MMWR

Surveillance Summaries

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Surveillance for Waterborne Disease Outbreaks -- United States, 1991-1992

Summary

Problem/Condition: Since 1971, CDC and the U.S. Environmental Protection Agency have maintained a collaborative surveillance program for collection and periodic reporting of data on the occurrence and causes of waterborne disease outbreaks.

Reporting Period Covered: January 1991 through December 1992.

Description of System: The surveillance system includes data about outbreaks associated with water intended for drinking and also about those associated with recreational water. State and local public health departments are the agencies with primary responsibility for the detection and investigation of outbreaks. State and territorial health departments report these outbreaks to CDC on a standard form.

Results: For the 2-year period 1991-1992, 17 states and territories reported 34 outbreaks associated with water intended for drinking. The outbreaks caused an estimated 17,464 persons to become ill. A protozoal parasite (Giardia lamblia or Cryptosporidium) was identified as the etiologic agent for seven of the 11 outbreaks for which an agent was determined. Five (71%) of the outbreaks caused by protozoa were associated with a surface-influenced groundwater source. One outbreak of cryptosporidiosis was associated with filtered and chlorinated surface water. Shigella sonnei and hepatitis A virus were implicated in one outbreak each; both were linked to consumption of contaminated well water. Two outbreaks due to acute chemical poisoning were reported; one had an associated fatality. No etiology was established for 23 (68%) of the 34 outbreaks, including the largest one reported during this period, in which an estimated 9,847 persons using a filtered surface water supply developed gastroenteritis. Most (76%) of the 34 outbreaks were associated with a well water source.

Twenty-one states reported 39 outbreaks associated with recreational water, in which an estimated 1,825 persons became ill. The most frequently reported illness was hot tub- or whirlpool-associated Pseudomonas dermatitis (12 outbreaks). Of 11 outbreaks of swimming-associated gastroenteritis, six were caused by Giardia or Cryptosporidium, including three outbreaks associated with chlorinated, filtered pool water. The first reported outbreak of Escherichia coli O157:H7 infection associated with recreational exposure occurred during this period. Primary amebic meningoencephalitis, caused by Naegleria fowleri infection, resulted in six deaths.

Interpretation: The number of waterborne disease outbreaks reported per year has not changed substantially in the past 5 years. However, etiologic agents only recently associated with waterborne disease, such as E. coli O157:H7 and Cryptosporidium, are being reported more frequently and from new settings. Water quality data for outbreaks during the period 1991-1992 indicate that available water disinfection technology is not always in place or used reliably. However, the high percentage of outbreaks attributed to relatively chlorine-resistant protozoa suggests that improvements in monitoring and treatment of potable water may be needed.

Actions Taken: Surveillance data, which identify the types of water systems and their deficiencies and the etiologic agents associated with outbreaks, are used to evaluate the adequacy of current technologies for providing safe drinking and recreational water, establish research priorities, and assist in improving water quality regulations.

INTRODUCTION

The reporting of waterborne disease outbreaks (WBDOs) is voluntary in the United States. National statistics on outbreaks associated with water intended for drinking have been available since 1920 (1). Since 1971, CDC and the Environmental Protection Agency (EPA) have maintained a collaborative surveillance program with collection and periodic reporting of data on the occurrence and causes of waterborne outbreaks (2,3). This summary includes data for 1991 and 1992 and for previously unreported outbreaks in 1988 and 1989.

The surveillance program includes data for outbreaks associated with water intended for drinking and with recreational water. Previous summaries have reported data for foodborne outbreaks of gastroenteritis on oceangoing passenger vessels that call on U.S. ports. Because these data are not related to the goals of the surveillance program, they will no longer be included in these summaries.

CDC and EPA activities related to waterborne disease surveillance have the following goals: a) to characterize the epidemiology of waterborne diseases; b) to identify deficiencies in water systems and the etiologic agents causing outbreaks; c) to train public health personnel in investigating WBDOs; and d) to collaborate with local, state, and other federal and international agencies on initiatives to prevent waterborne disease. The data gathered through surveillance are useful for evaluating the adequacy of current treatment technologies for providing safe drinking and recreational water. Surveillance information influences research priorities and may lead to improved water quality regulations.

State health departments can request epidemiologic assistance from CDC in the investigation of WBDOs. In addition, CDC and EPA can be consulted about the engineering and environmental aspects of water treatment and about collecting large-volume water samples to identify pathogenic bacteria, viruses, or parasites.

EPA REGULATIONS FOR WATER INTENDED FOR DRINKING

Public water systems are regulated under the Safe Drinking Water Act (SWDA) (PL 93-523) of 1974. The microbial content of drinking water is regulated by EPA through the Total Coliform Rule (54 FR 27544-27568) and the Surface Water Treatment Requirements (SWTR) (54 FR 27486-27541). A maximum contaminant level for total coliforms specifies the percentage of samples that may contain any coliforms during a month. The turbidity of finished water must meet specified maximum and monthly standards. All public systems using surface water or groundwater under the direct influence of surface water must provide disinfection. Systems must also filter the water unless they meet specific conditions, including source water quality criteria for turbidity and total or fecal coliforms and a watershed control program to minimize potential contamination by human enteric viruses and Giardia cysts. EPA is considering a groundwater disinfection rule and revisions to the SWTR.

METHODS

Sources of Data

State and local public health agencies are primarily responsible for the detection and investigation of disease outbreaks. State health departments voluntarily report WBDOs to CDC on a standard form (CDC form 52.12, Rev. 02-91). In December 1991 and 1992, CDC personnel sent requests for reports to the state and territorial epidemiologists or to persons designated as coordinators of WBDO surveillance. Personnel in states that did not respond to the letters were contacted by telephone. In addition, personnel from the EPA Health Effects Research Laboratory contacted state water supply agencies to obtain information about WBDOs.

Definition of Terms

The surveillance system for WBDOs differs from other systems in that the unit of analysis is an outbreak rather than an individual case of a particular disease. Two criteria must be met for an event to be defined as a WBDO. First, at least two persons must have experienced a similar illness after ingestion of water intended for drinking or after exposure to water used for recreational purposes. Second, epidemiologic evidence must implicate water as the source of the illness. The stipulation that at least two persons be ill is waived for single cases of laboratory-confirmed primary amebic meningoencephalitis and for single cases of chemical poisoning (if water quality data indicate contamination by the chemical). If primary and secondary cases are distinguished on the outbreak report form, only primary cases are included in the case counts.

Community and noncommunity public water systems are regulated under the SDWA. Community water systems are defined as public or investor-owned systems that serve large or small communities, subdivisions, or mobile-home parks with at least 15 service connections or 25 year-round residents. Noncommunity water systems serve institutions, industries, camps, parks, hotels, or businesses that may be used by the general public. Of the approximately 200,000 water systems in the U.S. classified as public, 30% (60,000) are community water systems and 70% (140,000) are noncommunity systems. Community water systems serve 91% of the U.S. population; the remaining 9% are served by nonpublic or individual systems, usually wells or springs, used by one or several residences or by persons traveling outside populated areas.

Deficiencies in water systems are classified as follows:

1 = untreated surface water (e.g., from rivers, lakes, or

reservoirs); 2 = untreated groundwater (e.g., from wells or springs); 3 = treatment deficiency (e.g., temporary interruption of

disinfection, chronically inadequate disinfection, filtration absent or inadequate); 4 = distribution system deficiency (e.g., a cross-connection,

back siphonage, contamination of water mains during construction or repair, or contamination of a storage facility); and 5 = unknown or miscellaneous deficiency. If more than one deficiency was reported for an outbreak, only the most important is noted in the line listings. Outbreaks due to contamination of water or ice at the point of use (e.g., a contaminated serving container) are not included in the line listings.

