 1-28.

Table I.3 Selected Outbreaks from Consumption of Contaminated Fish or Shellfish

Etiologic Agent	Number of cases	Location	Date	Exposure Pathway
AGI	150	New York	1982	Fourteen separate outbreaks of gastroenteritis due to the consumption of raw clams. It appears that the outbreak originated from coastal waters in Massachusetts, Rhode Island, and New York due to harvesting beds being contaminated as a result of heavy rains during May and June.[1]
Norwalk-like virus	20	N/A	1983	Consumption of raw clams.[2]
AGI	42	Maine	1984	Consumption of Seafood Newburg.[2]
Hepatitis A	**61**	**Multiple states**	**1988**	**Consumption of raw oysters harvested from water contaminated by human feces.[3]**
Vibrio cholerae	26	Guam	1990	Consumption of contaminated reef fish.[3]
Norwalk-like virus	73 103	Louisiana Multiple States	1993	A shellfish harvester with high levels of immunoglobulin A to Norwalk-like virus reported having been ill before the outbreak and admitted dumping sewage directly into harvest waters.[4]
Viral gastroenteritis	N/A	Florida and Georgia	1994-1995	December 1994 to January 1995, 34 clusters of cases of viral gastroenteritis were traced to shellfish harvested to beds in Florida's Apalachicola Bay. The source of the Norwalk-like virus was attributed to sewage contamination either from land-based sources or recreational or commercial vessels, according to preliminary findings.[5]
Viral gastroenteritis	493	Alabama, Florida, Georgia, Louisiana, and Mississippi	1996-1997	Consumption of oysters thought to have been contaminated by harvesters improperly disposing of sewage.[6]

[1]CDC. 1982. Epidemiologic Notes and Reports: Enteric Illness Associated with Raw Clam Consumption – New York. *Morbidity & Mortality Weekly Report* 31 (33): 449-451.

[2]CDC. 1990. Foodborne Disease Outbreaks, 5-Year Summary, 1983-1987. *Morbidity & Mortality Weekly Report Surveillance Summaries* 39 (SS-01): 15-23.

[3] CDC. 1996. Surveillance for Foodborne–Disease Outbreaks, United States, 1988-1992. *Morbidity & Mortality Weekly Report Surveillance Summaries* 45 (SS-05): 1-55.

[4] CDC. 1993. Multistate Outbreak of Viral Gastroenteritis Related to Consumption of Oysters – Louisiana, Maryland, Mississippi, and North Carolina,1993. *Morbidity & Mortality Weekly Report* 42 (49): 945-948.

[5] CDC. 1995. Epidemiologic Notes and Reports: Multistate Outbreak of Viral Gastroenteritis Associated with Consumption of Oysters – Apalachicola Bay, Florida, December 1994-January 1995. *Morbidity & Mortality Weekly Report* 44 (2): 37-39.

[6] CDC. 1997. Viral Gastroenteritis Associated with Eating Oysters – Louisiana, December 1996-January 1997. *Morbidity & Mortality Weekly Report* 46 (47): 1109-1112.

I.2 Interviewed Communities' and States' Roles and Responsibilities Matrix

As part of this report effort, EPA conducted a series of interviews with officials in state and local governments. Through the interviews, EPA sought a clearer understanding of the roles and responsibilities of these agencies in preventing, tracking, and monitoring for potential human health impacts associated with CSO and SSO discharges within their jurisdiction. The results of these interviews are summarized in the following two tables.

Table I.4 Local Agency Responsibilities Related to Human Health as Identified During Community Interviews

Community	Waterborne Illness Investigations	Recreational Water Monitoring & Posting	Wastewater Treatment	Drinking Water Monitoring	Monitoring Fish and Shellfish
Boston, MA	City Health	Metropolitan District Commission and MWRA	MWRA	MWRA	
Portland, ME	City Health Department State Health Department	State Environmental Agency	Public Works	Water District	State DEP
Cape May, NJ	County Health	County Health	County Municipal Utilities Authority	Individual Water Utilities, County Health State Environmental Agency	State Environmental Agency
New York, NY	City Health Department City Environmental Agency	State Environmental Agency	City Public Works State Environmental Agency	City Environmental Agency State Environmental Agency	State Environmental Agency
Arlington, VA	County Health Department	N/A	County Environmental Health Department	Public Works	State Environmental Agency
Erie County, PA	County Health Department	County Health Department	Public Works	Water District	N/A
Pittsburgh, PA	County Health Department	State Environmental Agency	Drinking and Wastewater Agency	Drinking and Wastewater Agency	N/A
Atlanta, GA	County Health Epidemiology & Environmental Division	County Health Environmental Division	Each municipality	Each municipality	Local Level Environmental Health
Ft. Pierce, FL	County Health Departments	County Health Departments	County Health Dept, State Environmental Agency	County Health Department	State Environmental Agency
Akron, OH	City Health Department	N/A			
Milwaukee, WI	City Health Department	City Health Department	Waste Treatment Agency		State Environmental Agency

