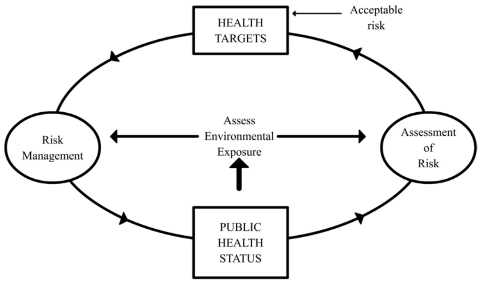

6

Disease surveillance and waterborne outbreaks

Yvonne Andersson and Patrick Bohan

Outbreaks are both a demonstration of a breakdown or failure in the system and, by acting as a 'natural experiment', present an opportunity to provide new insights into disease transmission and, perhaps, improvements to the system. This chapter outlines in detail the surveillance systems in Sweden and the US that are designed to detect waterborne disease outbreaks, and examines the actions taken upon suspecting an outbreak. It also examines some of the outbreaks that have occurred, principally from drinking water, details lessons that can be learnt from well-conducted investigations, and briefly looks at the worldwide situation.

6.1 THE SWEDISH SITUATION

Sweden has a long history of communicable disease awareness, with legislation dating back to 1875. The regulations are based on a selection of disease agents,

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their occurrence and the severity of the disease. Under the Communicable Disease Act, County Medical Officers have the main responsibility for dealing with such diseases and they have an overseeing and co-ordinating role for combating communicable diseases in their region.

Local doctors are responsible for any epidemiological investigation relating to a patient and also for giving hygiene advice to people who have contracted communicable diseases. A doctor who identifies a person with a notifiable disease is required to inform the County Medical Officer and the Swedish Institute for Infectious Disease Control (SIIDC) of the case and, in relation to diseases which may have been contracted via food, water and the environment, the local Environmental and Public Health Committee. The reporting of waterborne outbreaks, as such, however, is not mandatory.

Water is included under the Food Act in Sweden, the responsible authority being the National Food Administration. The reporting and investigation system can be quite complex with a large number of different bodies being involved.

6.1.1 Waterborne disease outbreaks in Sweden

Sweden has a long tradition in the reporting and surveillance of communicable diseases, including waterborne diseases. The first reported outbreaks of waterborne disease in Sweden were cholera epidemics between 1834 and 1874 (Arvidsson 1972). Based on historical data a retrospective summary of incidents and outbreaks has been made, dating back to 1880. The number of outbreaks and aetiological agents has varied over the years, according to prevailing knowledge, the interest of local authorities and diagnostic capabilities. Over a period of 100 years (between 1880 and 1979) 77 waterborne outbreaks, with 26,867 reported cases and 789 deaths were known (Andersson 1992). Most of the outbreaks (88%) during that period were due to known agents. At the start of the twentieth century the most commonly reported diseases (possibly of waterborne origin) were typhoid fever and shigellosis. The picture of hepatitis and polio reporting has changed in line with the improving general standards of hygiene in society.

6.1.1.1 Waterborne outbreaks since 1980

An improved reporting system, which includes the results of epidemiological investigations, has existed since 1980. Improvements have included the systematic investigation of possible waterborne outbreaks with a standardised questionnaire for large outbreaks, as well as clinical and environmental sampling. The enhanced system has resulted in an increase in the number of detected waterborne outbreaks. During the period 1980–99, 116 outbreaks of waterborne diseases were reported from both large and small water supply systems, the majority affecting systems with less than 15,000 consumers. In total, about 57,500 people were affected, but only two deaths were recorded. These numbers are based on epidemiological follow-ups and sometimes local authority reports. More than 70% of the outbreaks were due to unknown agents, and are termed Acute Gastrointestinal Illness (AGI). The most commonly identified agents were *Campylobacter* sp. and *Giardia lamblia*. A few outbreaks also involved *Entamoeba histolytica*, enterotoxigenic *E. coli* (ETEC) and *Cryptosporidium*. During this period, *Salmonella* spp. and *Shigella* spp. were only isolated from outbreaks associated with private wells. Over the last few years, the number of reported waterborne outbreaks involving caliciviruses has increased, owing to the use of better laboratory methods for clinical samples. The numbers of outbreaks and cases are shown in Table 6.1.

