Waterborne outbreaks reported in the United States

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ABSTRACT

Epidemic waterborne risks are discussed in this paper. Although the true incidence of waterborne illness is not reflected in the currently reported outbreak statistics, outbreak surveillance has provided information about the important waterborne pathogens, relative degrees of risk associated with water sources and treatment processes, and adequacy of regulations. Pathogens and water system deficiencies that are identified in outbreaks may also be important causes of endemic waterborne illness. In recent years, investigators have identified a large number of pathogens responsible for outbreaks, and research has focused on their sources, resistance to water disinfection, and removal from drinking water. Outbreaks in surface water systems have decreased in the recent decade, most likely due to recent regulations and improved treatment efficacy. Of increased importance, however, are outbreaks caused by the microbial contamination of water distribution systems. In order to better estimate waterborne risks in the United States, additional information is needed about the contribution of distribution system contaminants to endemic waterborne risks and undetected waterborne outbreaks, especially those associated with distribution system contaminants.

Key words | *Campylobacter*, *Cryptosporidium*, *E. coli* O157:H7, hepatitis, norovirus, *Shigella*, waterborne outbreaks

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INTRODUCTION

Waterborne disease outbreak (WBDO) statistics have been compiled in the United States since 1920. During 1920 to 1936, these data were collected by Gorman & Wolman (1939, 1948). From 1937 to 1970, WBDO statistics were collected by several Federal agencies, and various investigators have evaluated and summarized the information (Committee on Public Works 1947; Eliassen & Cummings 1948; PHS 1964; Weibel *et al.* 1964; EPA 1971; Craun & McCabe 1973; Craun *et al.* 1983; Craun 1986).

Since 1971, the US Environmental Protection Agency (EPA), Centers for Disease Control and Prevention (CDC) and Council of State and Territorial Epidemiologists have collaborated to collect information about the causes of WBDOs. In this paper, we provide a historical perspective of WBDOs reported in the United States.

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WATERBORNE OUTBREAK SURVEILLANCE SYSTEM

The WBDO surveillance program is conducted to: (1) characterize the epidemiology and etiology of WBDOs and identify important waterborne pathogens and water system deficiencies; (2) improve detection and investigation capabilities; and (3) collaborate with local, state, Federal, and international agencies on initiatives to prevent waterborne disease (Lee *et al.* 2002; Blackburn *et al.* 2004). The primary unit of analysis is an outbreak rather than an individual case of illness. State, territorial, and local public health agencies have the primary responsibility for detecting and investigating WBDOs, and these agencies voluntarily report WBDOs to the CDC. When requested, the CDC and EPA assist in outbreak investigations.

A standard reporting form is used to solicit data on the characteristics of the outbreak (e.g. dates of illness onset, duration of illness, and suspected or confirmed etiology), testing of water and patient samples, and contributory issues such as water disinfection practices and environmental factors. Information is also requested about the actual and estimated numbers of cases, hospitalizations, and fatalities. This information is evaluated and reported in WBDO surveillance summaries, which have been published biennially or annually since 1973 (CDC 1973, 1974, 1976*a*, *b*, 1977, 1979, 1980, 1981, 1982*a*, *b*, 1983, 1984, 1985; St. Louis, 1988; Levine & Craun, 1990; Herwaldt *et al.* 1991; Moore *et al.* 1993; Kramer *et al.* 1996; Levy *et al.* 1998; Barwick *et al.* 2000; Lee *et al.* 2002; Blackburn *et al.* 2004).

Outbreaks associated with drinking water, recreational water, and other types of water exposures are reported. WBDOs associated with cruise ships are not included in this surveillance system. In this paper, we consider only outbreaks associated with contaminated drinking water.

Classifying waterborne outbreaks and water systems

Outbreaks

For an event to be defined as a WBDO, two or more persons must have experienced a similar illness. This criterion is waived for single cases of laboratory-confirmed primary amebic meningoencephalitis (PAM) and for single cases of chemical poisoning if water quality data indicate contamination by the chemical (Blackburn *et al.* 2004). Waterborne pathogens of concern in the United States have multiple transmission routes, including person-to-person contact and ingestion of contaminated food. Thus, epidemiologic evidence must implicate water as the probable source of the illness.