Table I.4 continued

Community	Waterborne Illness Investigations	Recreational Water Monitoring & Posting	Wastewater Treatment	Drinking Water Monitoring	Monitoring Fish and Shellfish
Austin, TX	City/County Health Department	Watershed Protection Division			
Little Rock, AR	State Health Department	State Environmental Department	local municipalities	State Environmental Department	State Environmental Department
Tulsa, OK	County Health Department & State Health Department	State Environmental Department	City Government	City Government	State Environmental Department
Omaha, NE	County Health Department	County			
St. Louis, MO	City Health Department				
Denver, CO	City/County Environmental Agency	City/County Environmental Agency		Public Works	
Las Vegas, NV	County Health Department, Water Authority	Water Authority National Parks Service	Local Wastewater Treatment	Water Authority	County Health Department
Los Angeles, CA	State Health Department, City Health Department	City Health Department	Local sanitation districts	State Health Department, City Health Department	State Health Department
Orange County, CA	County Health Department Epidemiology	County Health Department Environmental County Sanitation District Wastewater Authority	Local water and sanitation districts	Water Authority under jurisdiction of State Department of Health	State Department of Health Services/ Biotoxin Monitoring
San Diego, CA	County Environmental Health, Department of Health Epidemiology	County Environmental Health	Municipal POTWs	Local water purveyor and State Department of Health	State Department of Health and County Environmental Health
Portland, OR	State Health Department	State Health Department (ocean beaches only) State Environmental Agency	State Environmental Agency (or the Native American tribes, if treatment is associated with tribal lands)	State Health Department – monitor groundwater in general	State Environmental Agency Department of Agriculture
Seattle, WA	County Health Department				

Table I.5 State Agency Responsibilities Related to Human Health, as Identified During Interviews

State	Waterborne Illness Investigations	Recreational Water Monitoring & Posting	Wastewater Treatment	Drinking Water Monitoring	Monitoring Fish and Shellfish
New Jersey	State Department of Health	State Environmental Agency and Local Health Departments	State Environmental Agency	State Environmental Agency and Local Health Departments	State Environmental Agency
Pennsylvania	State Health	State Environmental Protection, State Department of Health	State Environmental Protection	State Environmental Protection, State Department of Health	Department of Agriculture
Florida	State Department of Health	County health officers	State Environmental Agency permits the wastewater program	State Environmental Agency oversight for drinking water suppliers	The Dept. of Agriculture, DOH issues the health advisories. State environmental agency does tissue monitoring
Massachusetts	Local Boards of Health, State Department of Health	Local Boards of Health, State Department of Health	Local Boards of Health, State Environmental Agency	State Environmental Agency	State Environmental Agency- Division of Marine Fisheries, State Department of Health
Missouri	Department of Health		State Environmental Agency	State Environmental Agency	
Wisconsin	State Department of Health and local health agencies	Local or state agency that "owns the beach"	Local Government	Local Government	State Environmental Agency
Oregon	State Health Department State Environmental Agency	State Health Department (ocean beaches only)	State Environmental Agency (or the Native American tribes, if treatment is associated with tribal lands)	State Health Department – monitor groundwater in general	State Environmental Agency Department of Agriculture

I.3 Selected Case Studies

A Case Study of the 1993 Milwaukee Cryptosporidiosis Outbreak

Background
In the spring of 1993, the City of Milwaukee, Wisconsin and surrounding areas saw a marked increase in absenteeism and reported cases of diarrhea (MacKenzie 1994). Clinical investigations found that residents were suffering from Cryptosporidiosis, a diarrheal disease caused by a microscopic parasite, *Cryptosporidium parvum*. This parasite can live in the intestines of humans and other mammals and can be passed in the feces of an infected individual (CDC 2003a). It is estimated that more than 400,000 people were infected during this outbreak; more than 600 persons had laboratory confirmed cases (MacKenzie 1994).

