WATERBORNE DISEASE OUTBREAKS IN THE UNITED STATES OF AMERICA: CAUSES AND PREVENTION

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Introduction

In the United States of America, the reporting of waterborne outbreaks is voluntary. National statistics, available from 1920, are compiled from information obtained from the scientific literature and state public health and environmental protection agencies. Specific diseases are reported as a result of legislation or administrative rule in each state. Currently, information is provided to the federal government on the occurrence of 49 notifiable diseases, some of which may be waterborne. State and local public health agencies are primarily responsible for disease surveillance and the detection and investigation of outbreaks. The Environmental Protection Agency (EPA) and Centers for Disease Control (CDC) provide assistance when requested in the investigation of waterborne outbreaks. EPA and CDC have maintained a collaborative waterborne disease surveillance programme at the federal level since 1971. Periodically, waterborne outbreak data are analysed to identify the water system deficiencies and etiological agents responsible for the outbreaks *(1)*. This information is important to evaluate the adequacy of public health programmes, regulations, and treatment technologies to provide safe drinking-water.

Definitions

For an outbreak to be considered waterborne, acute illness affecting two or more persons with similar symptoms must be epidemiologically associated with the ingestion of water. Also included are single, well-documented cases of chemical poisoning such as infantile methemoglobinaemia associated with high nitrate concentrations. During most outbreaks, water was found to be bacteriologically or chemically contaminated, but in only a few outbreaks was the etiological agent isolated from water. Reported outbreaks are primarily associated with water used or intended for drinking or domestic purposes, but outbreaks are also associated with ingestion of nonpotable water. Included in the surveillance system but excluded from this analysis are waterborne outbreaks on cruise ships operating from United States ports and among swimmers, bathers, and hot-tub users, with dermal or inhalation exposure. Water systems are classified as community (systems with 25 year-round residents) or noncommunity (systems for institutions, industries, camps, parks, hotels or businesses). Outbreaks in residents without community systems or persons who consume water from nonpotable sources (e.g. backpackers, campers) and outbreaks in which contaminated water was ingested while swimming or bathing are classified as individual and recreational.

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Statistics

Since 1920, 1 702 waterborne outbreaks with 542 018 cases of illness, and 1 089 deaths have been reported in the United States. Almost all deaths were due to typhoid fever prior to 1940, but 9 deaths have occurred since 1971: 4 during an outbreak of diarrhoea caused by enterohaemorrhagic *E. coli* 0157:H7; 2 during an outbreak of shigellosis in an elderly population; and single deaths due to accidental fluoride contamination of a community water system, ethylene glycol contamination of drinking-water used for haemodialysis, and high nitrate in a farm well. Three additional cases of methemoglobinaemia reported since 1971 did not result in death.

During the past decade, 291 waterborne outbreaks were reported in community (43%) and noncommunity (33%) systems and from the ingestion of contaminated water from recreational (14%) and individual (10%) water sources. For all types of systems, the average frequency of occurrence was 29 outbreaks per year, which is only slightly less than reported during the previous decade and comparable to the number reported during the 1930s and 1940s *(Table 1)*.

TABLE 1. AVERAGE NUMBER OF WATERBORNE OUTBREAKS PER YEAR, UNITED STATES OF AMERICA, 1920-1990

TABLEAU 1. NOMBRE MOYEN DE FLAMBÉES DE MALADIES À TRANSMISSION HYDRIQUE PAR AN, ÉTATS-UNIS D'AMÉRIQUE, 1920-1990

Time period Période	Community systems Réseaux publics	Noncommunity systems Autres réseaux	All water systems Ensemble des réseaux d'adduction d'eau
1920-30	17.2	2.6	23.2
1931-40	12.8	3.1	30.6
1941-50	9.6	14.2	31.3
1951-60	4.1	3.9	11.1
1961-70	3.9	3.9	13.1
1971-80	12.3	16.1	32.6
1981-90	12.4	9.7	29.1
1920-90	8.9	7.1	20.2

More outbreaks are usually reported in community than in noncommunity systems. The number of outbreaks reported each decade in community systems declined until 1971. Outbreaks have also declined during the past decade. From 1981 to 1985, 186 waterborne outbreaks were reported with only 105 reported during 1986-1990. Eighty-nine outbreaks in community systems and 61 outbreaks in noncommunity systems were reported in the first half of the decade, compared with 35 and 36 outbreaks, respectively in the latter half.