Since 1989, WBDOs have been classified according to the strength of the evidence (Table 1) implicating water (Blackburn *et al.* 2004). The classification system ensures objectivity in the review of outbreak reports and consistency in the reported statistics as well as encouraging investigators to submit more complete information. Classification is based on epidemiologic and water quality data provided by investigators. Outbreaks without water quality data can be included in the surveillance system, but reports that lack epidemiologic data are not. A classifi-

Table 1 | Classification of investigations of waterborne outbreaks in the United States (from Blackburn *et al.* 2004)

Class	Epidemiologic data	Water-quality data
I	Adequate	Provided and adequate
	Data were provided about exposed and unexposed persons, and the relative risk or odds ratio was ≥ 2, or the p value was ≤ 0.05	Historical information or laboratory data (e.g. the history that a chlorinator malfunctioned or a water main broke, no detectable free-chlorine residual, or the presence of coliforms in the water)
II	Adequate	Not provided or inadequate (e.g. laboratory testing of water not done)
III	Provided, but limited	Provided and adequate
	Epidemiologic data were provided that did not meet the criteria for Class I, or the claim was made that ill persons had no exposures in common besides water, but no data were provided.	
IV	Provided, but limited	Not provided or inadequate

cation of I indicates that adequate epidemiologic and water quality data were reported; however, a classification of I "does not necessarily imply whether an investigation was optimally conducted" (Blackburn *et al.* 2004) or that all information requested on the reporting form was provided. Similarly, a classification of II or III should not be interpreted to mean that the investigation was inadequate. WBDOs that affect few persons are more likely to receive a classification of III rather than I because of the relatively limited sample size available for analysis. Most WBDOs have received the classification of III (44.5%) or I (42.0%). Only 10.0% of the WBDOs have received the classification of II.

By establishing guidelines to include investigations with limited epidemiologic data (3.5% were classified as IV), investigators are encouraged to report outbreaks which may have been difficult to investigate or where some of the findings may not be conclusive. This approach tends to reduce the specificity of the reported information, but it has helped identify new and unusual water quality problems (Craun *et al.* 2001).

Water systems

Public drinking water systems associated with WBDOs are identified as either community or non-community based on definitions of the Safe Drinking Water Act. A community water system serves year-round residents (an average of 25 or more persons or 15 or more service connections). Non-community systems can serve transients or non-transients. A non-transient system regularly serves at least 25 of the same persons at least six months of the year (e.g. schools, hospitals, or factories that have their own water supply). Transient systems serve persons at campgrounds, motels, gas stations, or other businesses that have their own water supply. WBDOs that occur in individual water systems (e.g. private wells) are also reported. The statistics reported in this paper also include WBDOs associated with the ingestion of water not intended for consumption, contaminated bottled water, and contamination of water or ice contaminated at its point of use (e.g. a contaminated water faucet or serving container). These WBDOs are classified as miscellaneous deficiencies.

Limitations of the surveillance data

The information pertains primarily to outbreaks, and the reported statistics do not include endemic or sporadic cases that may be waterborne. In addition, not all WBDOs are recognized and investigated and not all investigated WBDOs are reported. Since not all investigations were optimally conducted, some information (e.g. illness severity) may not be reported.

Outbreak reporting

Since WBDO surveillance is passive and reporting is voluntary, the statistics represent only a portion of the waterborne outbreaks that actually occur (Hopkins *et al.* 1985; Craun 1986; Blackburn *et al.* 2004). Blackburn *et al.* (2004) point out that the true incidence of WBDOs is markedly underestimated and studies have not been performed to assess the sensitivity of the surveillance regarding unrecognized or unreported outbreaks.

Multiple factors influence whether waterborne outbreaks are recognized and investigated. These factors include public awareness, availability of laboratory testing, requirements for reporting diseases, and resources available to local health departments for surveillance and investigation of probable outbreaks. In addition, changes in the capacity of public health agencies to detect an outbreak might influence the numbers of outbreaks reported in each state relative to other states. Thus, caution is urged in assessing trends in the occurrence of WBDOs. An increase in the number of reported WBDOs could reflect an actual increase or a change in sensitivity of surveillance practices.

Outbreaks most likely to be recognized and investigated are those of (1) acute illness characterized by a short incubation period, (2) serious illness or symptoms requiring medical treatment, and (3) recently recognized etiologies for which laboratory methods have become more sensitive or widely available (Blackburn *et al.* 2004). Increased reporting often occurs as water system deficiencies and WBDO etiologies become better recognized, often through improved state surveillance activities and laboratory capabilities (Hopkins *et al.* 1985; Frost *et al.* 1995, 1996). Recommendations for improving WBDO statistics include: (1) enhanced surveillance activities to better detect outbreaks; (2) additional laboratory support for clinical and water analyses during outbreak investigations; and (3) increased attention to potential sources of bias during investigations (Craun *et al.* 2001; Frost *et al.* 2003; Hunter *et al.* 2003).