About Cryptosporidiosis

Cryptosporidiosis, caused by the parasite *Cryptosporidium parvum*, is a disease affecting many large mammals. Its symptoms include, diarrhea, abdominal cramps, loss of appetite, low-grade fever, nausea, and vomiting (CDC 2003a). Cryptosporitiosis is highly contagious and is passed via fecal oral contamination from one host to another. *Cryptosporidium* oocysts are very resistant to disinfection and can survive outside of a host for a long period of time. *Cryptosporidium* oocysts are found throughout the United States in soil, animal waste, and water (CDC 2003a). Once ingested by the host, the parasite attacks the small intestine and rapidly reproduces.

Incubation takes two to fourteen days from the initial infection. For individuals with healthy immune systems, the infection will last approximately two weeks; however, symptoms may cycle and the individual can appear to get better and then experience a relapse (CDC 2003a). The disease is potentially fatal for immunocompromised individuals. In those individuals the symptoms may last longer, and the disease may reappear after white blood cell numbers drop (CDC 2003b).

It is estimated that in industrialized countries, approximately 0.4% of the population pass *Cryptosporidium parvum* oocysts at any one given time, and of patients admitted to hospitals for diarrhea, 2-2.5% have Cryptosporidiosis. Further, 30-35% of the U.S. population has antibodies for *Cryptosporidium parvum*, evidence that they have been exposed to the parasite at some point (Upton 2001).

Exposure Pathway and Source of Parasite
The Milwaukee Cryptosporidiosis outbreak was caused by ingestion of contaminated water from Lake Michigan. The Milwaukee Water Works (MWW) supplies water, obtained from Lake Michigan, to the City of Milwaukee and nine surrounding municipalities via two water treatment plants, one located in the northern part of the district and the other in the south.

Beginning on approximately March 21, 1993, and continuing through April 9, the southern treatment plant reported increases in the turbidity of treated water, rising from a low of 0.25 NTU to a peak of 1.7 NTU. This finding, coupled with the fact that a majority of the laboratory and clinically confirmed cases of Cryptosporidiosis were from households predominately supplied by the southern water treatment plant, led investigators to conclude that contaminated water from Lake Michigan was not properly filtered and was supplied to, and ingested by, residents in the southern plant treatment service area. (MacKenzie 1994) Although the environmental source of the parasite is not known, inferences include agricultural run-off, slaughterhouses, and untreated wastewater leaks (MacKenzie 1994).

Tracking, Reporting, and Response
On April 5, 1993, the Milwaukee Department of Health contacted the Wisconsin Division of Health after widespread absenteeism in key professions was reported. On April 7, 1993, two laboratories in the Milwaukee area identified *Cryptosporidium* oocysts in stool samples. On the evening of April 7, 1993, a boil water advisory was issued and the southern plant was temporarily closed on April 9, 1993 (MacKenzie 1994). Although the MWW was within required water quality limits, a streaming-current monitor, which helps determine the amount of coagulant needed for filtration, was not installed correctly. This was quickly fixed.

Impact
It is estimated that over 400,000 people were infected with Cryptosporidiosis (MacKenzie 1994). Their symptoms included: cramps, malaise, nausea, decreased appetite, weight loss, muscle pain, and rash (Frisby 1997). These symptoms resulted in decreased productivity and it was reported that the "gastrointestinal illness resulted in widespread absenteeism among hospital employees, students, and schoolteachers" (MacKenzie 1994).

Additional Comment
The Milwaukee outbreak helped identify shortcomings of the waterborne disease outbreak surveillance system that was in operation in the United States. Researchers suggested that laboratories should perform routine stool tests for *Cryptosporidium* when patients' symptoms warranted (Mac Kenzie 1994). They also suggested that the *Cryptosporidium* tests were not sensitive enough and should be repeated in order to account for the time needed for the *Cryptosporidium* oocysts to enter the feces (Cicirello 1997). Most importantly, at the time of the Milwaukee outbreak, Cryptosporidiosis was not legally required to be reported to state health officials. As a result of this, and other outbreaks, Cryptosporidiosis is now a "reportable illness" in many jurisdictions.

A Case Study of the 1998 Brushy Creek Cryptosporidiosis Outbreak

Background
On July 13, 1998, a lightning strike during a thunderstorm incapacitated the controls at a wastewater lift station located upstream from the Brushy Creek Municipal Utility District's (MUD) five drinking water wells. This power outage caused 167,000 gallons of raw sewage to flow into Brushy Creek (TDH 1998).