Although several large waterborne outbreaks occurred during the past decade, most outbreaks were in small communities. The relative size of outbreaks reported in community water systems during the past decade is among the lowest of any decade since 1920 and similar to the size of outbreaks in noncommunity systems *(Table 2)*. The number of illnesses per outbreak in noncommunity systems during the past decade is much larger than reported during any previous period, and the magnitude of these outbreaks indicates the potential effect on the large, travelling, transient population.

TABLE 2. CASES OF WATERBORNE ILLNESS PER OUTBREAKS, UNITED STATES OF AMERICA, 1920-1990

TABLEAU 2. NOMBRE DE CAS DE MALADIES À TRANSMISSION HYDRIQUE PAR FLAMBÉE ÉPIDÉMIQUE, ÉTATS-UNIS D'AMÉRIQUE, 1920-1990

Time period Période	Community systems Réseaux publics	Noncommunity systems Autres réseaux	All water systems Ensemble des réseaux d'adduction d'eau
1920-30	513	138	400
1931-40	748	60	339
1941-50	467	57	172
1951-60	247	51	112
1961-70	1 023	111	354
1971-80	483	114	241
1981-90	290	274	225
1920-90	438	83	221

Reporting

It is difficult to determine whether the decline in the reported number of waterborne outbreaks in the past 5 years is due to the occurrence of fewer outbreaks or less active surveillance and reporting. Outbreaks are most likely to be reported in community systems, and because less active surveillance should continue to recognize most outbreaks in these water systems, the decrease in reported outbreaks for community systems since 1985 may reflect a decrease in outbreak occurrence. An active surveillance programme is required to detect outbreaks in noncommunity systems, especially those involving travellers. Therefore, the large decline in outbreaks observed for noncommunity water systems during the same time may reflect less active surveillance.

The number of reported outbreaks increased dramatically during 1979-1983, and it can also be argued that this increase was primarily the result of improved surveillance and reporting, while the decrease in reported outbreaks since 1985 reflects a less active, more typical surveillance system. The number of waterborne outbreaks reported after 1983 is comparable to that reported during a similar period just prior to 1979. This suggests that increases or decreases in waterborne outbreak statistics primarily reflect surveillance and reporting changes rather than deterioration or improvement in water systems. Many factors influence the degree to which outbreaks are recognized, investigated and reported in any single year, including interest in the problem and the capabilities for recognition and investigation at the state and local level. While it is generally agreed that waterborne outbreak reporting is incomplete, it is difficult to estimate the number of outbreaks that may go undetected or unreported. Estimates suggest that only one-half to one-third or even one-tenth of all waterborne outbreaks are detected, investigated and reported *(2)*.

Causes of outbreaks

During 1981-1990, contaminated, untreated groundwater or inadequately disinfected groundwater was responsible for 43% of all reported waterborne outbreaks, and contaminated, untreated surface water or inadequately treated surface water was responsible for 24% of all reported outbreaks *(Table 3)*. Contaminated groundwater has consistently been responsible for more waterborne outbreaks than contaminated surface water. In each decade since 1920, 43-56% of all outbreaks were caused by contaminated groundwater, against 14-37% by contaminated surface water. Contaminated, untreated

TABLE 3. CAUSES OF WATERBORNE OUTBREAKS, UNITED STATES OF AMERICA, 1981-1990

TABLEAU 3. CAUSES DES FLAMBÉES DE MALADIES À TRANSMISSION HYDRIQUE, ÉTATS-UNIS D'AMÉRIQUE, 1981-1990

Cause of outbreak — Cause de la flambée épidémique	Percentage of outbreaks / Pourcentage de flambées épidémiques — Type of water system / Type de réseau d'adduction d'eau		
	Community Public	Noncommunity Autre	All systems Tous réseaux
Untreated groundwater — Eaux souterraines non traitées	12.1	44.3	26.5
Inadequate disinfection of groundwater — Eaux souterraines mal désinfectées	13.7	33.0	16.5
Ingestion of contaminated water while swimming — Ingestion d'eau contaminée en nageant	—	—	14.1
Inadequate disinfection of surface water — Mauvaise désinfection des eaux de surface	28.2	9.3	15.1
Distribution deficiencies — Problèmes de distribution	24.2	3.1	12.4
Filtration deficiencies — Problèmes de filtration	12.9	1.0	5.8
Unknown — Inconnue	5.6	3.1	3.8
Untreated surface water — Eaux de surface non traitées	1.6	4.1	3.4
Miscellaneous — Divers	1.7	2.1	2.4
Total	100	100	100