Recreational waters are categorized as freshwater swimming pools, whirlpools, and naturally occurring fresh and marine surface waters. Although the surveillance system includes whirlpool- and hot tub-associated outbreaks of dermatitis due to Pseudomonas, it does not include wound infections caused by waterborne organisms, such as Aeromonas species.

Classification of Outbreaks

In this surveillance system, outbreaks are classified according to the strength of the evidence implicating water (Table_1). Each outbreak, except single cases of illness resulting from chemical poisoning and primary amebic meningo- encephalitis, is classified (I through IV) based on the epidemiologic data and the presence or absence of water quality data on the report form. Epidemiologic data are weighted more heavily than water quality data. Thus, in this summary, some outbreaks without water quality data were included, but reports without supporting epidemiologic data were omitted. The classification numbers are included in the line listings to indicate what data were available. Classification numbers of II-IV do not necessarily imply that the investigations were flawed; the circumstances of each outbreak differ, and not all outbreaks can or should be rigorously investigated. A classification of I means that both epidemiologic and water quality data were reported but does not necessarily imply that the investigation was optimal.

RESULTS

Outbreaks Associated with Water Intended for Drinking

For the 2-year period 1991-1992, 17 states and territories reported 34 outbreaks associated with water intended for drinking. The outbreaks caused illness in an estimated 17,464 persons. Twenty-three outbreak reports (68%) were classified as Class I (i.e., adequate epidemiologic and water quality data were provided). Outbreaks are listed individually by state (Table_2 and Table_3) and are tabulated by etiologic agent and type of water system (Table_4) and by water system deficiency (Table_5).

Fifteen outbreaks were reported for 1991 and 19 for 1992. No outbreaks were reported for the months of October, November, or December. The month with the most outbreaks (nine) was June (Figure_1). The median outbreak size was 57 persons (range, 1-9,847). Twelve (35%) of the outbreaks were reported from Pennsylvania.

Thirty-one (91%) of the outbreaks caused gastroenteritis. The other waterborne illnesses were chemical poisoning (two outbreaks) and hepatitis (one outbreak). Of the estimated 17,464 persons reported ill, 40 persons were hospitalized and one died. Of the hospitalized persons, 29 had acute gastrointestinal illness of unknown etiology (AGI), four had cryptosporidiosis, three had hepatitis A infection, two had giardiasis, one had nitrate intoxication, and one had fluoride intoxication. The reported death occurred after fluoride poisoning.

Etiologic Agents

A protozoal parasite (Giardia lamblia or Cryptosporidium) was identified as the causative agent in seven outbreaks, representing 21% of the 34 outbreaks and 64% of the 11 WBDOs for which an etiology was determined. The four outbreaks of giardiasis, which affected an estimated 123 persons, were reported from California, Idaho, Nevada, and Pennsylvania. The outbreaks occurred in March (two), July (one), and September (one). Two were associated with community water systems and two with noncommunity systems. In the Nevada outbreak, the community was supplied by unfiltered surface water that contained low levels of Giardia cysts; however, neither source nor tap water had detectable coliforms present. Chlorination of finished water had not been maintained consistently in this system. The other three giardiasis outbreaks were associated with groundwater supplies. In one of these, a cross-connection resulted in contaminated surface water entering a system using a spring water source. In another, coliforms were present in a water sample, but the source of contamination of either the well or the underground storage tanks was not determined. No deficiency was identified in the remaining outbreak, which was associated with a chlorinated well water source. In this outbreak, consumption of well water was implicated epidemiologically; untreated water analyzed 3 months after the outbreak did not contain coliforms.

Three outbreaks of cryptosporidiosis, which resulted in illness in an estimated 3,551 persons, occurred in Oregon (two) and Pennsylvania (one). They began in February, May, and August, respectively. Although the two Oregon outbreaks occurred in geographically adjacent locations and may have overlapped in time, epidemiologic evidence suggests they were separate outbreaks. Because of some overlap in the affected populations, case counts for the two outbreaks (Table_3) have been added together.

Two distinct water supplies were implicated in the Oregon outbreaks. The first outbreak was associated with a disinfected spring water source that supplied a community of 80,000 people. Low numbers of Cryptosporidium oocysts were found in water samples obtained over a 2-week period, but none were found in numerous samples collected for 10 weeks thereafter. Sporadic low levels of coliforms, algae, and diatoms suggested that the spring may have been influenced by surface water.

The other Oregon outbreak was associated with inadequate filtration of a river water source. The river received waste water discharges, and water quality had deteriorated because of low stream flow during dry weather (4). The presence of Cryptosporidium oocysts in the filtered water was not confirmed. However, a reliable examination was not possible because the filtered water contained an excessive number of oocyst-sized particles (e.g., algae). The turbidity of the filtered effluent water was elevated; however, mean levels did not exceed the limits of the EPA SWTR. For both Oregon outbreaks, a review of water quality records showed that each system had consistently met the coliform and turbidity maximum contaminant level (MCL) over the past several years.

The third outbreak of cryptosporidiosis was associated with a noncommunity well water source. Detection of coccidian oocysts that were the size and shape of Cryptosporidium, algae, and diatoms indicated that the well was influenced by surface water. Finished water in all three outbreaks was free of coliforms, and chlorine levels were probably sufficient to inactivate bacteria but not Cryptosporidium oocysts, which are highly chlorine resistant.

Nonparasitic infectious etiologies were identified for only two outbreaks. One, a WBDO caused by Shigella sonnei, which resulted in illness in an estimated 150 persons, occurred in a park in which an untreated spring-water source was contaminated with surface water. Shigella was demonstrated both in water samples and in stool specimens. An outbreak of serologically confirmed hepatitis A infection, associated with an untreated well water supply (individual household), was the only outbreak in which a viral pathogen was identified.

Two outbreaks due to acute chemical intoxication were reported. A case of methemoglobinemia (5) was due to ingestion of infant formula diluted with water that contained elevated levels of nitrate and copper. The water was from a shallow well that supplied an individual household equipped with a reverse-osmosis membrane filter. The filter reduced elevated nitrate-nitrogen levels in well water (58 mg/L) to a concentration in tap water (9.9 mg/L) that was close to the MCL. A large outbreak of acute fluoride poisoning caused illness in 262 persons and one fatality. Symptoms included nausea, vomiting, diarrhea, abdominal pain, numbness, and tingling. Serum chemistry abnormalities, including elevated lactic acid dehydrogenase and phosphorus levels and low magnesium levels, persisted for at least a week in some ill persons. The outbreak was attributed to improperly installed equipment and to inadequate monitoring of the community water system, which resulted in fluoride levels in the water that were 12-fold higher than recommended.

In 23 WBDOs (68%), no etiologic agent was identified. Fourteen of these outbreaks of AGI included cases in which the symptom complex, incubation period, and duration of illness were consistent with a viral syndrome. In 15 of the outbreaks of AGI, stool specimens were negative for bacterial pathogens. Stool specimens were examined for ova and parasites in three investigations and for viral pathogens in only one. Coliforms were found in water samples for 19 (83%) of the AGI outbreaks, and chlorination deficiencies were associated with two others. In the largest AGI outbreak, an estimated 9,847 persons in Puerto Rico became ill when the water system resumed operation after an interruption due to drought. Waste water discharges into the river water source, temporary lack of chlorination, filtration deficiencies, and insufficient flushing of old water from pipes and tanks were identified as possible factors contributing to the outbreak.