Illness reporting

The reported cases of illness in WBDOs are primary cases, either actual or estimated. Few investigations have identified secondary cases (i.e. persons infected by contact with primary case-patients). The cases may be defined by signs and symptoms or may be confirmed by laboratory analysis of clinical specimens. Cases may be under- or over-reported in some WBDOs. For example, even though the 1993 Milwaukee cryptosporidiosis outbreak investigation was extensive (MacKenzie *et al.* 1994; Hoxie *et al.* 1998; Proctor *et al.* 1998; Naumova *et al.* 2003), outbreak-related cases may have been over estimated (Hunter & Syed 2001). However, a study of *Cryptosporidium*-specific antibody responses in children by McDonald *et al.* (2001) also suggests that infection may have been more widespread.

During the investigation it is important to recognize and take steps to control potential biases and assess their affects, especially recall bias. Recall bias may result in the reporting of more illnesses than actually occurred (Craun & Frost 2002; Craun *et al.* 2001; Cooper 1995; Hunter & Syed 2001).

WATERBORNE OUTBREAK STATISTICS

Outbreaks

During 1920 to 2002, at least 1870 outbreaks were associated with drinking water, an average of 22.5 per year. The average annual number of WBDOs ranged from a low of 11.1 during 1951–1960 to as many as 32.4 WBDOs during 1971–1980 (Figure 1). In the most recent 12-year period (1991–2002), 207 WBDOs and 433 947 illnesses were reported; slightly more WBDOs occurred in non-community water systems (42%) than either community (36%) or individual systems (22%).

Cases of illness

During 1920 to 2002, 883 806 illnesses were reported, an average of 10 648 cases per year. The average annual number of cases ranged from a low of 1249 during 1951–1960 to a high of 36 162 cases during 1991–2002 (Figure 2). In the remaining six time periods that were evaluated, an average of 4640–9331 cases was reported each year. WBDOs in community systems ranged from 247 to 5714 illnesses per outbreak, while WBDOs in non-community

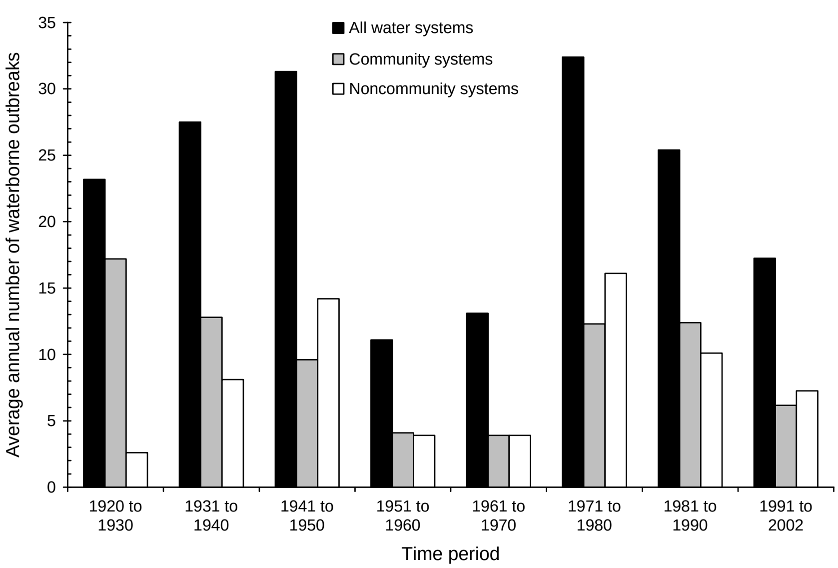

Figure 1 | Reported waterborne outbreaks, 1920 to 2002.

Figure 2 | Reported cases in waterborne outbreaks, 1920 to 2002.

systems ranged from 51 to 268 illnesses per outbreak (Table 2).

Fifty-eight percent of the WBDOs reported since 1971 were relatively small, resulting in 50 or fewer illnesses; only 4% of these WBDOs resulted in more than 1000 illnesses (Figure 3). The six largest WBDOs accounted for the majority (88%) of illnesses during this time period (Figure 3), demonstrating the impact that large WBDOs can have on illness statistics. The largest WBDO, an estimated 403 000 illnesses, occurred in Milwaukee in 1993.