Table 6.1. Waterborne disease outbreaks in Sweden (1980–99)

Years	No. of outbreaks	No. of cases
1980	3	4030
1981	3	105
1982	3	622
1983	3	1266
1984	9	1149
1985	12	5256
1986	12	5575
1987	8	900
1988	5	13,144
1989	4	223
1990	4	100
1991	4	935
1992	4	588
1993	5	297
1994	8	4070
1995	10	13,574
1996	7	3135
1997	6	209
1998	4	2310
1999	2	180

In Sweden, surface water is used for approximately half of community water supplies; the remainder being supplied by groundwater or artificially recharged groundwater. The number of outbreaks attributable to surface water since 1980 is relatively small: however, as a source it has been responsible for the largest reported outbreaks, affecting thousands of people. Problems often occur in early spring, when the surface of the water is still frozen and the final water receives little or no chlorination.

The largest outbreak between 1980 and 1999 occurred in early 1988 (Andersson 1991) and affected approximately 11,000 people (with an attack rate of 41%). Investigation revealed that the water treatment plant was undergoing refurbishment and as a consequence there was a chlorination failure. During the short period of chlorination failure the raw surface water received only filtration and pH adjustment.

The other large outbreak due to surface water (affecting 10,000 people) was due to a change in pipeline (Wahren 1996). A pipeline, containing stagnant raw water, was brought into use without being flushed first.

Groundwater was most commonly associated with the outbreaks outlined in Table 6.1. Generally, however, the problem was not the quality of the groundwater *per se*, but technical difficulties or communication breakdowns leading to cross-connections with sources of contamination. In a Swedish ski resort 3600 people became ill (*Giardia* and *Entamoeba histolytica*) when a drinking water reservoir was contaminated with sewage through a pipeline connected to a spillway overflow (Andersson and de Jong 1989; Ljungstrom and Castor 1992). A damaged septic tank led to contamination of a drinking water well which supplied water to a restaurant resulting in at least ten customers reporting campylobacteriosis. An illegal cross-connection to a creek to serve as a private source of irrigation led to contaminated creek water being pumped into the community water supply and approximately 600 people falling ill with a variety of infections including campylobacteriosis, giardiasis and cryptosporidiosis (Thulin 1991).

6.1.1.2 Recognition of waterborne outbreaks

An outbreak or epidemic normally means that more cases are clustered than the anticipated, endemic, background level. The World Health Organization (WHO) definition of a food- or waterborne outbreak is when two or more persons experience a similar illness after ingestion of the same type of food or water from the same source and when the epidemiological evidence implicates the food or the water as the source of the illness (Schmidt 1995).

The probability of detecting an outbreak depends on both knowledge and resources (both microbiological and personnel). Rapid recognition of the possibility of an outbreak and a timely start to the investigation greatly increase the likelihood of determining cause.

There are a number of different possibilities that could suggest a waterborne outbreak:

- non-potable water found by routine sampling
- complaints about water quality
- an increase of AGI in the community, in general practices, or in hospitals (clinical surveillance)
- an increase of positive laboratory results indicating possible waterborne agents (laboratory surveillance).

6.1.1.3 Water sampling

The routine monitoring of drinking-water quality cannot prevent an outbreak but can detect that contamination has occurred, thus it plays an important role as it reveals basic water quality and the likely risk of an outbreak.

Communication can play a vital role in the detection, and prevention, of outbreaks. In the investigations of some Swedish surface-water-related outbreaks it was found that the raw-water quality deteriorated every spring with high levels of faecal coliforms and/or coliforms. Although this information was collected each year, it was not interpreted and as a result no action was taken. If this type of water-quality monitoring had been used as intended, an appropriate action might have been to increase disinfection levels each spring, possibly averting an outbreak.