Beginning on July 24, 1998, the Texas Department of Health Infectious Disease Epidemiology and Surveillance Division (IDEAS) and the Williamson County and Cities Health Districts began to receive calls from Brushy Creek residents complaining of nausea, diarrhea, and abdominal cramps. It was later determined that residents of Brushy Creek were suffering from Cryptosporidiosis. It is estimated that 60 percent of Brushy Creek's population of 10,000 were exposed to the parasite and approximately 1,440 residents contracted Cryptosporidiosis (TDH 1998).

Exposure Pathway and Source of Parasite
The Brushy Creek Cryptosporidiosis outbreak was caused by ingestion of contaminated water from the Brushy Creek MUD wells. It was reported that MUD customers whose water came from the contaminated wells were five times more likely to be ill than MUD customers whose water came from treated surface water (TDH 1998). Fecal coliform tests performed on raw water samples taken from the five wells after the sewage leak showed high levels of *E. coli* and helped to confirm that the wells had been contaminated (four of the five wells were positive)(TDH 1998).

Tracking, Reporting, and Response
In response to the massive sewage spill, the Texas Natural Resources Conservation Commission (TNRCC) instructed the Brushy Creek MUD to test its five water wells for fecal coliform (July 17). Based on results of those tests, received on July 21, the Brushy Creek MUD was ordered to take all the wells off-line and purchase water from the city of Round Rock. On July 24, 1998, the Texas Department of Health and local health districts began receiving residents' complaints of symptoms related to gastrointestinal disease, and TNRCC contacted the Texas Department of Health to request assistance with a possible waterborne disease outbreak in Williamson County (TDH 1998). In cooperation with local health departments, IDEAS distributed specimen containers to Brushy Creek residents in order to obtain stool samples. Twelve of the specimen containers were returned, all were tested and found negative for viral and bacterial pathogens, six however, were positive for *Cryptosporidium parvum* (TDH 1998).

Impact
It is estimated that 1,440 people suffered from Cryptosporidiosis during this outbreak (there were 89 laboratory confirmed cases). The infected persons complained of nausea, diarrhea, and abdominal cramps. Based on a residents survey, the mean duration of the illness was seven days (range 1- 45 days) (TDH 1998).

Additional Comments
Brushy Creek MUD wells are 100 feet deep and encased in cement. It is generally thought that these types of wells would not be influenced by surface water. This presumption is probably the reason residents of Brushy Creek were supplied water from the contaminated well for approximately eight days. This outbreak illustrates that even wells with this degree of protection can be contaminated by surface water (TDH 1998).

Forty-five additional cases of Cryptosporidiosis were reported in the Brushy Creek area between September 1 and December 31, 1998. It was not possible to determine if these cases would have occurred without the earlier water contamination because no reliable data were collected to establish a normal rate of Cryptosporidiosis in Texas.

A Case Study of the 1995 Idaho Shigellosis Outbreak

Background

In August 1995 the local health department requested that the Idaho Department of Health investigate reports of diarrheal illness among resort visitors in Island Park, Idaho. Clinical investigations found that these individuals were suffering from Shigellosis, a diarrheal disease caused by a microscopic parasite, *Shigella sonnei* (CDC 1996). This parasite can live in the intestines of humans and other mammals and can be passed in the feces of an infected organism. (CDC 2003c). Eighty-two cases were identified among visitors to the resort as well as a few cases among local residents (CDC 1996).

About Shigellosis

Shigellosis, caused by the parasite *Shigella sonnei*, is a well-recognized cause of gastrointestinal illness in humans and is the most common cause of bacillary dysentary in the United States (CDC 2003c). Symptoms include diarrhea, fever, abdominal pain, and blood or mucus in the stool. Most outbreaks of Shigellosis are attributed to person-to-person transmission, however, the disease has also been reported to spread through food, water, and swimming (CDC 2003c). Waterborne outbreaks are commonly associated with wells that have been fecally contaminated. However, because Shigella organisms rarely are isolated from water sources, the identification of a waterborne source usually is based on epidemiologic evidence (CDC 2003c).

Most people who are infected with *Shigella* develop diarrhea, fever, and stomach cramps starting a day or two after they are exposed. The diarrhea usually resolves in five to seven days. In some persons, especially young children and the elderly, the diarrhea can be so severe that the patient needs to be hospitalized. Some persons who are infected may have no symptoms at all, but may still pass the bacteria to others.