Table 2 | Average size of waterborne outbreaks in the United States, 1920–2002

	Illnesses per outbreak		
Time period	**Community systems**	**Non-community systems**	**All systems**
1920–30	513	138	400
1931–40	748	60	339
1941–50	467	57	172
1951–60	247	51	113
1961–70	1023	111	354
1971–80	483	113	241
1981–90	289	268	250
1991–2002	5714	119	2096

Duration of illness

Information about the duration of illness was available for 40% of the WBDOs reported during 1971–2002. The mean and median of the reported duration of illness for all etiologies was 5.6 and 2.2 days, respectively; the longest reported duration was 74 days. A median duration of 6 days or less was reported in 80% of the WBDOs (Figure 4). Typically, the shortest duration of illness was found in WBDOs of a chemical or viral etiology.

Mortality

During 1920 to 2002, 1165 deaths were reported, an average of 14 deaths per year. Most deaths occurred before 1940 during WBDOs of typhoid fever (Craun 1986). During the 12-year period 1991–2002, 73 deaths (an average of 6 deaths per year) were reported (Figure 5). Fifty deaths were associated with the 1993 Milwaukee WBDO. A study of mortality during the outbreak period found that cryptosporidiosis was listed on the death certificate as the contributing cause of death for 54 persons; four cryptosporidiosis deaths were expected under normal circumstances (Hoxie *et al.* 1998). Of the 54 deaths, 46 (85%) occurred among persons whose underlying cause of death was AIDS; in 4 (7%) deaths, the underlying cause was coccidiosis. Another protozoan agent, *Naegleria fowleri* was responsible for two deaths in a single WBDO in 2002. During 1991–2002, deaths were also attributed to bacterial pathogens: seven due to *Salmonella typhimurium*, six due to *Vibrio cholerae*, non *01*, four due to *Legionella*; two deaths occurred during a WBDO caused by both *E. coli* O157:H7 and *Campylobacter jejuni*. The remaining deaths during this period occurred during WBDOs caused by excess fluoride concentration (one death) and norovirus (one death).

Hospitalizations

Information about hospital admissions was also examined for the WBDOs reported during the most recent 12-year period. During 1991–2002, illnesses in WBDOs were severe enough in 67 WBDOs for 4901 persons to be admitted to the hospital; 4400 of the hospital admissions occurred during the

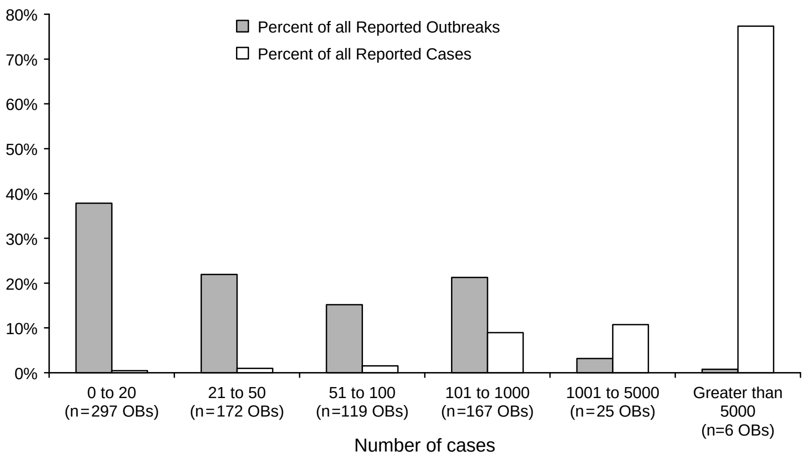

Figure 3 | Size and occurrence of reported drinking water outbreaks 1971–2002.

Milwaukee WBDO. Most WBDOs that reported hospitalizations were of a bacterial (42%) or protozoan (18%) etiology. Protozoa were responsible for most (91%) cases that required hospitalization. Nine persons were hospitalized during four viral WBDOs, and 46 persons were hospitalized during 15 WBDOs of undetermined etiology.

Water system deficiencies

Since 1971, each WBDO has been classified into one of five water system deficiency categories. We evaluated the deficiencies associated with WBDOs during 1971–2002 (Figure 6). The proportion of WBDOs reported in untreated groundwater systems has remained relatively constant since 1971. The proportion of WBDOs associated with