Outbreaks may start with complaints about water quality (Thulin 1991). A rapid collection of water samples and technical investigation may confirm deficient water quality. Taking prompt control measures may prevent a waterborne outbreak or at least reduce the number of cases.

6.1.1.4 Clinical and laboratory surveillance

In Sweden, there are two mandatory surveillance systems: the reporting of notifiable diseases and reporting from the laboratories. Diseases that should be reported by doctors which may be of interest in waterborne outbreaks are hepatitis A, cholera, typhoid fever, paratyphoid fever, salmonellosis, shigellosis, campylobacteriosis, yersiniosis, enterohaemorrhagic *E. coli* O157, giardiasis and amoebiasis.

The diseases reported only by laboratories (voluntarily) are enterohaemorrhagic *E. coli* (other than serotype O157), caliciviruses, rotaviral enteritis, cryptosporidiosis and diarrhoea caused by *Cyclospora* sp.

To recognise an increase in illness from the reporting system is a slow way of discovering a waterborne outbreak. Normally, it will take about one to two weeks before the surveillance system recognises an increase. It also suffers from a lack of sensitivity, as outlined below.

One major problem with outbreak detection is that a significant number of people may not consult a doctor. There have been waterborne outbreaks with several hundred or a thousand people affected, which were discovered more or less accidentally. Therefore, even with a surveillance system waterborne outbreak detection can be down to luck (Figure 6.1).

Gastrointestinal symptoms → will see a doctor
→ will not see a doctor

→ the person will be sampled
→ the person will not be sampled

→ negative result
→ positive result

Figure 6.1. Conditions for a pathogenic micro-organism to be diagnosed.

There have been very few examples of outbreaks in Sweden in which the surveillance system first revealed that a waterborne outbreak existed. Two such examples are:

- One small outbreak of *Giardia lamblia* in which a private well at a 'holiday village' was suspected as the source of the cases.
- A laboratory reported seven patients with campylobacteriosis at the hospital to the County Medical Office. All of them came from the same small town. It was later revealed that a large, waterborne, *Campylobacter* outbreak had occurred with about 2500 people falling ill (Andersson *et al*. 1994).

Investigations, based on interviews and standardised questionnaires, often reveal many more cases of illness, as shown in Table 6.2. The attack rate is unexpectedly high, confirming the underestimation of cases.

Table 6.2. Initially reported cases and actual numbers of cases in selected outbreaks in Sweden

Causative agent	Initially reported sick	Sick identified by lab	Estimated no. of sick	No. at risk	Attack rate (%)
Campylobacter	380	221	2000	15,000	13
Unknown	45	–	2000	2500	82
Unknown & *Giardia*	Several ill	56	550	750	73
Unknown	Several ill	Unknown	1000	1200	85
Unknown, *Giardia* & *Entamoeba*	Several ill	*Giardia*: 1480 *Entamoeba:* 106	3600	4000	90
Unknown	700	Unknown	11,000	26,000	41
Campylobacter	200	7 initially	2500	10,000	25

6.1.1.5 Common causes of outbreaks

A thorough investigation is vital to determine the outbreak cause (and an example of outbreak management is given later). In Nordic countries outbreak investigation analysis has revealed a number of common causes of outbreaks (Stenstrom *et al.* 1994). From community systems supplied with surface water the following occurrences were highlighted:

- Wastewater contamination of raw water source in combination with disinfection deficiencies
- No disinfection
- Cross-connections
- Regrowth in the distribution system.

Similar occurrences were identified from outbreaks involving groundwater, with the most common problem being source water contamination through wastewater infiltration. These problems and deficiencies are not confined to Nordic countries as similar causes have been reported elsewhere (e.g. Tulchinsky *et al*. 1988).