Approximately 14,000 laboratory confirmed cases of shigellosis and an estimated 448,240 total cases (mostly due to *Shigella sonnei*) occur in the United States each year (CDC 2003d). This disease is very common in developing countries and, depending on the strain, can be deadly. Further, Shigella has, in some areas, become resistant to antibiotics.

Exposure Pathway and Source of Parasite

The Island Park Shigellosis outbreak was probably caused by the ingestion of contaminated well water. Testing of wells in the neighborhood indicated that a number of the wells were contaminated with fecal coliform bacteria (CDC 1996). While cultures did not indicate the presence of *Shigella sonnei*, it is known that Shigella organisms are rarely successfully isolated from water sources. Identification of a waterborne source is generally based on epidemiologic evidence (CDC 1996). Plasmid profile analyses indicated that the Shigella organisms were of the same strain in both the infected resort visitors and the infected neighbors. This suggests that the organisms may have been transmitted from multiple wells in the same area through common groundwater (CDC 1996). The water table in the area was higher than normal due to increased rainfall levels during the spring. Inspection of a nearby sewer line found that the wastewater was not draining properly, but no specific leaks were identified when sections were excavated for inspection (CDC 1996).

Tracking, Reporting, and Response

After receiving reports of diarrheal illness among guests at the resort, the local health department recommended several prevention measures before initiating the investigation (CDC 1996). On August 17, the resort posted warning signs at water taps cautioning against drinking water; on August 19, food service was terminated; and on August 21, bottled water was placed in every room. Resort water is supplied by one well, which was dug in 1993 (CDC 1996). Samples of water obtained from the well on August 23 were positive for fecal coliform bacteria; however, cultures were negative for Shigella. After this testing was completed the local health department required that the resort provide bottled or boiled water to visitors and recommended that persons residing in the area have their well water tested and boil all drinking water. Since the investigation, the resort has drilled a new and deeper well (CDC 1996).

Impact

Eighty-two cases were identified among resort visitors and six cases were identified among individuals in neighboring houses. After testing well water throughout the neighborhood the local health department recommended that residents have their well water tested and a boil water advisory was put into effect. No specific source of Shigella organisms was ever identified.

Additional Comments

Routine water-quality testing, including testing for fecal coliform bacteria, is the most practical indicator of possible bacterial contamination of drinking water from both community and private water supplies. However, many privately owned wells are never tested for fecal coliform bacteria (CDC 1996). In addition, timely testing, reporting, and follow-up in cases of contaminated public water systems are often constrained by limited resources available to local health departments (CDC 1996).

A Case Study of the 1993 Las Vegas Cryptosporidiosis Outbreak

Background

Over a seven month period in 1993 and 1994, Clark County, Nevada, which includes Las Vegas, experienced a rise in the number of HIV-infected individuals with diarrheal disease. Clinical investigations found that these individuals were suffering from Cryptosporidiosis. There was no estimate of the number of individuals infected during the course of this outbreak (Goldstein 1996).

Exposure Pathway and Source of Parasite

The Clark County Cryptosporidiosis outbreak was most likely caused by ingestion of contaminated water from Lake Mead. The water treatment plant serving Clark County supplies water, obtained from Lake Mead, to the City of Las Vegas and the rest of the county (Goldstein 1996). It was not reported to be malfunctioning at any point during the seven month outbreak period. The maximum recorded turbidity value during the outbreak period reached 0.17 NTU, as compared with the 1.7 NTU value recorded during the 1993 Milwaukee Cryptosporidiosis outbreak (Goldstein 1996).

Due to the widespread geographic nature of the infected patients, it is assumed that the municipal drinking water supply was contaminated before reaching the treatment plant (Goldstein 1996). While the water was filtered and chlorinated at the treatment plant some *Cryptosporidium* oocysts survived the process and entered the municipal drinking water system. This is not surprising considering the resistance of *Cryptosporidium* oocysts to chlorination. Individuals then were exposed. The lack of positive test results for this parasite in the water supply, coupled with the persistence of this outbreak suggest an intermittent, low-level of contamination of the water.

Tracking, Reporting, and Response

Because water quality exceeded all standards, waterborne transmission of this parasite was not suspected and no advisory warning residents to boil their water was issued. This situation remained unchanged for approximately fourteen weeks after the possible outbreak was first noted in mid-March 1993 (Goldstein 1996).