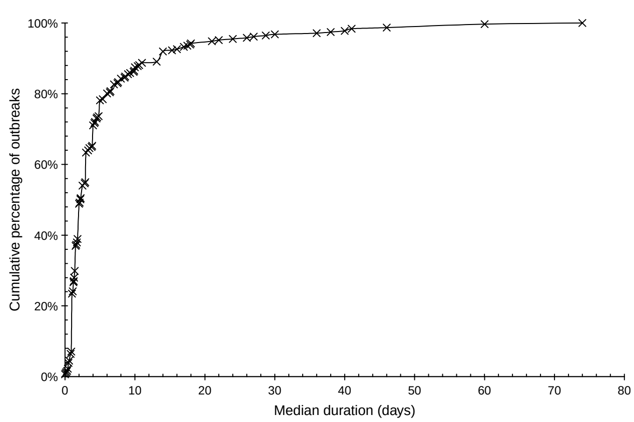

Figure 4 | Distribution of median duration of illness in waterborne outbreaks 1971–2002.

contaminated, untreated surface water has decreased since 1971, and since 1991 no WBDOs have been associated with untreated surface water systems. This is largely due to EPA rules and regulations that require the adequate treatment of public water systems using surface water.

Over the past 32 years, water treatment deficiencies have become less important as a cause of WBDOs (Figure 6). Treatment deficiencies, such as inadequate or no filtration of surface water and inadequate or interrupted disinfection of groundwater, caused 42% and 50% of all WBDOs reported during 1971–1980 and 1981–1990, respectively. However, water treatment deficiencies were responsible for 34% of WBDOs during 1991–2000 and only 14% of WBDOs during 2001–2002. This decreased importance may also reflect increased regulations and improvements in the water treatment, operation, and monitoring of surface water systems. The first WBDO caused by the inadequate treatment of surface water in a community system in over five years occurred in 2001 after the failure of a bag filtration system in a small town (Blackburn *et al.* 2004). In the previous five years, WBDOs in community surface water systems occurred in 1997 (a disinfected, unfiltered surface water system) and 1995 (a filtered surface water system). In comparison, during 1991–1994, eight community-system WBDOs were caused by inadequately treated surface water.

Water distribution system deficiencies have now become more important as a cause of WBDOs. These deficiencies were responsible for more than half of all WBDOs reported

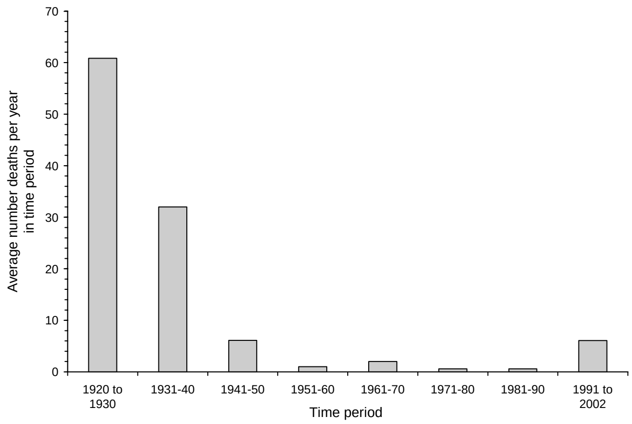

Figure 5 | Deaths associated with reported drinking water outbreaks in the United States 1920–2002.

during 2001–2002 and almost 25% of all WBDOs during 1991–2000 (Figure 6). During the 20-year period 1971–1990, these deficiencies were implicated in less than 20% of WBDOs. Distribution system-associated WBDOs tend to be small, as contamination usually affects only a portion of the distribution system, limiting the potential exposure. On average during the past 32 years, these WBDOs resulted in 152 cases per outbreak. However, five distribution system-associated WBDOs resulted in more than 1000 illnesses, with the largest causing 5000 illnesses. Although a chemical etiology is often found (35% of the WBDOs), distribution-system WBDOs are also caused by bacterial (17%), protozoan (14%), viral (4%), or undetermined (30%) pathogens.

ETIOLOGY OF WATERBORNE OUTBREAKS

A historical perspective of the etiologies of reported WBDOs is provided in Figure 7. During the late 19th and early 20th centuries, cholera and typhoid were frequent causes of WBDOs in the United States. Only three WBDOs of cholera with 131 cases have been reported since 1920. Two occurred in American territories, and one occurred in a non-community system in Texas. Waterborne typhoid fever continued to occur after 1920; 70% of all WBDOs reported during 1920–1940 were attributed to *Salmonella typhi*. WBDOs of typhoid fever decreased considerably over the next 30 years to only 22% and 11% of WBDOs reported during 1941–1960 and 1961–1970, respectively. An even more dramatic decrease occurred in cases of typhoid associated with WBDOs; 87 675 typhoid cases were reported during 1920–1941 but only 108 cases occurred from 1961–1970. Since 1971, five small WBDOs occurred, and only 282 cases of typhoid fever were reported.