Realising some of the common causes of outbreaks led to a Swedish survey and inventory of all community supplies in the country and an examination of some of the larger private water supplies. Over 4000 supplies were subject to survey, of which 2281 were community supplies. Table 6.3 shows the risk factors that were identified as a result of the survey.

Table 6.3. Risk factors identified from a water supply survey (community supplies and larger private supplies (adapted from Hult 1991)

Factor	Percentage of total number
Safety area for source not established	74
Risk due to wastewater pipes close to source	13
Pollution risk at groundwater source	9
Pollution risk at low reservoir from drain gutter	4
Pollution risk at low reservoir from overflow pipe	8
No disinfection	79*
Unsatisfactory control of disinfection	69
Unsatisfactory water treatment (other than disinfection)	5
Unsatisfactory control programme for distribution system	62

* mainly small groundwater systems

Although sanitary inspection is a sensible step in developed countries (Prescott and Winslow 1931), a literature search suggests that it receives very little attention (Bartram 1996). In a number of developing countries, however, it is used extensively as a primary monitoring tool, in line with recommendations by WHO (1997).

6.2 THE SITUATION IN THE US

The surveillance system for Waterborne Disease Outbreaks (WBDO) in the US (while voluntary in nature) has much in common with that in Sweden, and suffers many of the same problems. In line with worldwide definitions, the unit of analysis for the WBDO surveillance system in the US 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, two or more people must have experienced a similar illness after either ingestion of drinking water or exposure to water used for recreational purposes (this stipulation is waived for single cases of laboratory-confirmed primary amoebic meningoencephalitis). Second, epidemiologic evidence must implicate water as the probable source of the illness. Outbreaks caused by contamination of water or ice at the point of use are not classified as WBDOs.

6.2.1 Overview

Since 1971, the Centers for Disease Control (CDC) and the US Environmental Protection Agency (EPA) have maintained a collaborative surveillance system for collecting and periodically reporting data that relate to occurrences and causes of waterborne disease outbreaks. The surveillance system includes data about outbreaks associated with drinking water and recreational water, and these data are published in Morbidity and Mortality Weekly Reports (MMWR) approximately every two years (CDC 1990, 1991, 1993; Kramer *et al*. 1996; Levy *et al*. 1998; Louis 1988).

State, territorial, and local public health departments are primarily responsible for detecting and investigating WBDOs and for voluntarily reporting them to CDC on a standard form. CDC annually requests reports from state and territorial epidemiologists or from persons designated as the WBDO surveillance co-ordinators. When necessary, additional information about water quality and treatment is obtained from the state's drinking-water agency. There is no national surveillance system in place for waterborne disease outbreaks and all the data gathered is voluntarily reported to CDC.

6.2.1.1 Considerations

The waterborne disease surveillance data, which identify the types of water systems, their deficiencies, and the respective aetiologic agents associated with the outbreaks, are useful for evaluating the adequacy of current technologies for providing safe drinking and recreational water. However, the data presented here have at least one important limitation: they almost certainly do not reflect the true incidence of WBDOs or the relative incidence of outbreaks caused by various aetiologic agents. Not all WBDOs are recognised, investigated, and reported to CDC or EPA; and clearly, the extent to which WBDOs are unrecognised and under-reported is unknown.

The likelihood that individual cases of illness will be detected, epidemiologically linked, and associated with water varies considerably depending on locale, and is dependent upon a number of factors, including:

- public awareness
- the likelihood that several ill people consult the same rather than different health-care providers
- the interest of health-care providers
- availability of laboratory testing facilities
- local requirements for reporting cases of particular diseases
- surveillance and investigative activities and capacities of state and local health and environmental agencies.