groundwater has declined in importance as a cause of outbreaks, and inadequate or interrupted disinfection has increased in importance, causing 17-27% of all outbreaks since 1971. Prior to 1971, only 2-6% of all outbreaks were caused by inadequate disinfection of groundwater. The increased occurrence of outbreaks in disinfected groundwater systems may be due to increased use of disinfection with little or no effort to reduce or eliminate sources of contamination. The lack of attention to providing effective, continuous disinfection is also important. Although most outbreaks in disinfected groundwater systems during the 1980s were the result of improper chlorination, several occurred in systems using iodine. Causes of outbreaks in untreated groundwater during the 1980s included: overflow or seepage of sewage into wells or springs (25%); surface runoff or flooding (13%); chemical contamination (5%); and contamination through limestone or fissured rock (4%). The investigation of most outbreaks (52%) caused by untreated groundwater was insufficient to identify a cause.

In surface water systems, outbreaks now occur primarily because of inadequate or interrupted disinfection in systems that do not provide filtration. Prior to 1971, outbreaks in surface water systems were caused most often by contaminated, untreated water. In the 1980s, a large increase also occurred in outbreaks in filtered surface water systems; in previous decades, except for the 1920s, only 2-4% of all outbreaks occurred in filtered surface water systems. Proper design and operation of filtration facilities are important in preventing waterborne outbreaks.

The causes of outbreaks differed in community and noncommunity systems during 1981-1990. In community systems, most outbreaks were caused by inadequate disinfection of surface water (28%) and contamination of water in the distribution systems (24%), primarily through cross-connections and repairs of mains. In noncommunity systems, almost all outbreaks (77%) were caused by contaminated, untreated and inadequately disinfected groundwater.

Etiology

Etiological agents responsible for waterborne outbreaks have changed since 1920 *(Table 4)*. Typhoid fever is no longer a threat in the United States. Hepatitis A replaced typhoid fever in the 1960s as the most frequently identified etiology, but it has declined in importance. Since 1971, the most frequently identified etiology has been giardiasis. During the past decade, some 65% of waterborne giardiasis outbreaks were caused by contaminated surface water and 13% were caused by faecal contamination of groundwater or groundwater under the influence of surface water. Inadequate disinfection of surface water when disinfection was the only treatment, and ineffective filtration or pretreatment of surface water were responsible for most outbreaks and cases of giardiasis. *Giardia* can be inactivated by disinfection but only if stringent conditions are met and consistently maintained *(2)*.

Although any of the identified etiological agents can be transmitted through either contaminated surface or groundwater, some agents were more frequently associated with groundwater contamination. Almost all (82%) reported outbreaks of hepatitis A were caused by contaminated groundwater. Contaminated groundwater was also responsible for 60% of the outbreaks of campylobacterosis, 48% of the outbreaks of viral gastroenteritis, 27% of the outbreaks of shigellosis, as well as for a single outbreak of amoebiasis, and 2 outbreaks of chronic gastroenteritis.

During the past decade, the etiology of acute gastroenteritis (AGI) was not determined in almost half of the outbreaks. In outbreaks caused by contaminated groundwater, only 38% were of a defined etiology, against 77% of outbreaks caused by surface water. In many outbreaks, the search for an etiological agent was limited or clinical specimens could not be collected in a timely manner. Although the symptoms and incubation period suggest viral illness in some outbreaks, it is felt that outbreaks of AGI represent a combination of viral, bacterial and parasitic etiologies.

In 1984 unpasteurized milk was implicated in Brainerd, Minnesota, in an outbreak of a distinctive chronic diarrhoeal illness characterized by dramatic, urgent watery diarrhoea persisting for many months; no causative agent could be identified *(3)*. In 1987 the first waterborne outbreak of chronic gastroenteritis occurred; untreated well water in an Illinois restaurant was implicated as the vehicle of transmission *(4)*. Nonbloody diarrhoea with a median frequency of 12 stools per day persisted in 87% of patients after 6 months. No bacterial, mycobacterial, viral or parasitic agents known to be enteropathogenic were detected in stools or well water. The well water was contaminated with coliforms. A second outbreak, also associated with untreated well water, occurred in a small Oklahoma community in 1988, but again no agent could be isolated. More research is required to help identify agents which may cause this and other unidentified waterborne illnesses, in order to assess the adequacy of current water treatment process and regulations. Although more timely investigations may help identify some agents, increased availability of laboratory procedures is also needed.