Water Quality Data

Water quality data were obtained within 1 month of the WBDO for 30 (94%) of the 32 outbreaks that had a known or suspected infectious etiology. For all 30 of these WBDOs, water was tested for coliforms; in five outbreaks, samples were also examined for protozoa. Coliforms were noted for 24 outbreaks (80%). Overall, for outbreaks with bacterial, viral, or unknown etiologies, coliform testing was positive in 21 (88%). However, for protozoal outbreaks, finished water collected within a month of the outbreak contained coliforms in only two (33%) of six. Water was shown to contain the etiologic agent for four outbreaks: Shigella (one), Giardia (two), and Cryptosporidium (one).

Water Supply

Twenty-three (68%) of the 34 WBDOs were associated with noncommunity systems and only eight (24%) with community systems, but the outbreaks in community systems resulted in 77% of the total cases (Table_4, Figure_2). Outbreaks in community systems were primarily associated with surface water sources (63%). In contrast, only 4% of noncommunity outbreaks were associated with surface water.

Of the 34 outbreaks, 26 (76%) occurred in systems using well water. In 12 (46%) of the 26, the water was untreated. Inadequate or interrupted disinfection was the deficiency identified in another 12 (46%). Ten of these systems used chlorine disinfection; two systems used ultraviolet (UV) light. Of the remaining two outbreaks associated with treated well-water systems, one was attributed to a cross-connection with an unapproved supplemental pond water source, and no deficiency was reported for the other.

Water Source

In six (18%) of the 34 outbreaks, the water source was a lake or river (surface water). All systems provided chlorination, and four also provided filtration. In the filtered systems, distribution deficiencies were found for one outbreak, no deficiency was identified for one, and the other two were associated with poor filtration of water. During one of these latter outbreaks, the water was also temporarily not chlorinated. One of the unfiltered systems was preparing for an exemption from the filtration required by EPA's Surface Water Treatment Rule, and its raw water quality had been excellent (low turbidity, no coliforms) before the outbreak.

Two outbreaks (6%) were associated with spring water. A giardiasis outbreak occurred when a cross-connection at the water storage tanks allowed contaminated surface water to enter the distribution system. For the other outbreak, which was due to Cryptosporidium, evidence (i.e., presence of algae and diatoms) suggested that surface water had entered the spring water.

Outbreaks attributed to water contaminated at the point of use rather than at its source or in its distribution traditionally are not included in the line listings. CDC received five reports of such outbreaks, which caused an estimated 593 persons to become ill, including three who were hospitalized. Four of the five were outbreaks of AGI associated with contamination of a container (three outbreaks) or ice (one outbreak). The other was an outbreak caused by Norwalk virus, which apparently contaminated an ice machine aboard an oceangoing passenger ship.

Outbreaks Associated with Recreational Water

For the period 1991-1992, 21 states reported a total of 39 outbreaks associated with water used for recreation (Table_6 and Table_7). Thirty-three outbreaks were reported for 1991 and six for 1992. Two of the 21 states submitted 13 of the 39 reports: Washington (seven) and Minnesota (six). Outbreaks were reported for each month except April and November, but most outbreaks occurred in June (nine) or July (eight) (Figure_1).

The outbreaks caused illness in an estimated 1,825 persons. Median outbreak size was seven persons (range, 1-595). Reported illnesses included dermatitis (15 outbreaks), gastroenteritis (11), meningoencephalitis (six), Pontiac fever (four), conjunctivitis with otitis or pharyngitis (two), and leptospirosis (one). Twenty-one persons reportedly were hospitalized. The six deaths associated with recreational water exposure were all due to amebic meningoencephalitis.

Of the 15 outbreaks of dermatitis, which affected an estimated 292 persons, 12 (80%) were outbreaks of rash or folliculitis associated with hot tubs, whirlpools, or swimming pools. In eight of the 12, Pseudomonas was confirmed as the etiologic agent, and in the other four, the clinical syndrome was consistent with this etiology. In seven of the investigations, water sampling demonstrated low chlorine concentrations or the presence of Pseudomonas, or both. In the three dermatitis outbreaks not associated with Pseudomonas, a clinical syndrome consistent with schistosomal dermatitis (swimmer's itch) was noted. Two of these outbreaks were associated with swimming in lakes in Utah and Wyoming. The third was associated with ocean water in Delaware; local snails were found to contain cercariae of Austrobilharzia variglandis, an avian schistosome implicated as a cause of cercarial dermatitis (6).

The etiologic agent identified in six (55%) of the 11 outbreaks of gastroenteritis (Table_7, Figure_3) was a protozoal parasite, either Giardia (four) or Cryptosporidium (two). Three Giardia outbreaks were related to unintentional ingestion of untreated water from a lake (one) or small wading pools (two). The other three parasitic outbreaks were associated with community pools that were chlorinated and filtered. No treatment deficiencies in the pools were identified. In five of the parasitic outbreaks, no water sampling for protozoa was done. In the other, examination of filter backwash from the pool 3 months after the outbreak did not reveal an etiologic agent.

Two outbreaks of gastroenteritis of unknown etiology were reported. Three other outbreaks of gastroenteritis were attributed to bacterial pathogens; each outbreak was associated with swimming in a lake. S. sonnei was implicated for all three outbreaks. In one of the three, Escherichia coli O157:H7 was also implicated. This was the first reported outbreak of E. coli O157:H7 linked to recreational water. Bacterial subtyping indicated that lake-associated transmission of both pathogens continued for 3 weeks (personal communication, W. Keene). Poor water exchange was a contributing factor in at least two of the three outbreaks, and, for both of these, fecal coliforms in shallow lake water exceeded recommended state levels by several-fold.

Four outbreaks of hot tub- or whirlpool-associated Pontiac fever were reported. In three of the four, serologically confirmed Legionella infection was documented (7). For the other, although the clinical syndrome was consistent with Pontiac fever, serologic results were negative.

Two outbreaks of conjunctivitis were reported. Adenovirus serotype 3 was implicated (from clinical and water samples) in an outbreak of conjunctivitis, pharyngitis, and fever. Over a 2-month period, an estimated 595 persons became ill after swimming in an inadequately chlorinated pond (8). A swimming-pool-associated outbreak of conjunctivitis, otitis, and rash was caused by Pseudomonas.

An outbreak of leptospirosis was associated with swimming in a rural pond that was stagnant because of drought (9). Leptospira interrogans serovar grippotyphosa was demonstrated in urine specimens from patients and also from pond water; this was the first reported investigation in which the organism was cultured from both clinical and environmental samples.

The six cases of fatal primary amebic meningoencephalitis occurred during the summer and fall of 1991 (10,11). Naegleria was demonstrated in brain autopsy specimens from five cases and in cerebrospinal fluid from the sixth. Cases were associated with swimming in a lake (two), pond (one), or stream (one), or with facial immersion in a puddle during a fight (one). Another was related to bathing in a hot spring that had been associated with two previous cases (10).

Previously Unreported Outbreaks

Reports of three previously unpublished outbreaks from 1988 through 1989 were received (Table 8). The etiologic agent for all three was S. sonnei. In the two associated with water intended for drinking, an estimated 141 persons were reported ill and 13 were hospitalized. Both outbreaks occurred in noncommunity well-water systems. Although each system was equipped for chlorination and one also had filtration and UV capabilities, the equipment was not being used appropriately. In the WBDO associated with recreational water, an estimated 61 persons were ill and six hospitalized after swimming in a lake in which an ill child had defecated.