The fact that Cryptosporidiosis is a reportable disease in Nevada combined with the awareness of physicians regarding the sensitivity of immunocompromised patients to exposure to this disease led to recognition of an outbreak that might have otherwise not been reported (Goldstein 1996). Generally, the appropriate laboratory tests that would identify Cryptosporidiosis infection are not carried out unless a physician is aware of a source of contamination in the community or if they are dealing with an individual who is particularly sensitive to this type of disease.

Impact

There is no estimate of the number of people infected during the course of this outbreak. A much higher incidence of reported infections occurred among HIV-infected individuals. The short-term mortality rate for the HIV-infected adults who had cryptosporidiosis was high. Two thirds of those who died during or shortly after the outbreak had cryptosporidiosis listed on their death certificates. These data do not differentiate dying "of" from dying "with" cryptosporidiosis. For these HIV-infected case-patients early mortality was higher, but one year mortality was not when compared with a HIV-positive, but non-*Cryptosporidium* exposed control group (Goldstein 1996).

Additional Comments

Laboratories do not routinely test for this type of infection as this diagnosis is rarely considered when not dealing with an immunosuppressed patient. Researchers suggest that the public health significance of waterborne-*Cryptosporidium* infection in the United States must be determined. To accomplish this task epidemiologists need more sensitive and rapid methods for detecting oocysts in water, workable surveillance systems able to detect cases associated with low-level transmission of *Cryptosporidium*, and epidemiologic studies specifically designed to address the risk for waterborne transmission of *Cryptosporidium* in nonoutbreak settings (Goldstein 1996).

A Case Study of the 1985 Braun Station, Texas Cryptosporidiosis Outbreak

Background

In a period between May and July 1984 two distinct gastroenteritis outbreaks were identified in the community surrounding Braun Station, Texas (D'Antonio 1985). Clinical investigations found that individuals impacted during the first outbreak were suffering from Norwalk virus and those impacted during the second outbreak were suffering from Cryptosporidiosis. This parasite can live in the intestines of humans and other mammals and can be passed in the feces of an infected organism. (CDC 2003a). *Cryptosporidium* oocysts were identified in 47 of 79 tested Braun Station patients (D'Antonio 1985). Oocycsts were also identified in samples from 12 patients suffering from gastroenteritis, but who did not reside in Braun Station.

Exposure Pathway and Source of Parasite

No geographical clustering or age-related patterns emerged upon examination of the July Cryptosporidiosis outbreak in Braun Station. However, consumption of tap water was greater among those afflicted and individuals who were not in the area during the month of July were generally not infected (D'Antonio 1985). Public drinking water is drawn from an artesian well that is not filtered, but is chlorinated shortly before distribution. The outbreak was investigated as it occurred. Well water is generally not tested in this region of Texas, but community complaints convinced authorities to begin testing in mid-June. Chlorinated water samples were found to be coliform-negative. However, untreated well water samples tested had fecal coliform counts as high as 2600/100 mL (D'Antonio 1985). A boil water advisory was put into effect. Subsequent dye tests indicated that the community's wastewater system was leaking into the well water. Attempts to identify the exact site of contamination were not successful. The pattern of repeated outbreak but differing major causative agent suggested that contamination of the water supply was intermittent (D'Antonio 1985). The community was provided with an alternate water supply.

Tracking, Reporting, and Response

A cluster of patients suffering from gastroenteritis in Braun Station led to the recognition of both outbreaks. Community-requested water testing and subsequent dye tests identified wastewater contamination of the community's well water. A boil water advisory was issued after evidence of contaminated water was gathered. When the source of the wastewater could not be identified and stopped, an alternative water source was provided to the community. The differing types of causative agents at the root of each outbreak suggested intermittent water supply contamination.

Impact

Symptoms associated with Cryptosporidiosis infection were experienced by an estimated 2,006 patients in Braun Station. Once the source of infection was identified, proper steps were taken to ensure that the community was supplied with a healthy water supply.

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I.4 Tables showing various concentrations of pathogenic bacteric, enteric viruses, and parasitic protozoa in sewage.