Outbreaks of 2 newly-recognized waterborne etiological agents were reported. Although its waterborne transmission had been suspected and it had been isolated from water *(5, 6)*, *E. coli* 0157:H7 had not previously been documented as a cause of waterborne outbreaks. In 1989 an outbreak of 243 cases occurred in Cabool, Missouri, where one-third of the ill persons had bloody diarrhoea, 32 were hospitalized and 4 died *(1)*. The water distribution system was identified as the likely source of contamination. The severity of illness associated with this organism reinforces the need to prevent waterborne outbreaks. Waterborne transmission of *Cyanobacteria (blue-green algae-like bodies)* (CLB) has been identified in stool specimens from patients around the world, and its role in causing diarrhoeal illness is currently being investigated *(7)*. An outbreak in a Chicago hospital was associated with drinking-water in a building in which open-air, rooftop storage tanks were used to maintain water pressure. Ill persons had remissions and relapses of explosive watery diarrhoea. CLB but no ova or parasites were found in stool specimens; no CLB were found in water samples but algae were found in a storage tank.

The protozoan *Cryptosporidium* has only recently been recognized as a cause of diarrhoea illness in humans. Like *Giardia*, animals as well as humans may serve as sources of environmental contamination and human infection *(8)*. The first waterborne outbreak was reported in 1985 in a Texas community with sewage-contaminated groundwater. It was also responsible for one of the largest waterborne outbreaks in the United States, affecting an estimated 13 000 persons in Carrollton, Georgia, in 1987 *(9)*. This community used surface water which underwent conventional treatment: coagulant feed, rapid mix, flocculation, sedimentation, filtration through anthracite sand filters, and chlorination. EPA water quality regulations were not exceeded for turbidity or coliforms and disinfection was not interrupted. *Cryptosporidium* oocysts identified in the water system during the outbreak most likely entered because of the operational practice of stopping and later restarting the flow of water through some filters without backwashing the filter. This practice resulted in higher-turbidity water from these filters. Limited studies have been conducted, but evidence indicates that this protozoan is very resistant to ation *(2, 8)*. Only 90% inactivation of oocysts was found at 100 mg/l free chlorine for 2 hours contact. In comparison, 99% inactivation of *Giardia* occurs at about 2.5 hours at 1 mg/l, polio virus at 3 minutes at 1 mg/l, rotavirus and *E. coli* bacteria at less than 1 minute at 0.1 mg/l.[b]

The occurrence of *Cryptosporidium* is widespread in water supplies in the United States *(10)*. Oocysts were detected at an average concentration of 43/100l in 55% of 257 samples collected from surface water and springs in 17 states and less than 1/100l in 17% of 36 drinking-water samples. In comparison, an average of 3 *Giardia* cysts/100l were found in 16% of the same water samples, and none were found in the drinking-water samples. No correlation was found between the occurrence of either protozoan and the current water quality indicator, coliforms. Additional research is needed to determine why so few waterborne outbreaks have been reported. Endemic cases may not be well reported, asymp-

[a] Information for comparative purposes only: EPA regulations require inactivation of 99.9% for *Giardia* and 99.99% for viruses.