DISCUSSION

General Interpretation of Surveillance Data for Waterborne Disease Outbreaks

The data in this surveillance summary should be interpreted with care. They probably do not reflect the true incidence of WBDOs or the relative incidence of outbreaks caused by various etiologies. Only a fraction of WBDOs may be recognized, investigated, and/or reported to CDC or EPA, and the extent of underrecognition and underreporting is unknown.

The likelihood that individual cases of illness will be epidemiologically linked and associated with water varies considerably among locales and is dependent on factors such as consumer awareness, physician interest, and surveillance activities of state and local health and environmental agencies. Therefore, the states with the most outbreak reports are not necessarily the ones with the most outbreaks. Recognition of WBDOs is dependent on certain outbreak characteristics; outbreaks involving serious illness are most likely to come to the attention of health authorities. In cities, large outbreaks are more likely to be recognized than sporadic cases or small outbreaks in which ill persons may consult different physicians. Outbreaks occurring in community water systems are more likely to be recognized than those in noncommunity systems because the latter serve nonresidential areas and transient populations. Outbreaks in individual systems are the most likely to be underreported because they generally involve small numbers of persons. Outbreaks of acute disease are more readily identified than those associated with disease from chronic, low-level exposure to a pathogen or chemical.

Identification of the etiologic agent of a WBDO is dependent on timely outbreak recognition so that appropriate clinical and environmental samples can be obtained. The interests and expertise of the investigators and the routine practices of local laboratories also influence whether the causative agent is identified. For example, diarrheal stool specimens generally are examined for bacterial pathogens but not viruses. In most laboratories, routine stool examination for ova and parasites does not include the special procedures needed to identify Cryptosporidium. Water quality data are also highly variable and depend on factors such as the health department's fiscal, investigative, and laboratory resources. Furthermore, a few large outbreaks may substantially alter the relative proportion of cases of waterborne disease attributed to a particular agent. The number of reported cases is generally an approximate figure, and the method and accuracy of the approximation vary among outbreaks.

1991-1992 Outbreaks Associated with Water Intended for Drinking

The total numbers of outbreaks reported for 1991 and 1992 are comparable with those reported for recent years: 15 and 19, respectively. With the addition of previously unreported outbreaks, 16 WBDOs have been reported for 1988, 13 for 1989, and 14 for 1990 (2,3). WBDO reports peaked during 1979-1983 (Figure 4 and Figure 5); the increase and the subsequent decrease in reports may reflect, at least in part, changes in surveillance activity rather than deterioration or improvement in water systems (12).

During the years 1971-1990, comparable proportions of WBDOs were associated with noncommunity (45%) and community systems (43%) (2,3,13). However, during 1991-1992, substantially more noncommunity than community outbreaks (68% versus 24%) were reported. Although these data may not indicate a new trend, they may reflect increased public usage of noncommunity systems in recreational areas; June and July were the months with the most noncommunity outbreaks. Outbreaks in noncommunity systems were more likely than those in community systems to be associated with untreated water (44% versus 13%).

Protozoal parasites were the most frequently identified etiologic agents. From 1978 through 1991, Giardia was the most commonly implicated pathogen (2). However, in 1992, the same numbers of outbreaks of giardiasis and cryptosporidiosis were reported. The increased identification of cryptosporidiosis may be due to heightened awareness that the organism may cause WBDOs (14- 16). However, outbreaks caused by Cryptosporidium are probably still underrecognized. An important factor in the recognition of the outbreaks in 1992 was routine screening of stool specimens for Cryptosporidium by certain local laboratories, which is not standard practice in most areas. The continued importance of waterborne cryptosporidiosis was recently underscored by an outbreak in Milwaukee (in March and April of 1993) that was the largest WBDO ever reported in the United States; an estimated 403,000 persons had watery diarrhea (personal communication, JP Davis). Cryptosporidium oocysts are widespread in U.S. raw water sources in both pristine and polluted areas (17). Water analysis at 66 U.S. and Canadian surface water treatment plants has revealed low levels of Cryptosporidium oocysts in up to 27% of drinking water samples (18), but the methods used do not assess viability or potential infectivity of the cysts. The risk posed by these low levels of oocysts for immunocompetent and immunocompromised persons is unknown. In the Oregon outbreak in February 1992, oocyst levels in environmental samples were low, and the attack rate (less than 5%) was also lower than the attack rates reported for Cryptosporidium outbreaks in which oocyst levels in water samples were more than 10-fold higher (14). More information is needed about the infective dose, the differences in virulence among strains, and whether acquired immunity is protective and long lasting.

Two outbreaks caused by acute chemical intoxication were reported. Methemoglobinemia has been previously documented after ingestion of water contaminated with nitrates, often from agricultural fertilizers (19). The EPA has established an MCL of 10 mg/L for nitrate-nitrogen, but the regulation applies only to public water systems. In this report, the reverse-osmosis filter reduced nitrate levels only to the MCL (5). Elevated copper levels in the water may have contributed to the development of methemoglobinemia by inducing emesis in exposed ill persons, resulting in elevation of gastric pH with subsequent growth of nitrate-reducing bacteria and increased nitrate-to-nitrite conversion in the stomach. The 1992 outbreak of acute fluoride intoxication is the largest reported to date, and clinical follow-up of ill persons showed that metabolic abnormalities and elevated urine and/or serum fluoride levels can persist for a week or more.

As in previous years (Figure 4), the majority of outbreaks (68%) during 1991-1992 were classified as AGI of unknown etiology. Although some outbreaks were rigorously investigated, for many of these, the search for a causative agent was limited or clinical specimens could not be or were not obtained in a timely manner. The likelihood of identifying an etiologic agent was equally low (approximately one-third) for surface water and groundwater sources. However, the agent was much more frequently identified for WBDOs in community systems (63%) than in noncommunity systems (17%), emphasizing the difficulty of investigating outbreaks affecting the transient populations that use noncommunity water. Although the clinical features of illness in more than half of the AGI outbreaks suggest a viral etiology, clinical diagnosis is not specific; the group of outbreaks of AGI probably includes viral, bacterial, and parasitic etiologies. Availability of rapid diagnostic tests for viruses and newly emerging pathogens can aid in identifying the causative agents of these outbreaks. Information about the pathogens responsible for WBDOs is important for evaluating the adequacy of current water treatment processes and regulations. Nevertheless, the water quality data from AGI outbreaks suggest that available water disinfection technology is not always in place or used reliably; for 91% of these outbreaks, water sampling showed the presence of coliforms and/or deficiencies in chlorination.

During 1991-1992, 24 outbreaks (71%) were associated with contaminated untreated or inadequately treated groundwater. Adequate, continuous disinfection of groundwater should reduce the occurrence of WBDOs, particularly in small systems in which intermittent contamination of wells and springs is difficult to detect or prevent. In addition, wells and springs must be protected from sources of contamination such as surface runoff, septic tank drainage, and sewage discharges.

Two outbreaks were associated with treatment deficiencies in water systems using UV light for disinfection. UV light can be an effective disinfectant if properly applied, operated, and maintained. It may be effective for disinfecting bacteria and viruses but not protozoa (20,21). Reduced efficacy of UV systems for colored or turbid water has been noted (22), and UV light is not approved by EPA for use in surface water systems or in groundwater systems under the influence of surface water. For many of the outbreaks associated with inadequately treated water, chlorination was not maintained consistently. Adequate, consistent levels of chlorine are particularly important for disinfection of relatively chlorine-resistant organisms such as Giardia (23). Unfortunately, Cryptosporidium is highly resistant to disinfection by chlorine. Ozone is more effective than chlorine against Cryptosporidium (24), but no residual disinfectant is provided with this treatment. Ozone may not be suitable for small systems because of expense and the technical expertise required, and it is used as a disinfectant by less than 1% of the drinking water systems that serve populations of more than 10,000. Therefore, efforts to reduce the risk of waterborne giardiasis and cryptosporidiosis should focus on source protection and removal of cysts and oocysts by filtration.