Table I.6 Concentrations of Common Pathogenic Bacteria in Sewage

Bacteria	Concentration in Sewage (per 100mL)	Reference
Camplyobacter	3,700	Holler 1988
	10,000-100,000	WHO 2003
Pathogenic *E.coli*	1,321,594 (30,000-6,200,000)	Payment 2001
	1,000,000-10,000,000	WHO 2003
	1,190,000 2,500,000 3,180,000 4,120,000 2,880,000 1,600,000 2,170,000	Gore et al. 1999
Salmonella	2.3-8,000	NAS 1993
	240-1,200 93-1,100 1,100-11,000 150-1,100	Koivunen 2003
	100-10,000	NRC 1998
	400-8,000	EPA 1992
	8,000	NRC 1996
	528	Bitton 1980
	400-1,200	Pettygrove and Asano 1985
	500-8,000	Yates 1994
	418	Payment and Franco 1993
	0.2-8,000	WHO 2003
	13 62 >190 45 <20 170 <40	Gore et al. 1999
S. typhi	--	--
Shigella	1-1,000	NAS 1993
	1-1,000	EPA 1992
	1,000	NRC 1996
	1-1000	NRC 1998
	0.1-1,000	WHO 2003
Vibrio cholera	--	--
Vibrio non-cholera	10-10,000	NAS 1993
Yersinia	--	--

Table I.7 Concentrations of Enteric Viruses Present in Sewage

Virus Group	Concentration in Sewage (per 100mL)	Reference
Adenovirus	10-10,000	NAS 1993
Astrovirus	--	--
Noravirus (includes Norwalk-like viruses)	--	--
Echovirus	--	--
Enterovirus (includes polio, encephalitis, conjunctivitis, and coxsackie viruses)	18.2-9,200	NAS 1993
	>0.720 >11 23 4.5	Rose 2001a
	96.2 (0.4-1,251)	Payment et al. 2001
	1,000-10,000 1.085 1 7 5 40 2 1	NRC 1998
	1.1	Rose 2001 (WER article)
	100-50000	EPA 1992
	7 (0.75-80)	Hejkal 1984
	1.98 0.05 14.8 3.95 6.91 3.95	Smith and Gerba 1982
	50,000	NRC 1996
	100-49,200	Pettygrove and Asano 1985
	10,000-100,000	Yates 1994
	0.284	Payment and Franco 1993
	0.42	Rose 1996
	10,000	Wyn-Jones and Sellwood 2001

Table I.7 continued

Virus Group	Concentration in Sewage (per 100mL)	Reference
Reovirus	0.1-124.7	NAS 1993
Rotavirus	40.1	NAS 1993
	0.98 (0.1-32.1)	Hejkal et al. 1984
	9.6 9.6 6.7 17.4 8 1.5	Smith and Gerba 1982
	400-85,000	WHO 2003

Table I.8 Concentrations of Common Parasitic Protozoa Present in Sewage

Parasitic Protozoa	Concentration in Sewage (per L)	Reference
Cryptosporidium	10-1000	NAS 1993
	47.7	Chauret 1999
	6 (1-560)	Payment 2001
	<40-625 226.0 60 (3-400) 20 (0-3,000)	Mahin and Pancorbo 1999
	20 17 <4.348 8.16 9.52	Rose 2001a
	14.84 15 0.3 2 1 15	NRC 1998
	15	Rose 2001b
	7.42	Payment and Franco 1993
	40 280 160 80 120	LA County SD 2003
	3.7	Rose 1996
	69.1	Gennaccaro et al. 2003
	1-390	WHO 2003
	<2-24 0 0 <2 2 <2-8 <2-8 <2-24 4.1-13,700	McCuin and Clancy 2004
Entamoeba	28-52	NAS 1993
	0-100	EPA 1992
	4.0	Bitton 1980
	4	WHO 2003

Table I.8 continued

Parasitic Protozoa	Concentration in Sewage (per L)	Reference
Giardia	530-100,000	NAS 1993
	82.5	Chauret 1999
	1,165 (100-9,200)	Payment 2001
	390 315 10-13,600 642-3,375 354 (90-2,830) 290 (40-1,140)	Mahin and Pancorbo 1999
	200 480 200 220 42.86	Rose 2001a
	490 69 39 325 2 69	NRC 1998
	490	Rose 2001b
	13.76	Payment and Franco 1993
	29,000 19,000 16,000 27,000 32,000 4,760 5,080 15,560 9,760 19,280	LA County SD 2003
	500-100,000	EPA 1992
	100,000	NRC 1996
	9,000-200,000	Yates 1994
	39	Rose 1996
	125-200,000	WHO 2003

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