TABLE 4. ETIOLOGY OF WATERBORNE OUTBREAKS, UNITED STATES OF AMERICA, 1920-1990

TABLEAU 4. ÉTIOLOGIE DES FLAMBÉES DE MALADIES À TRANSMISSION HYDRIQUE, ÉTATS-UNIS D'AMÉRIQUE, 1920-1990

Time period Période	Disease Maladie	Number of outbreaks Nombre de flambées épidémiques
1920-1940	Typhoid fever — Fièvre typhoïde	372
	Gastroenteritis — Gastro-entérite	144
	Shigellosis — Shigellose	10
	Amoebiasis — Amibiase	2
	Hepatitis A — Hépatite A	1
	Chemical poisoning — Intoxication chimique	1
	Subtotal — Total partiel	530
1941-1960	Gastroenteritis — Gastro-entérite	265
	Typhoid fever — Fièvre typhoïde	94
	Shigellosis — Shigellose	25
	Hepatitis A — Hépatite A	23
	Salmonellosis — Salmonellose	4
	Chemical poisoning — Intoxication chimique	4
	Paratyphoid fever — Paratyphoïde	3
	Amoebiasis — Amibiase	2
	Tularaemia — Tularémie	2
	Leptospirosis — Leptospirose	1
	Poliomyelitis — Poliomyélite	1
	Subtotal — Total partiel	424
1961-1970	Gastroenteritis — Gastro-entérite	39
	Hepatitis A — Hépatite A	30
	Shigellosis — Shigellose	19
	Typhoid fever — Fièvre typhoïde	14
	Salmonellosis — Salmonellose	9
	Chemical poisoning — Intoxication chimique	9
	Toxigenic *E. coli* — *E. coli* entérotoxigène	4
	Giardiasis — Giardiase	3
	Amoebiasis — Amibiase	3
	Subtotal — Total partiel	130
1971-1980	Gastroenteritis (AGI) — Gastro-entérite (AGI)	181
	Giardiasis — Giardiase	39
	Chemical poisoning — Intoxication chimique	38
	Shigellosis — Shigellose	24
	Hepatitis A — Hépatite A	16
	Viral gastroenteritis — Gastro-entérite virale	12
	Salmonellosis — Salmonellose	8
	Typhoid fever — Fièvre typhoïde	4
	Campylobacterosis — Campylobactérose	3
	AGI (toxigenic *E. coli*) — Gastro-entérite aiguë (*E. coli* toxigène)	1
	Subtotal — Total partiel	326
1981-1990	Gastroenteritis (AGI) — Gastro-entérite (AGI)	128
	Giardiasis — Giardiase	71
	Shigellosis — Shigellose	22
	Chemical poisoning — Intoxication chimique	18
	Viral gastroenteritis — Gastro-entérite virale	15
	Hepatitis A — Hépatite A	11
	Campylobacterosis — Campylobactérose	10
	Salmonellosis — Salmonellose	4
	Cryptosporidiosis — Cryptosporidiose	2
	Yersiniosis — Yersiniose	2
	Chronic gastroenteritis — Gastro-entérite chronique	2
	AGI (*E. coli* 0157:H7) — Gastro-entérite aiguë (*E. coli* 0157:H7)	1
	Typhoid fever — Fièvre typhoïde	1
	Dermatitis (chlorine) — Dermatite (due au chlore)	1
	AGI (cyanobacteria-like body) — Gastro-entérite aiguë due aux organismes analogues à des cyanobactéries	1
	Cholera — Choléra	1
	Amoebiasis — Amibiase	1
	Subtotal — Total partiel	291

tomatic infection may be high, and protective immunity may be important. Some oocysts in the environment may not be infective for humans, and oocysts identified in water may not be viable (current analysis cannot assess viability). Although the infective dose is thought to be low, it may not be high enough in most water systems to cause sufficient infection in large numbers of people. For example, 46 oocysts/100l were detected in the Carrollton outbreak compared with only 0.5-1.7 oocysts/100l in the water survey *(8, 9)*.

Discussion

New strategies are needed to prevent waterborne outbreaks. Outbreaks have occurred in systems that have not exceeded regulations for coliforms and turbidity, and the data clearly show that disinfection has not been effective as the only treatment for surface waters. The important waterborne diseases at the turn of the century were typhoid fever and cholera. These diseases are transmitted exclusively among humans, and waterborne transmission can be prevented by protecting water sources from sewage contamination. Since these pathogens are very susceptible to disinfection, chlorination was found to be adequate as the only treatment of some surface waters. Important waterborne diseases are now caused by protozoa which cause infection at a lower dose and are much more resistant to disinfection. Water contamination by these protozoa is not necessarily detected by coliform occurrence. In addition to human reservoirs, wild and domestic animals are important primary or intermediate sources of infection by these protozoa and also by other newly-recognized etiological agents. Since it is impossible to exclude animals from watersheds, greater emphasis must be placed on water treatment barriers. Although the protection of raw water quality is still important, it is only one barrier to the transmission of waterborne disease. It is necessary to maintain additional barriers—filtration and disinfection—to ensure adequate margins of safety for surface-water systems. More emphasis must also be placed on the design and operation of filtration facilities if they are to be effective as part of the multiple barrier concept. The new EPA surface-water treatment requirements address disinfection and filtration of surface waters (54 FR 27486-541, June 19, 1989).