The SWTR requires filtration of all but exceptionally well-protected surface water sources, including groundwater influenced by surface water. The SWTR was promulgated to reduce the risk of disease caused by waterborne protozoal parasites. Three protozoal outbreaks during 1991-1992 occurred in systems that were equipped with chlorine disinfection and met EPA coliform standards but were not equipped with filtration. EPA is considering an Information Collection Rule (ICR) that would require larger water utilities to monitor for Cryptosporidium, Giardia, and perhaps other pathogens in source water and, under certain conditions, in treated water for 18 months. Under the ICR, careful laboratory analysis and quality control would be needed, and the currently available laboratory methods do not assess infectivity of cysts or oocysts. Epidemiologic studies in conjunction with information on the occurrence of cysts and oocysts in source water will be helpful in assessing waterborne disease risks, determining the need for an enhanced Surface Water Treatment Rule, and determining whether specific monitoring for protozoal pathogens is necessary to supplement the total coliform MCL. The water quality data collected for WBDOs in the years 1991-1992 indicated that coliforms were detected for 88% of the outbreaks with bacterial, viral, or unknown etiologies but only 33% of the protozoal outbreaks. These data suggest that the use of coliforms as indicators of water contamination is generally sound but may not be adequate to detect contamination by protozoa.

Four of the six surface water systems associated with WBDOs were equipped with filtration. In three of these outbreaks, raw water quality had deteriorated because of sewage effluents that were not appropriately diluted as a result of low stream flows during dry weather. During the outbreaks associated with these systems, filtration deficiencies were noted, with elevated turbidity in finished water. Decreased filtration efficiency combined with deterioration in raw water quality also contributed to the WBDO in Milwaukee (1993). Although turbidity measurements indicated inefficient operation of the filtration process for the water systems associated with the 1993 Milwaukee outbreak and one Oregon outbreak (May 1992), none of the then-existing EPA water quality regulations were violated. Outbreaks associated with filtered systems illustrate the importance of improved operation and monitoring of the filtration process and the necessity for multiple barriers; in addition to disinfection and filtration, protection of raw water quality is essential for preventing transmission of waterborne diseases.

1991-1992 Outbreaks Associated with Recreational Water Use

In the period 1991-1992, the most frequently reported WBDOs due to recreational water were outbreaks of dermatitis associated with hot tubs, whirlpools, and swimming pools. Although factors such as host susceptibility, immersion time, and number of bathers can influence acquisition of infection (25), in general, most outbreaks are directly related to inadequate operation and maintenance procedures. Outbreaks are preventable if water is maintained at a pH of 7.2-7.8 with free residual chlorine levels from 2 to 5 mg/L, as specified in CDC's guidelines for public spas and hot tubs (26). Pontiac fever due to aerosolized Legionella pneumophila is also associated with use of hot tubs and whirlpools (27,28).

The six deaths associated with recreational water were caused by primary amebic meningoencephalitis (PAM). The presence in fresh water of the etiologic agent, Naegleria fowleri, is related to water temperature. Cases of PAM in the United States are rare but generally have been acquired during summer months when exposure to warm water is highest (29). Although behavioral risk factors for PAM are unknown, three cases in 1991 occurred in persons who may have had an increased risk of inhaling water; two were in young children learning to swim and the third in a young man whose face was immersed during a fight.

Swimming and other recreational activities in which unintentional ingestion of water can occur are known to increase the risk of gastrointestinal illness, even in non-outbreak settings (30,31). The number of outbreaks of gastroenteritis due to inadvertent ingestion of water during swimming (Figure_3) was similar to the number previously reported (11 in 1991-1992 compared with 13 in 1989-1990). However, in contrast to past years, approximately half (55%) of the gastroenteritis outbreaks were attributed to protozoal parasites: Giardia (four) and Cryptosporidium (two). Cryptosporidiosis associated with recreational water has been previously reported (32) but probably is underrecognized. The two cryptosporidiosis outbreaks were identified because drinking water outbreaks of Cryptosporidium in the region earlier in the year had led to increased awareness of the need to consider this diagnosis. Three of the outbreaks of protozoal gastroenteritis occurred in pools that were chlorinated and filtered; two were in settings (wave pool or water slide) with an increased risk of unintentional ingestion of water. Typical pool chlorination will disinfect Giardia cysts but may require more than 15 minutes, depending on temperature, pH, and chlorine concentration. Even though Cryptosporidium oocysts are resistant to disinfection by chlorine, they can be removed by most pool filtration systems. However, rates of filtration are generally slow, requiring up to 6 hours for a complete turnover of pool water. Therefore, water treatment does not ensure protection against protozoal infection in these settings.

Outbreaks of swimming-associated shigellosis, which have been documented previously (2,33,34), continue to be reported. The probable source of the pathogen in the three 1991-1992 outbreaks, as in past outbreaks, was fecal contamination of lake water by other swimmers. A contributing factor in at least two of the outbreaks may have been poor water exchange in the swimming area. In one outbreak, a history of having swallowed lake water was a risk factor for illness. Because the infectious dose of Shigella is low, infection may be acquired without swallowing large quantities of water (35). An outbreak of E. coli O157:H7 infection occurred in conjunction with one of the Shigella outbreaks. This is the first reported E. coli O157:H7 outbreak associated with recreational water exposure. This outbreak was recognized rapidly because E. coli O157:H7 infection had been made reportable by the state during the previous year. E. coli O157:H7, like Shigella, appears to have a low infectious dose (36). Furthermore, it can survive in water under certain conditions for long periods; in one study, only a 2-log reduction in bacterial counts was found to have occurred after 5 weeks at 5 C (37). The long period of transmission in this outbreak may have been due to reintroduction of the particular E. coli O157:H7 subtype into the swimming area, but it is more likely that it persisted in lake water for the duration of the outbreak.

The EPA has published criteria for evaluating the quality of fresh and marine recreational waters (38,39). Microbial monitoring has been recommended for recreational areas potentially contaminated by sewage. However, the value of routine monitoring of untreated water for fecal contamination due to bathers has not been established. Prevention efforts have focused on providing adequate toilet facilities at recreational areas and limiting the density of bathers.

CONCLUSION

Information from national WBDO surveillance is used to characterize the epidemiology of waterborne diseases in the United States. Data regarding the types of water systems and deficiencies associated with outbreaks are necessary to evaluate the adequacy of treatment regulations and current water quality monitoring. Identification of the etiologic agents of outbreaks is particularly critical because agents newly associated with waterborne outbreaks may require new methods of control. In recent years, Cryptosporidium and E. coli O157:H7 have been identified as important waterborne pathogens. Rapid recognition and control of several outbreaks in 1991-1992 were aided by surveillance for these agents at the local and state level. Maintaining the capabilities of local and state health departments to investigate outbreaks and to conduct surveillance is a key factor in waterborne disease control and prevention. In addition to outbreak investigation, epidemiologic studies are needed to evaluate the risk of waterborne disease; evidence suggests that a substantial proportion of non-outbreak-related diarrheal illness may be associated with consumption of water that meets all current water quality standards (40).

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Table_1

Note: To print large tables and graphs users may have to change their printer settings to landscape and use a small font size.