Therefore, the states that report the most outbreaks might not be those in which the most outbreaks occur, but those with the most rigorous investigation procedures. Recognition of WBDOs is also dependent on certain outbreak characteristics:

- Those involving serious illness are most likely to receive the attention of health authorities.
- Outbreaks of acute diseases, particularly those characterised by a short incubation period, are more readily identified than those associated with disease from chronic, low-level exposure to an agent such as a chemical.
- Outbreaks associated with community water systems are more likely to be recognised than those associated with non-community systems because the latter serve mostly non-residential areas and transient populations.
- Outbreaks associated with individual systems are the most likely to be under-reported because they generally involve relatively few people.

The identification of the aetiologic agent of a WBDO is dependent on the timely recognition of the outbreak so that appropriate clinical and environment samples can be obtained. The interests and expertise of investigators and the routine practices of local laboratories can also influence whether the aetiologic agent is identified. Diarrhoeal stool specimens, for example, are generally examined for bacterial pathogens, but not for viruses. In most laboratories, testing for *Cryptosporidium* is carried out only if requested and is not included in routine stool examinations for ova and parasites. The water quality data that are collected vary widely among outbreak investigations, depending on such factors as available fiscal, investigative, and laboratory resources. Furthermore, a few large outbreaks can substantially alter the relative proportion of cases of waterborne disease attributed to a particular agent. Finally, the number of reported cases is generally an approximate figure, and the method and accuracy of the approximation vary among outbreaks.

6.2.2 Waterborne outbreaks between 1995–6

During the two-year period between January 1995 and December 1996, 13 states reported a total of 22 outbreaks associated with drinking water, of which 15 were attributed to infectious agents. A total of 36 outbreaks were attributed to recreational water affecting an estimated 9129 people, including 8449 people in two large outbreaks of cryptosporidiosis. Twenty-two of the recreational water incidents were outbreaks of gastroenteritis.

6.2.2.1 Drinking water

Of the 15, non-chemically-related, drinking-water outbreaks the aetiological agent was identified in 7 cases. The outbreaks are summarised in Table 6.4.

Table 6.4. Waterborne disease outbreaks associated with drinking water, by aetiological agent and water system type.

	Type of water system							
	Community		Non-com.		Individual		Total	
Agent	O	C	O	C	O	C	O	C
AGI	1	18	6	658	1	8	8	684
Giardia lamblia	1	1449	0	0	1	10	2	1459
Shigella sonnei	0	0	2	93	0	0	2	93
SRSV	1	148	0	0	0	0	1	148
P. shigelloides	0	0	1	60	0	0	1	60
E. coli O157:H7	0	0	1	33	0	0	1	33
Total	3	1615	10	844	2	18	15	2477

AGI = acute gastrointestinal illness of unknown aetiology; SRSV = small round structured virus; Non-com. = non-community; O = outbreaks; C = cases.

Both outbreaks of giardiasis were associated with surface water. The small outbreak occurred in Alaska and was caused by untreated surface water, and the second outbreak occurred in New York affecting an estimated 1449 people, and was associated with surface water that was both chlorinated and filtered. A dose–response relation was found between consumption of municipal water and illness. No interruptions in chlorination were identified at the water plant; however, post-filter water turbidity readings exceeded the regulated limit before and during the outbreak.

One outbreak of shigellosis occurred in Idaho and affected 83 people. This outbreak was at a resort supplied by untreated well water, which became contaminated with sewage from a poorly-draining line (CDC 1996). The other outbreak of shigellosis was in Oklahoma and affected 10 people. It was associated with tap water in a convenience store that was supplied by chlorinated well water. Although the factors contributing to contamination of the water were not determined, the water was thought to have been inadequately chlorinated.

The outbreak of E. coli O157:H7 infection occurred at a summer camp in Minnesota that was supplied by chlorinated spring water. Several of the 33 affected persons had stool samples that also were positive for Campylobacter jejuni and Salmonella serotype London. Water samples from the spring and distribution system were positive for coliforms and E. coli. The contamination was attributed to flooding from heavy rains and to an improperly protected spring.