Adequate disinfection of groundwater should reduce the occurrence of waterborne outbreaks, particularly for small systems where intermittent contamination of wells and springs cannot be readily determined or prevented. Disinfection is not a substitute for proper development and protection of groundwater sources from contamination; it is an additional barrier for an increased level of protection. EPA has recently drafted requirements for disinfection of public water systems using groundwater.

Disinfection must continue as the final barrier against waterborne disease, but concerns over the human health effects that may be associated with long-term exposures to chlorine or chlorinated by-products may require changes in disinfection techniques or disinfectants *(11, 12)*. These concerns, however, must be tempered with considerations of the benefits provided by chlorination. Alternative disinfectants may be more expensive and not technologically feasible for developing countries where waterborne disease may be a greater threat. Additional research is required to better define the potential risks associated with chlorine and alternative disinfectants.

Chlorination may be the final, but it must not be the only, barrier against transmission of waterborne pathogens. Source protection is also important for both surface and groundwater. Properly designed and operated filtration plants can make disinfection more effective by removing turbidity and substances that exert chlorine demand and by reducing microbiological contamination. When disinfection is a part of the multiple barrier approach and not relied upon so heavily, lower concentrations of chlorine can be used, thereby lowering the levels of chlorinated by-products produced.

SUMMARY

National statistics on waterborne outbreaks in the United States of America show that 1 702 waterborne outbreaks with 542 018 cases of illness and 1 089 deaths have been reported. Almost all deaths prior to 1940 were due to typhoid fever; 9 deaths from other causes have occurred since 1971. During the past decade, 291 waterborne outbreaks were reported in community (43%) and noncommunity (33%) systems, and from the ingestion of contaminated water from recreational (14%) and individual (10%) water sources.

Although several large waterborne outbreaks occurred during the past decade, most were in small communities. The number of illnesses per outbreak in noncommunity systems during the past decade is much larger than that reported during any previous period, and the magnitude of these outbreaks indicates the potential effect on the travelling, transient population.

During 1981-1990, contaminated, untreated groundwater or inadequately disinfected groundwater was responsible for 43% of all reported waterborne outbreaks, and contaminated, untreated surface water or inadequately treated surface water was responsible for 24% of all reported outbreaks. The use of untreated groundwater has declined in importance as a cause of outbreaks, and more outbreaks are now caused by inadequate or interrupted disinfection of groundwater. The increased occurrence of outbreaks in disinfected groundwater systems may be due to *(i)* increased use of disinfection with little effort to reduce or eliminate sources of contamination, and *(ii)* not providing effective, continuous disinfection.

In surface-water systems, outbreaks occur primarily because of inadequate or interrupted disinfection in systems that do not provide filtration, but a large increase in outbreaks has recently occurred in fil-

tered systems. In community systems, most outbreaks were caused by inadequate disinfection of surface water (28%) and contamination of water in the distribution systems (24%), primarily through cross-connections and repairs of water mains. In noncommunity systems, almost all outbreaks (77%) were caused by contaminated groundwater.

Since 1971, the most frequently identified etiology was giardiasis. Inadequate disinfection of surface water when disinfection was the only treatment, and ineffective filtration or pretreatment of surface water were responsible for most outbreaks and cases of giardiasis, but 13% were caused by faecal contamination of groundwater or groundwater under the influence of surface water. Almost all (82%) outbreaks of hepatitis A were caused by contaminated groundwater. Contaminated groundwater was also responsible for: 60% of outbreaks of campylobacterosis, 48% of outbreaks of viral gastroenteritis, 27% of outbreaks of shigellosis, a single outbreak of amoebiasis, and 2 outbreaks of chronic gastroenteritis.

In 1987 the first waterborne outbreak of a distinctive chronic diarrhoeal illness characterized by dramatic, urgent, watery diarrhoea persisting for many months was reported in Illinois. Untreated well water in a restaurant was implicated as the vehicle of transmission, but no causative agent could be identified. A second outbreak also associated with untreated well water occurred in 1988, but again no agent could be isolated.

Outbreaks of two newly recognized waterborne etiological agents were reported. In 1989 an outbreak of 243 cases of *E. coli* 0157:H7 occurred in Cabool, Missouri, where one-third of the ill persons had bloody diarrhoea, 32 were hospitalized and 4 died. Waterborne transmission of Cyanobacteria (blue green algae-like bodies) was identified in an outbreak in a Chicago hospital where open-air, roof-top storage tanks were used to maintain water pressure.