TABLE 1. Classification of investigations of waterborne disease outbreaks

Class *	Epidemiologic data	Water quality data
I	ADEQUATE: + (A) data were provided about exposed and unexposed persons; and (B) the relative risk or odds ratio was >=2 or the p-value was <=0.05.	PROVIDED AND ADEQUATE: could be historical information or laboratory data. Examples: the history that a chlorinator malfunctioned or a water main broke; no detectable free chlorine residual; the presence of coliforms in the water.
II	ADEQUATE.	NOT PROVIDED OR INADEQUATE. Example: stating that a lake was crowded.
III	PROVIDED, BUT LIMITED: (A) epidemiologic data were provided that did not meet the criteria for Class I; or (B) the claim was made that ill persons had no exposures in common besides water, but no data were provided.	PROVIDED AND ADEQUATE.
IV	PROVIDED, BUT LIMITED.	NOT PROVIDED OR INADEQUATE.

* Classification was based on the epidemiologic and water quality data that were provided on the outbreak report form.
\+ Adequate to implicate water.

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Table_2

Note: To print large tables and graphs users may have to change their printer settings to landscape and use a small font size.

TABLE 2. Outbreaks associated with water intended for drinking -- United States, 1991 (N=15) *

State +	Month	Class &	Etiologic agent @	No. cases	Type of system **	Deficiency ++	Source	Setting
CA	Jul	I	Giardia	15	NC	4	spring	recreation area
IL	May	II	AGI	386	NC	5	well	school
MI	Jun	I	AGI	1,320	NC	2	well	campground
MI	Aug	I	AGI	33	NC	2	well	resort
MN	Jun	I	AGI	30	NC	2	well	campground
MN	Jul	I	AGI	30	NC	4	well	resort
MN	Aug	I	AGI	17	NC	2	well	restaurant
NM	Aug	I	AGI	38	NC	2	well	camp
PA	Jun	I	AGI	170	NC	3	well	picnic area
PA	Jul	I	AGI	8	NC	3	well	restaurant
PA	Sept	III	Giardia	13	NC	3	well	park
PA	Aug	I	Cryptosporidium	551	NC	3	well	picnic area
PA	Jun	I	AGI	300	NC	3	well	camp
PR	Aug	I	AGI	202	Com	4	river	penitentiary
PR	Aug	I	AGI	9,847	Com	3	river	community

* See Methods section for description of reporting variables.
\+ Includes territories.
& See Table 1 for class definitions.
@ AGI = acute gastrointestinal illness of unknown etiology.
** NC = noncommunity; Com = community.
++ See Methods section for definitions of deficiencies.

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Table_3

Note: To print large tables and graphs users may have to change their printer settings to landscape and use a small font size.

TABLE 3. Outbreaks associated with water intended for drinking -- United States, 1992 (N=19) *

State	Month	Class +	Etiologic agent &	No. cases	Type of system @	Deficiency	Source	Setting
AK	May	I	Fluoride **	262	Com	3	well	community
ID	Mar	III	Giardia	15	Com	2	well	trailer park
MN	Feb	I	AGI	250	NC	3	lake	restaurant
NV	Mar	I	Giardia	80	Com	3	lake	community
NY	Apr	III	AGI	107	NC	4	well	restaurant
NC	Jan	I	AGI	200	NC	2	well	restaurant
OH	Jun	III	AGI	129	NC	4	well	campground
OR	Feb	I	Cryptosporidium	++	Com	3	spring	community
OR	May	I	Cryptosporidium	++	Com	3	river	community
PA	Mar	III	AGI	5	NC	3	well	restaurant
PA	May	II	AGI	28	Com	5	river	park
PA	Jun	III	AGI	38	Ind	2	well	private home
PA	Jun	III	AGI	42	NC	3	well	camp
PA	May	I	AGI	50	NC	3	well	camp
PA	May	III	AGI	57	NC	3	well	camp
PA	Aug	I	AGI	80	NC	3	well	camp
WA	Jun	I	Hepatitis A	10	Ind	2	well	private home
WI	Jun	I	Nitrate	1	Ind	3	well	farm
WY	Jul	I	Shigella sonnei	150	NC	2	well	park

* See Methods section for description of reporting variables.
\+ See Table 1 for class definitions.
& AGI = acute gastrointestinal illness of unknown etiology.
@ NC = noncommunity; Com = community; Ind = individual.
** Resulted in one death.
++ Total estimated number of cases for the Oregon outbreaks was 3,000; see text.

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Table_4

Note: To print large tables and graphs users may have to change their printer settings to landscape and use a small font size.

TABLE 4. Outbreaks associated with water intended for drinking, by etiologic agent and type of water system -- United States, 1991-1992 (N=34)

	Type of water system *							
	Community		Noncommunity		Individual		Total	
Agent +	Outbreaks	Cases	Outbreaks	Cases	Outbreaks	Cases	Outbreaks	Cases
AGI	3	10,077	19	3,252	1	38	23	13,367
Giardia	2	95	2	28	0	0	4	123
Cryptosporidium	2	3,000	1	551	0	0	3	3,551
Hepatitis A	0	0	0	0	1	10	1	10
Shigella sonnei	0	0	1	150	0	0	1	150
Nitrate	0	0	0	0	1	1	1	1
Fluoride	1	262	0	0	0	0	1	262

Total	8	13,434	23	3,981	3	49	34	17,464
(Percent &)	(24)	(77)	(68)	(23)	(9)	(<1)	(100)	(100)

* See Methods section for description of types of water systems.
\+ AGI = acute gastrointestinal illness of unknown etiology.
& The percentage of 34 outbreaks or of 17,464 cases.

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Table_5

Note: To print large tables and graphs users may have to change their printer settings to landscape and use a small font size.

TABLE 5. Outbreaks associated with water intended for drinking, by type of deficiency and type of water system -- United States, 1991-1992 (N=34)

	Type of water system							
	Community		Noncommunity		Individual		Total	
Type of deficiency	No.	(%)	No.	(%)	No.	(%)	No.	(%)
Untreated surface water	0	(0)	0	(0)	0	(0)	0	(0)
Untreated groundwater	1	(13)	7	(30)	2	(67)	10	(29)
Treatment	5	(63)	11	(48)	1	(33)	17	(50)
Distribution system	1	(13)	4	(17)	0	(0)	5	(15)
Unknown	1	(13)	1	(4)	0	(0)	2	(6)
Total	8	(100)	23	(100)	3	(100)	34	(100)