In spite of better laboratory methods and more thorough investigations, WBDOs classified as acute gastroenteritis (AGI) of undetermined etiology continue to be important. Usually the etiology was not determined because specimens were not collected or laboratory analyses were not available. However, in some WBDOs, the agent could not be identified even though laboratory analyses were available. During the five time periods that we analyzed, the etiology was determined in 37–73% of reported WBDOs (Figure 7). During the most recent 12 years, the etiology was determined

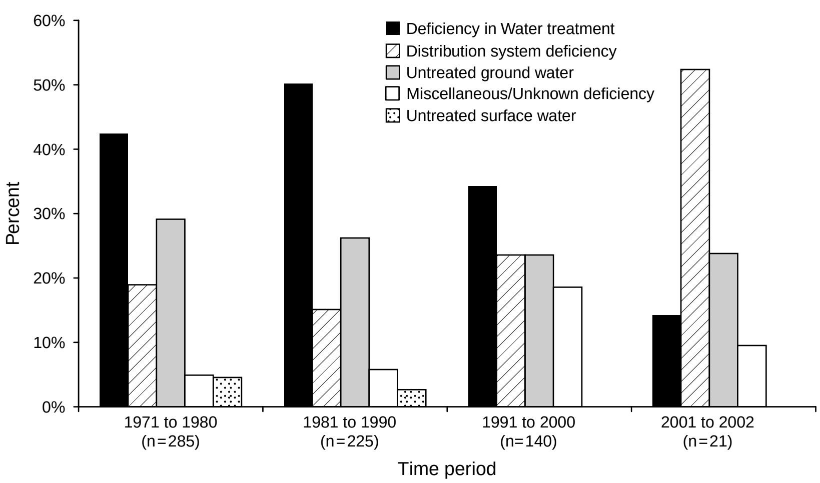

Figure 6 | Trends in system deficiencies in public water systems.