The protozoan *Cryptosporidium* has only recently been recognized as a cause of diarrhoeal illness in humans. As with *Giardia*, animals as well as humans may serve as sources of environmental contamination and human infection. The first waterborne outbreak was reported in 1985 in a community with sewage-contaminated groundwater. One of the largest waterborne outbreaks, an estimated 13 000 cases of cryptosporidiosis, occurred in 1987 in a community using surface water treated by an apparently complete filtration and disinfection process; water quality regulations were not exceeded for turbidity or coliforms and disinfection was not interrupted.

New strategies are needed to prevent waterborne outbreaks. Outbreaks have occurred in systems that have not exceeded regulations for coliforms and turbidity, and the data clearly show that disinfection has not been effective as the only treatment for surface waters. Although the protection of raw water quality is still important, it is only one barrier to the transmission of waterborne diseases. It is necessary to maintain additional barriers—filtration and disinfection—to ensure adequate margins of safety for surface water systems. More emphasis must also be placed on the design and operation of filtration facilities.

Adequate disinfection of groundwater should reduce the occurrence of waterborne outbreaks, particularly for small systems where intermittent contamination of wells and springs cannot be readily determined or prevented. Disinfection is not a substitute for the proper development and protection of groundwater sources from contamination; it is an additional barrier for an increased level of protection. Disinfection is required to protect against waterborne disease transmission, and concerns for health effects which may be associated with long-term exposure to disinfectants and disinfection by-products must be tempered with considerations of the benefits. When disinfection is part of the multiple-barrier approach, lower concentrations can be used, thereby lowering levels of disinfection by-products.

RÉSUMÉ

Flambées de maladies à transmission hydrique aux Etats-Unis d'Amérique: causes et prévention

D'après les statistiques nationales concernant les flambées de maladies à transmission hydrique aux Etats-Unis d'Amérique, 1 702 flambées, au cours desquelles ont été enregistrés 542 018 cas et 1 089 décès, ont été signalées. Avant 1940, pratiquement tous les décès étaient dus à la fièvre typhoïde; depuis 1972, 9 décès dus à d'autres maladies ont été signalés. Au cours des 10 dernières années, 291 flamblées de maladies à transmission hydrique ont été signalées, 43% dans les réseaux publics d'adduction d'eau, 33% dans d'autres réseaux, 14% suite à l'ingestion d'eau polluée dans des zones de loisirs et 10% d'eau de sources privées.

Plusieurs poussées importantes de maladies à transmission hydrique sont survenues au cours des 10 dernières années, mais la plupart du temps dans de petites collectivités. Dans chaque circonstance, le nombre de cas enregistrés dans des réseaux non publics au cours des 10 dernières années était beaucoup plus important qu'au cours de toute autre période antérieure, et l'importance des foyers donne une idée du risque encouru par les voyageurs et les personnes de passage.

De 1981 à 1990, 43% des flambées de maladies à transmission hydrique notifiées étaient imputables à des eaux souterraines contaminées, non traitées ou mal désinfectées, et 24% à des eaux de surface contaminées, non traitées ou mal désinfectées. La consommation d'eaux souterraines non traitées n'est plus une cause aussi importante d'épidémies et la plupart des flambées sont désormais provoquées par une mauvaise désinfection ou une absence passagère de désinfection des eaux souterraines. L'augmentation de flambées épidémiques survenant

dans des réseaux d'eaux souterraines désinfectées peut être due *i)* à un recours accru de la désinfection sans chercher à réduire ou éliminer les sources de pollution ou *ii)* à l'absence de systèmes efficaces de désinfection en continu.

En ce qui concerne les eaux de surface, les flambées épidémiques surviennent principalement en raison de l'insuffisance ou de l'interruption de la désinfection dans des réseaux dépourvus de systèmes de filtration, mais une augmentation importante a récemment été observée dans des réseaux dotés de systèmes de filtration. Dans les réseaux publics, la plupart des flambées ont été provoquées par une mauvaise désinfection des eaux de surface (28%) et par la contamination de l'eau des réseaux de distribution (24%), principalement lors de raccordements ou de la réparation des conduites d'eau. Dans les autres réseaux, la presque totalité des flambées (77%) ont été provoquées par des eaux souterraines contaminées.