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Figure_1

FIGURE 1. Waterborne outbreaks, by month — United States, 1991–1992

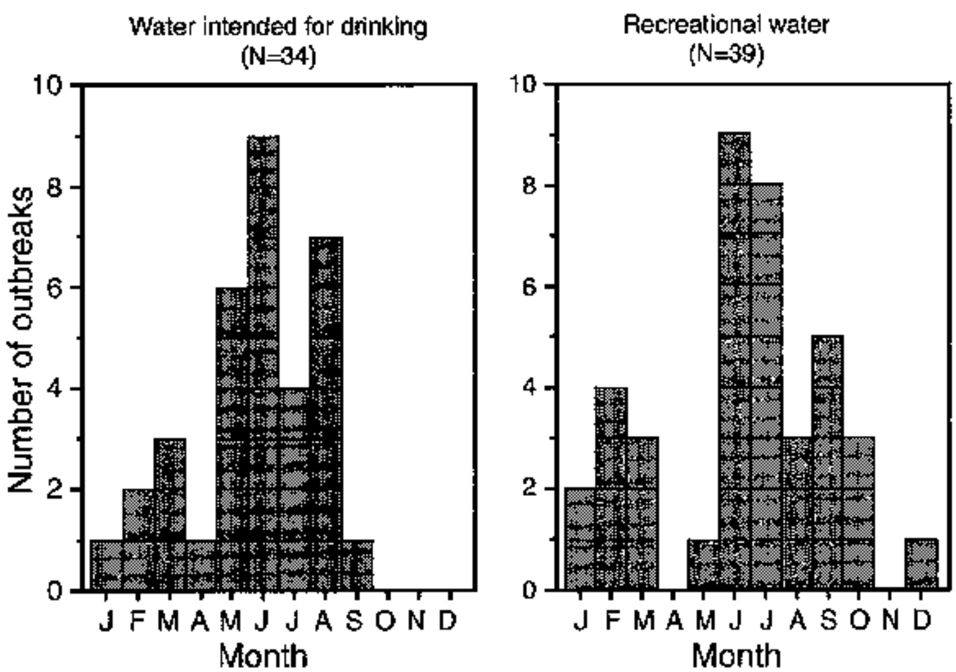

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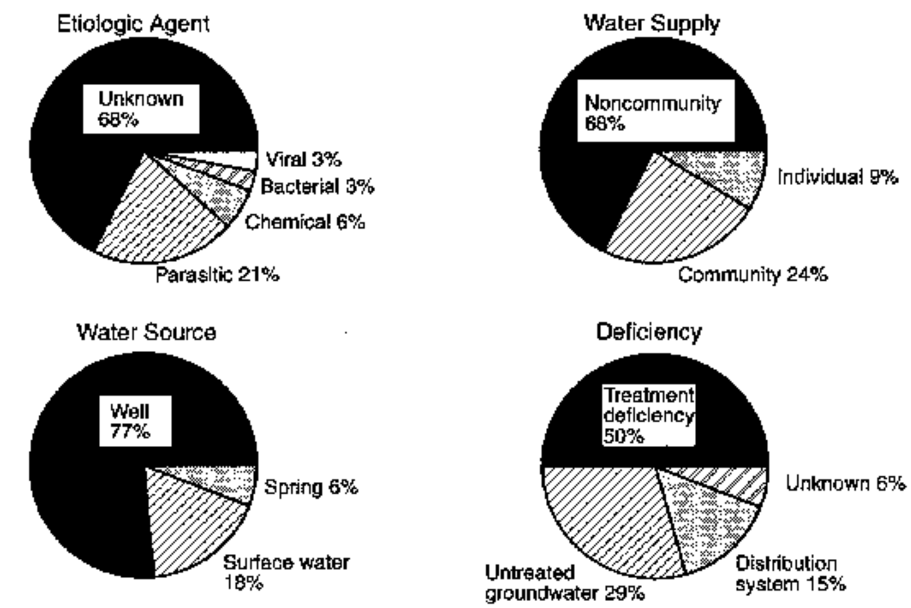
Figure_2

FIGURE 2. Outbreaks associated with water intended for drinking — United States, 1991–1992 (N=34)*



*See Methods section for description of reporting variables.

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Table_6

Note: To print large tables and graphs users may have to change their printer settings to landscape and use a small font size.

TABLE 6. Outbreaks of dermatitis associated with recreational water -- United States, 1991-1992 (N=15)

State	Year	Month	Class *	Etiologic agent +	No. cases	Source	Setting
DE	1991	Oct	I	c/w Schistosoma sp.	30	ocean	beach
MN	1991	Feb		Pseudomonas	7	hot tub	private home
MN	1992	Sept		Pseudomonas	29	swimming pool	school
UT	1991	Jun	IV	c/w Schistosoma sp.	5	lake	swimming area
WA	1991	Jun		Pseudomonas	8	hot tub	private home
WA	1991	Dec		Pseudomonas	5	hot tub	apartment spa
WA	1991	Oct		c/w Pseudomonas	5	hot tub	private home
WA	1991	Sept		c/w Pseudomonas	2	hot tub	private home
WA	1991	Jul		c/w Pseudomonas	3	hot tub	private home
WA	1991	Feb		Pseudomonas	6	hot tub	private home
WI	1991	Jun		Pseudomonas	8	hot tub	private home
WI	1991	Mar		c/w Pseudomonas	45	whirlpool	motel
WI	1991	Feb		Pseudomonas	24	whirlpool	motel
WI	1992	Feb		Pseudomonas	10	whirlpool	motel
WY	1991	Jun	IV	c/w Schistosoma sp.	5	lake	park

* See Table 1 for class definitions.
+ c/w = consistent with.

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Table_7

Note: To print large tables and graphs users may have to change their printer settings to landscape and use a small font size.

TABLE 7. Other outbreaks associated with recreational water -- United States, 1991-1992 (N=24)

State *	Year	Month	Class +	Illness	Etiologic Agent &	No. cases	Source	Setting
CA	1991	Oct		meningoencephalitis	Naegleria @	1	hot spring	recreation area
FL	1991	Aug		meningoencephalitis	Naegleria @	1	puddle	rural area
GA	1991	Jul	I	gastroenteritis	Giardia	9	wading pool	day care center
GA	1991	Jul	II	gastroenteritis	Giardia	7	wading pool	day care center
GU	1991	Sept		meningoencephalitis	Naegleria @	1	stream	rural area
ID	1992	Aug	II	gastroenteritis	Cryptosporidium	26	water slide	park
IL	1991	Jul	I	leptospirosis	Leptospira	6	pond	rural area
MD	1991	Jun	II	gastroenteritis	Giardia	14	swimming pool	park

MD	1992	Jul	III	gastroenteritis	AGI	15	creek	private home
MN	1992	Jan	I	otitis, conjunctivitis, and rash	Pseudomonas	35	swimming pool	hotel
MO	1991	Aug	II	gastroenteritis	AGI	61	dunking booth	fair
MT	1991	Mar	II	Pontiac fever	Legionella	4	hot tub	ski resort
NC	1991	Jun	I	pharyngitis	adenovirus 3	595	pond	camp
NC	1991	Sept		meningoencephalitis	Naegleria @	1	pond	swimming area
NC	1991	Sept		meningoencephalitis	Naegleria @	1	lake	swimming area
OR	1991	Jul	I	gastroenteritis	E. coli O157:H7 **	80	lake	park
OR	1992	Jun	II	gastroenteritis	Cryptosporidium	500	wave pool	park
PA	1991	Jun	I	gastroenteritis	Shigella sonnei	203	lake	park
RI	1991	Jul	IV	gastroenteritis	Shigella sonnei	23	lake	swimming area
TX	1991	Jul		meningoencephalitis	Naegleria @	1	lake	swimming area
VT	1991	Jan	II	Pontiac fever	Legionella	6	hot tub	ski resort
WA	1991	Jul	IV	gastroenteritis	Giardia	4	lake	campground
WI	1991	May	I	Pontiac fever	Legionella	6	whirlpool	motel
WI	1991	Mar	II	Pontiac fever	unknown	33	whirlpool	motel

* Includes territories.
+ See Table 1 for class definitions.
& AGI = acute gastrointestinal illness of unknown etiology.
@ Resulted in one death.
** Mixed outbreak of Escherichia coli O157:H7 and Shigella sonnei.