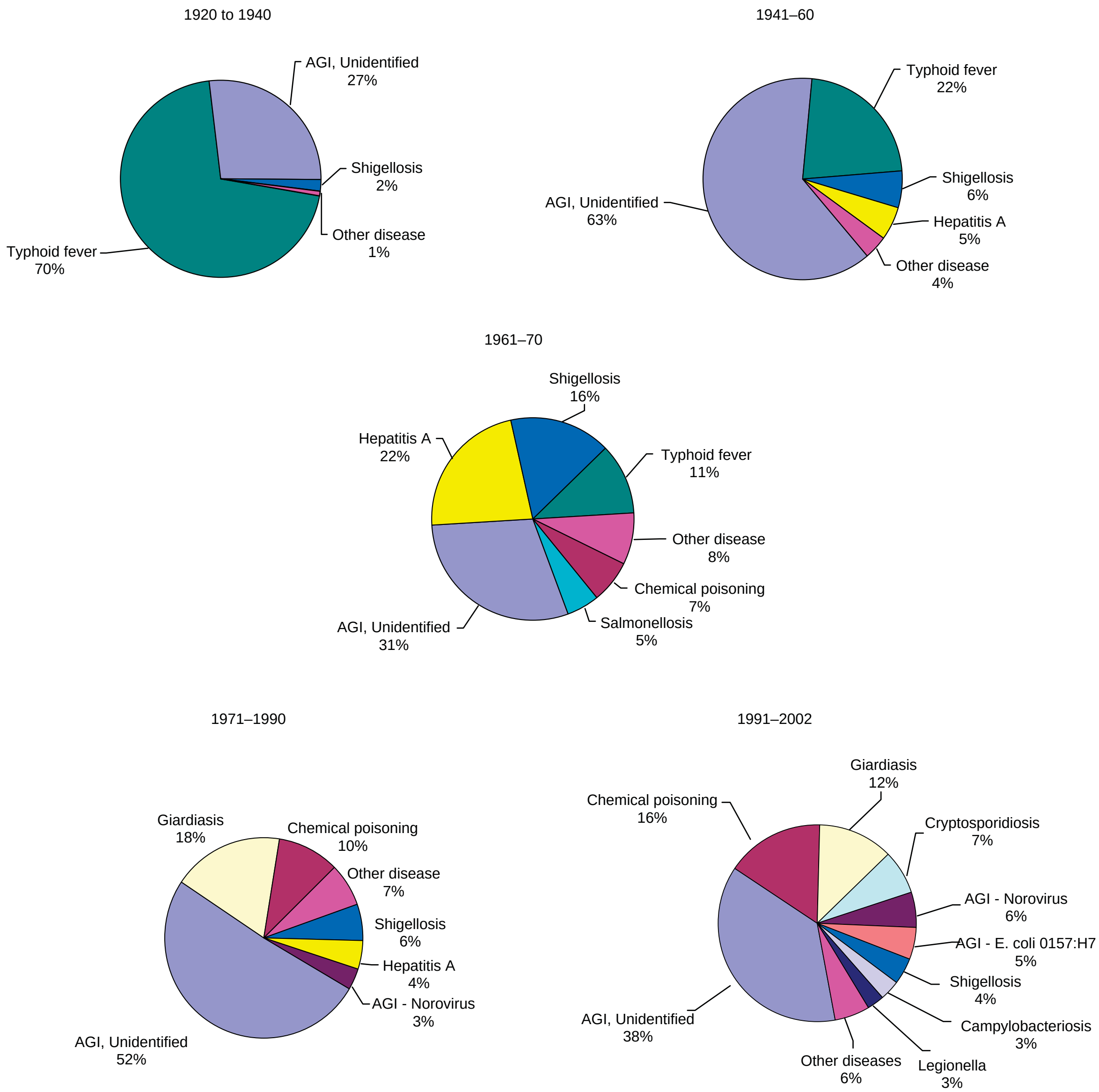

Figure 7 | Etiologies of waterborne outbreaks, 1920–2002.

in 63% of the WBDOs, an improvement over the 48% reported during the previous 20-year period 1971–1990.

Hepatitis A (22%) and *Shigella* (16%) were the two most frequently identified etiologic agents in the 1960s. During 1971–1990, WBDOs of hepatitis A (4%) and *Shigella* (6%) decreased, and the two most frequently identified etiologic agents were *Giardia* (18%) and various chemicals causing acute illness (10%). During 1991–2002, *Giardia* (16%) and chemical contaminants (12%) continued to be important, but WBDOs were caused by a number of other pathogens including *Cryptosporidium* (7%), norovirus (6%), *E. coli* O157:H7 (5%), *Campylobacter* (3%), and *Legionella* (3%).

WBDOs caused by *Legionella* species have only been tabulated since 2001 (Blackburn *et al.* 2004). *Legionella* was responsible for 6 of the 11 WBDOs associated with distribution system contamination during 2001–2002. These WBDOs occurred in large buildings or institutional settings, were related to amplification of *Legionella* in the distribution system, and mostly likely spread by aerosolization of water from the system, usually from hot water taps. In two WBDOs, *Legionella* may have entered during a mains break or back-siphonage.

Increasing numbers of waterborne pathogens have been identified as causes of WBDOs in the United States. During 1920–1940, only four waterborne pathogens were identified; during 1991–2002, 13 pathogens were identified (Table 3). Among the recently recognized waterborne pathogens is *Cyclospora*, which caused a single WBDO in a Chicago building that housed hospital personnel (Herwaldt *et al.* 1991). Other yet to be identified pathogens may become important. For example, two WBDOs of chronic diarrhea were reported, but no causative agent was identified even after extensive laboratory analyses (Parsonnet *et al.* 1989).

Before 1970, ten protozoan WBDOs were reported; these were primarily caused by *E. histolytica*. After 1970, 159 protozoan WBDOs were reported, primarily caused by *Giardia* and *Cryptosporidium*; only one *E. histolytica* WBDO has been reported since 1971.

DISCUSSION

Although the WBDO surveillance statistics are imperfect for estimating the incidence of epidemic waterborne illness, they can help identify important waterborne pathogens and water system deficiencies. These same pathogens and deficiencies may also be important to consider when assessing endemic risks. Surveillance information can also be used to identify changing sources of contamination and the adequacy of current treatment and regulations. If current treatment is inadequate to remove or inactivate these pathogens and if water system deficiencies that cause outbreaks are not identified and corrected, both endemic and epidemic waterborne risks are increased.

Although the number of outbreak-associated illnesses may be relatively small when compared with the possible endemic waterborne risk in the United States, illness estimates should consider the extent to which WBDOs may go unrecognized and the likelihood that one of more large WBDOs may occur in the future. The statistics for 1991–2002 are dominated by the largest WBDO since surveillance began; an estimated 403 000 persons became ill, 4400 persons were hospitalized, and 50 persons died. The concern is whether current treatment technologies, monitoring, and operational practices are adequate to remove or kill a more virulent emerging waterborne pathogen.