A non-community water system supplying a New York restaurant was responsible for the outbreak of Plesiomonas shigelloides infection. This outbreak affected 60 people and is thought to be the largest outbreak of Plesiomonas infection reported in the US (CDC 1998a). Chlorinated spring water that supplied a kitchen tap in the restaurant had a high coliform count (including E. coli) and the disinfectant residual was zero. The chlorinator was found to be depleted of disinfectant, and cultures of water from the river adjacent to the uncovered reservoir where treated water was stored grew Plesiomonas.

One outbreak in 1995 was thought to have been caused by a Small Round Structure Virus (SRSV). It occurred at a high school in Wisconsin and affected 148 people. The school received its drinking water from a community water supply. Contamination is thought to have occurred from back-siphonage of water through hoses submerged in a flooded football field. The source of the virus was not determined.

Eight of the WBDOs associated with drinking water had no identified aetiologic agent. Of these, three outbreaks were associated with untreated well water, three with inadequate chlorination of unfiltered well water and one with possible short-term cross-connection and back-siphonage problems in the distribution system. The other outbreak was associated with water from an outside tap at a wastewater treatment plant that was not marked as non-potable.

6.3 OUTBREAK MANAGEMENT

Once a potential waterborne outbreak has been identified, the public health authorities have the responsibility of conducting further investigations. The objectives of these investigations are to determine the size and nature of the outbreak and its cause. This is important in order to implement control measures to reduce the number of cases and to ensure that the outbreak does not happen again. A more detailed description of the general approach to outbreak investigation is given elsewhere (Hunter 1997). This chapter presents a brief outline based upon UK procedure.

Even before the outbreak is detected, good outbreak management depends on prior planning. This planning will have identified the agencies that need to be involved and will have obtained agreement with them over their roles. The prior planning will also have led to the setting up of appropriate surveillance systems (as already outlined), without which outbreaks are unlikely to be identified.

Once a possible outbreak is identified, the next step is outbreak confirmation. This is essentially a quick look at possible alternative explanations for the apparent increase in illness, such as laboratory false positives or changes in notification behaviour. Should there be no alternative explanation, an outbreak control team is formed.

The first action of the outbreak control team is to agree an explicit statement of the case definition. This is essential to know whether individual illnesses should be included in the outbreak. Case definitions may include a range of possible onset dates, clinical symptoms, geographical locations and microbiological results. Case definitions can be very broad or very narrow to either include many possible cases or few. The broader the definition, the more cases will be identified, although many of these additional cases may not be related to the main outbreak. Case definitions can and should change as new information becomes available.

Once a case definition has been agreed, case finding is the next step. For case definitions that include a microbiological diagnosis the easiest way of identifying cases is to review microbiology laboratory results. A positive microbiological result will be very specific. However, relying on such results will exclude those patients who have not had microbiological investigation samples taken. It may be necessary to encourage doctors to increase their sampling rate or to report all episodes of particular clinical syndromes. A common alternative is to develop more than one case-definition, one that includes microbiology data and one that relies exclusively on clinical features. These can be called confirmed cases and presumptive cases.

The next stage of the investigation is outbreak description. Outbreak description requires that a basic set of data is collected on every individual who satisfies the case definitions. As a minimum, these data will include name, address, age, sex, date of onset, the results of microbiological examination and sufficient clinical information to prove that the individual satisfies the case definition. It is also usual to record place of work or schooling, a basic food or contact history and any travel history. This type of data may be collected by a trawling questionnaire that asks a series of open questions covering activities during the period before the onset of illness. The results of these early investigations are usually presented in tabular and graphical form.

At this stage it may be possible to develop a hypothesis as to the cause of the outbreak. The hypothesis generated at this point may then indicate possible control measures. One of the more difficult decisions in any outbreak investigation is when control measures should be implemented. For control measures to be effective, they have to be implemented early in the outbreak at a time when the working hypothesis is still far from proven. The damage to a water company's image and financial position may be great if it has to make major changes to its treatment processes or issue a notice for its customers to boil their water. If the outbreak is eventually proven to be due to another cause, this will have been for no purpose.