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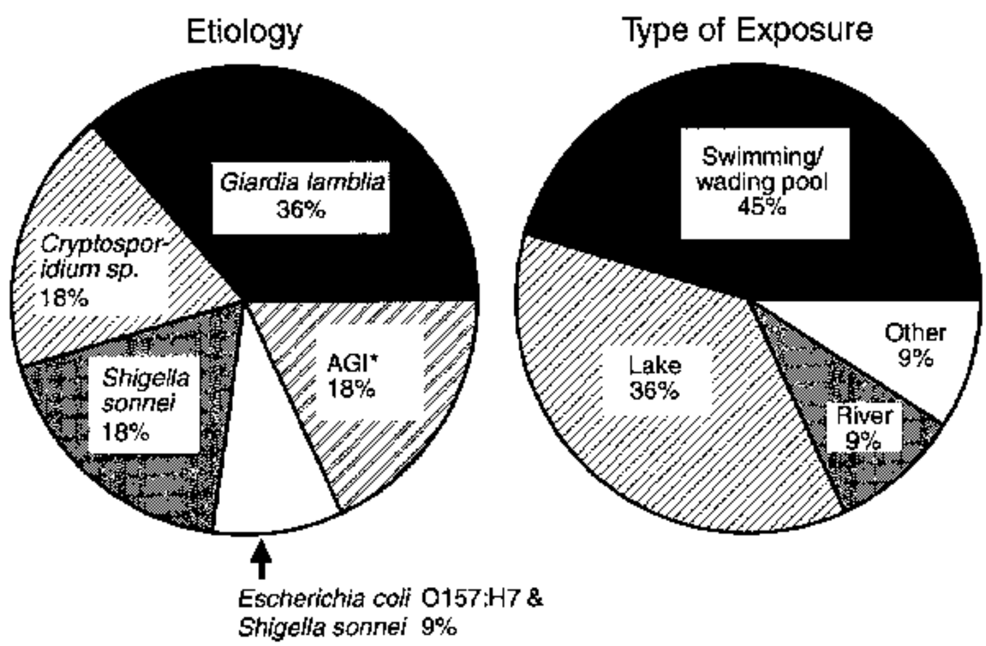
Figure_3

FIGURE 3. Outbreaks of gastroenteritis associated with recreational water use — United States, 1991–1992 (N=11)



*AGI=acute gastrointestinal illness of unknown etiology.

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Table_8

Note: To print large tables and graphs users may have to change their printer settings to landscape and use a small font size.

TABLE 8. Waterborne outbreaks not included in previous summaries -- United States, 1988-1989 (N=3) *

A. Outbreaks associated with water intended for drinking.

State	Year	Month	Class +	Etiologic agent	No. cases	Type of system &	Deficiency	Source	Setting
IL	1988	Jul	I	Shigella sonnei	11	NC	5	well	restaurant
PA	1989	Apr	I	Shigella sonnei	130	NC	3	well	restaurant

B. Outbreaks associated with recreational water.

State	Year	Month	Class +	Illness	Etiologic agent	No. cases	Source	Setting
IL	1988	Jun	I	gastroenteritis	Shigella sonnei	61	lake	beach club

* See Methods section for description of reporting variables.
+ See Table 1 for class definitions.
& NC = noncommunity.

TX	1991	Jul		meningoencephalitis	Naegleria @	1	lake	swimming area
VT	1991	Jan	II	Pontiac fever	Legionella	6	hot tub	ski resort
WA	1991	Jul	IV	gastroenteritis	Giardia	4	lake	campground
WI	1991	May	I	Pontiac fever	Legionella	6	whirlpool	motel
WI	1991	Mar	II	Pontiac fever	unknown	33	whirlpool	motel

* Includes territories.
+ See Table 1 for class definitions.
& AGI = acute gastrointestinal illness of unknown etiology.
@ Resulted in one death.
** Mixed outbreak of Escherichia coli O157:H7 and Shigella sonnei.

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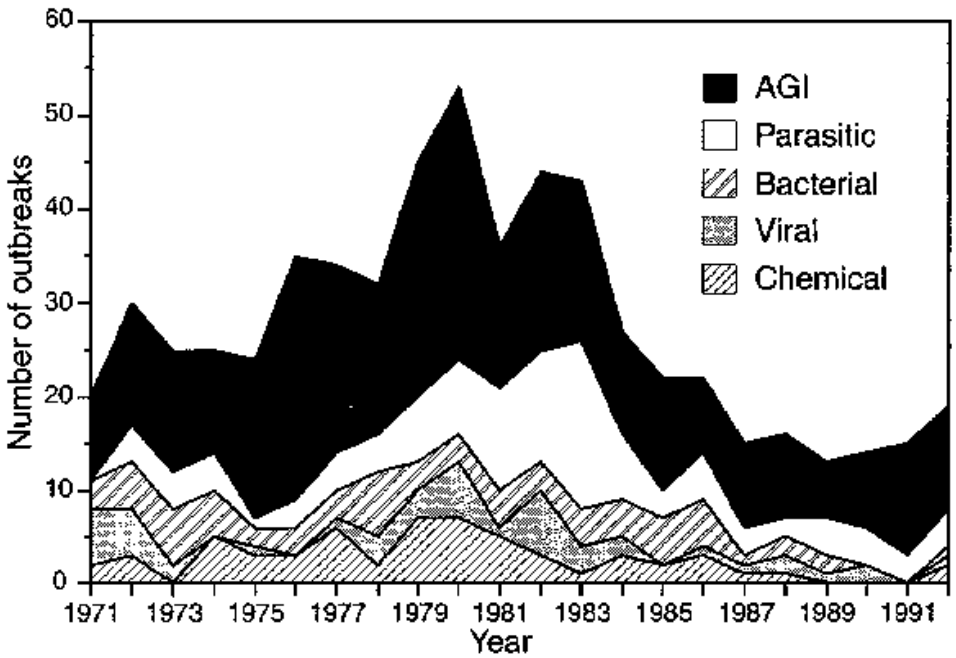
Figure_4

FIGURE 4. Waterborne outbreaks, by year and etiologic agent — United States, 1971–1992 (N=609)



AGI=acute gastrointestinal illness of unknown etiology.

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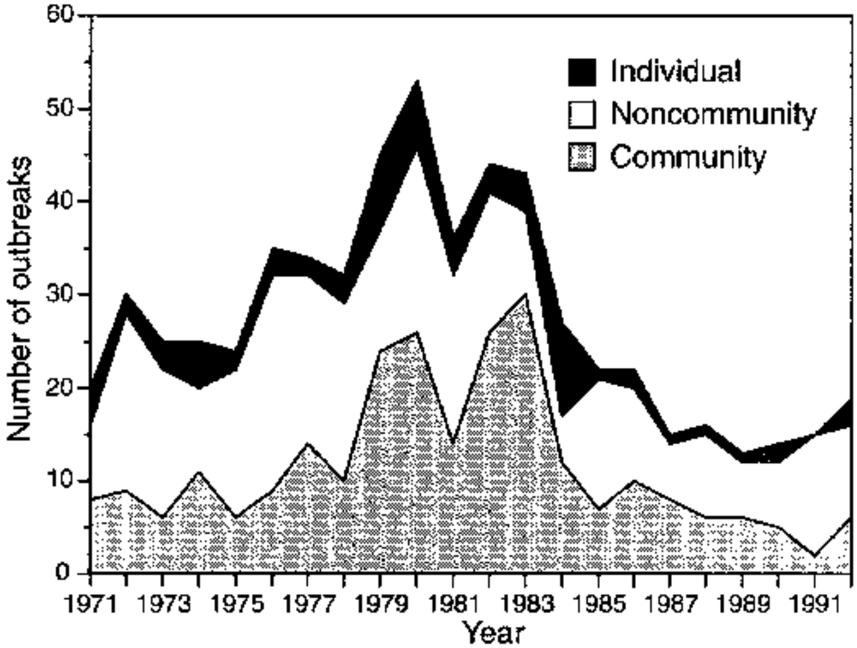
Figure_5

FIGURE 5. Waterborne outbreaks, by year and type of water system — United States, 1971–1992 (N=609)*



*See Methods section for description of types of water systems.

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