WBDO etiologies have changed over the years and will likely continue to change. Since 1991, 14 waterborne pathogens have caused WBDOs in the United States. The infectivity and virulence of these pathogens vary as does the host response to infection. The changing nature of waterborne pathogens suggests that other pathogens may well be important in the future. The most frequently identified etiologic agents in the last 12 years have been *Giardia* and *Cryptosporidium*, two pathogens characterized by a low infectious dose, good survival in a cold water environment, and resistance to water treatment practices that were once state-of-the art. Pathogens of emerging importance may be resistant to current water treatment practices, which have recently been upgraded to remove or kill *Giardia* and *Cryptosporidium*. WBDO surveillance can help identify changing water quality conditions and guide research strategies to ensure that treatment technologies are adequate for newly identified waterborne pathogens.

Although the mortality associated with WBDOs has decreased since 1920, an increase has occurred during the last 12 years. This increase is largely due to the 50 deaths during the Milwaukee WBDO. The underlying cause of these deaths was primarily AIDS, but the contributing cause of death was cryptosporidiosis. *Cryptosporidium* infection may lead to mild or no symptoms in some persons but to an illness of relatively long duration in others. The infection can be severe in persons with a suppressed immune system. As the population that is susceptible to severe illness or death (e.g. elderly, organ transplants, HIV infected persons, AIDS patients) becomes larger, future WBDOs may have a greater public health impact.

Since 1991, an increased proportion of WBDOs have been associated with contaminants that have entered the water distribution system. Microbial contaminants have been implicated in two-thirds of the distribution-system-associated WBDOs, and many of these pathogens are not likely to be killed by the relatively low levels of disinfectant residuals maintained in the water distribution system. These WBDOs are also among these that may frequently go unrecognized. Although these outbreaks have tended to be relatively small,

Table 3 | Etiology of waterborne outbreaks reported in the United States, 1991–2002

Etiological agent	Outbreaks	Cases
AGI	77	16 036
Chemical	33	577
Giardia	25	2283
Cryptosporidium	15	408 371
Norovirus	12	3361
E. coli O157:H7	11	288
Shigella	9	663
Campylobacter jejuni	7	360
Legionella	6	80
Salmonella, non-Typhoid	3	833
V. cholerae	2	114
Hepatitis A	2	56
Naegleria fowleri	1	2
Plesiomonas shigelloides	1	60
Campylobacter and *Yersinia*	1	12
E. coli O157:H7 & *Campylobacter*	1	781
Unidentified SRSV	1	70
Total	207	433947

several recent distribution-system-associated WBDOs have resulted in a large number of illnesses. A better understanding is needed of the extent to which these WBDOs are detected and the importance of distribution system contamination for endemic waterborne risks.

CONCLUSIONS AND RECOMMENDATIONS

WBDO surveillance statistics have been helpful in evaluating the adequacy of current technologies and regulations and identifying the relative degrees of risk associated with source waters, types of systems, and treatment processes. Even though the WBDO surveillance data have inherent limitations and represent only a portion of the actual occurrence of WBDOs in the United States, a national estimate of drinking waterborne disease risks should consider both endemic and epidemic illness.

An estimate of the number of illnesses that may be associated with WBDOs should consider the extent to which WBDOs and associated illnesses are not being recognized and reported. Contamination of the distribution system has become increasingly important as a cause of WBDOs, and unless surveillance systems are designed to specifically detect these outbreaks, a large number may go unreported.

Few studies that have attempted to estimate the extent to which WBDOs are under-reported, and research should be conducted to help assess the sensitivity of current surveillance to detect outbreaks and the extent to which WBDOs and associated illnesses may be under-reported.

Waterborne pathogens that cause WBDOs should be considered when assessing endemic risks. These pathogens may also be important causes of endemic waterborne illness. Epidemiologic studies should evaluate the endemic waterborne risks associated with the most frequently identified agents. Many WBDOs continue to be classified as AGI of undetermined etiology, and additional resources and efforts should be made available during outbreak investigations to identify the etiology. These efforts may lead to better information about important waterborne pathogens for both outbreak and endemic risks.

WBDO surveillance data indicate that measures of disease severity, such as duration of illness, are important for risk managers to consider in the national estimate of endemic waterborne illness. By considering specific infectious diseases (e.g. cryptosporidiosis, shigellosis) in additional epidemiologic studies of endemic risks, the severity of endemic illness can be better evaluated. WBDO investigators are also encouraged to collect additional information about disease severity (e.g. physician visits, age distribution of cases).

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DISCLAIMER

The views expressed in this paper are those of the individual authors and do not necessarily reflect the views and policies of the U.S. Environmental Protection Agency or the Centers for Disease Control and Prevention. The paper has been subject to the Environmental Protection Agency's peer review and approved for publication.

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