Depuis 1971, c'est la giardiase qui a été l'affection la plus fréquemment observée. Une mauvaise désinfection des eaux de surface — en l'absence de tout autre traitement — et lorsqu'une filtration ou un pré-traitement inefficaces des eaux de surface ont été responsables de la plupart des flambées épidémiques et des cas de giardiase, mais 13% s'expliquent par une contamination fécale des eaux souterraines ou l'infiltration d'eaux de surface dans les eaux souterraines. Pratiquement toutes les flambées épidémiques d'hépatite A (82%) ont été provoquées par des eaux souterraines contaminées. La pollution des eaux souterraines est également responsable de 60% des flambées de campylobactériose, de 48% des flambées de gastro-entérite virale, de 27% des flambées de shigellose, d'une flambée d'amibiase et de 2 flambées de gastro-entérite chronique.

En 1987, la première flambée épidémique d'une maladie diarrhéique chronique d'origine hydrique caractérisée par une diarrhée aqueuse très profuse persistant pendant plusieurs mois a été signalée dans l'Illinois. De l'eau non traitée provenant d'un puits consommée dans un restaurant a été mise en cause dans la transmission mais aucun agent étiologique n'a pu être identifié. Une deuxième flambée également imputable à de l'eau de puits non traitée est survenue en 1988, mais là encore aucun agent n'a pu être isolé.

Des flambées imputables à deux agents étiologiques à transmission hydrique récemment identifiés ont été signalées. En 1989, une flambée de 243 cas d'infection à *E. coli* 0157:H7 s'est produite à Cabool, dans le Missouri, où un tiers des personnes malades présentaient des diarrhées sanglantes, 32 ont été hospitalisées et 4 sont décédées. La transmission hydrique d'organismes analogues à des cyanobactéries (algues bleues) a été relevée lors d'une flambée épidémique survenue dans un hôpital de Chicago où des réservoirs d'eau à l'air libre placés sur le toit étaient utilisés pour assurer une pression d'eau suffisante.

Un protozoaire, *Cryptosporidium*, n'a été reconnu comme cause de maladie diarrhéique chez l'homme que très récemment. Tout comme pour *Giardia*, l'animal et l'homme peuvent constituer des sources de contamination de l'environnement et d'infection humaine. La première flambée épidémique d'origine hydrique a été signalée en 1985 dans une collectivité dont les eaux souterraines avaient été contaminées par des eaux usées. Une des plus importantes flambées de maladie hydrique, où l'on avait dénombré quelque 13 000 cas de cryptosporidiose, est survenue en 1987 dans une collectivité consommant des eaux de surface ayant subi un traitement complet de filtration et de désinfection; les valeurs-limites relatives à la turbidité ou aux coliformes n'avaient pas été dépassées et la désinfection n'avait pas été interrompue.

De nouvelles méthodes doivent donc être mises au point pour prévenir les flambées de maladies à transmission hydrique. Certaines ont éclaté dans des réseaux où les valeurs-limites relatives aux coliformes ou à la turbidité n'avaient pas été dépassées et les données indiquent clairement que la désinfection n'a pas toujours été efficace comme seul traitement pour les eaux de surface. Bien que la protection de la qualité de l'eau non traitée soit toujours importante, elle n'est qu'une mesure de protection parmi tant d'autres contre la transmission des maladies hydriques. Il est donc nécessaire de s'assurer des protections supplémentaires — filtration et désinfection — afin de garantir une marge de sécurité suffisante dans les réseaux utilisant les eaux de surface. Il faudrait également accorder davantage d'attention à la conception et au mode de fonctionnement des systèmes de filtration.

Une bonne désinfection des eaux souterraines devrait réduire la survenue des flambées de maladies à transmission hydrique, en particulier dans les petits réseaux où une contamination intermittente des puits ou des sources est difficile à déceler ou à prévenir. La désinfection ne saurait remplacer l'exploitation judicieuse et la protection des sources d'eau souterraine de toute pollution; ce n'est qu'un élément de plus pour garantir un niveau accru de protection. La désinfection est nécessaire pour se prémunir contre la transmission des maladies hydriques et l'inquiétude que peuvent soulever les risques d'une exposition de longue durée aux désinfectants et aux sous-produits de la désinfection doit être tempérée par les avantages potentiels qu'elle présente. Lorsque la désinfection s'insère dans une stratégie de protection à plusieurs volets, de plus faibles concentrations de désinfectants peuvent être utilisées, ce qui permet aussi de réduire la concentration des sous-produits de la désinfection.

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