Once a hypothesis as to the cause of the outbreak has been generated, the next step is to prove it. This may involve further epidemiological investigations such as case-control studies, more microbiological investigations such as typing any isolates or environmental investigations into the treatment plant and its records. If the hypothesis is proven by the further investigations, then more definitive control measures may be put in place to prevent a recurrence.

The final phase in any outbreak investigation is the dissemination of lessons learnt. It is usual for a detailed report to be prepared for local stakeholders. This report may be used by legal staff in possible civil and criminal proceedings. As we have seen earlier, in many outbreaks more general lessons are learnt and these should be published more widely in the medical or scientific literature.

6.4 UNDER-REPORTING

The previous sections have touched upon the problems and reasons for under-reporting. Estimates of the level of under-reporting vary, reflecting differences in surveillance systems and access to medical care as well as true differences in disease incidence. Ford (1999) cites an analysis recently conducted in India, where it was estimated that hospital incidence data from Hyderabad underestimated the incidence of waterborne disease by a factor of approximately 200 (Mohanty 1997). In their study of food-related illness, Mead and colleagues (1999) used adjustment factors ranging from 20 to 38, depending upon the pathogen concerned, to account for under-reporting of gastrointestinal symptoms. Table 6.5 (adapted from WHO (1999)) illustrates the number of waterborne outbreaks in Europe following a survey conducted in 1997. Of the 52 European countries asked for information on waterborne disease outbreaks, 26 returned information and 19 provided information specifically on outbreaks.

Table 6.5 probably sheds considerably more light on the enthusiasm for surveillance and outbreak detection than it does on the actual level of outbreaks. Interestingly, the figures reported for Sweden are considerably lower than those reported in Table 6.1! The survey response in general would seem to suggest that a degree of confusion exists, since in many cases countries reported fewer cases of gastrointestinal disease linked with drinking water than cases of gastrointestinal illness linked with waterborne outbreaks.

Table 6.5. Reported waterborne disease outbreaks associated with drinking and recreational water in 19 European countries, 1986–96 (adapted from WHO 1999)

Country	Agent or disease (no. of outbreaks)	Total no. of outbreaks	No. of cases (with details)
Albania	Amoebic dysentery (5), typhoid fever (5), cholera (4)	14	59 (3)
Croatia	Bacterial dysentery (14), gastroenteritis (6), hepatitis A (4), typhoid (4), cryptosporidiosis (1)	29[1]	1931 (31[1])
Czech Republic	Gastroenteritis (15), bacterial dysentery (2), hepatitis A (1)	18[2]	76 (3)
England & Wales	Cryptosporidiosis (13), gastroenteritis (6), giardiasis (1)	20	2810 (14)
Estonia	Bacterial dysentery (7), hepatitis A (5)	12	1,010 (12)
Germany	No outbreaks reported	0	0
Greece	Bacterial dysentery (1), typhoid (1)	2	16 (1)
Hungary	Bacterial dysentery (17, gastroenteritis (6), salmonellosis (4)	27[3]	4884 (27)
Iceland	Bacterial dysentery (1)	1	10 (1)
Latvia	Hepatitis A (1)	1	863 (1)
Lithuania	No outbreaks reported	0[4]	0
Malta	Gastroenteritis (152), bacterial dysentery (4), hepatitis A (4), giardiasis (1), typhoid (1)	162	19 (6)
Norway	No outbreaks reported	0	0
Romania	Bacterial dysentery (36), gastroenteritis (8), hepatitis A (8), cholera (3), typhoid (1), methaemoglobinaemia (1)	57	745 (1)
Slovak Republic	Bacterial dysentery (30), gastroenteritis (21), hepatitis A (8), typhoid (2)	61	5173 (61)
Slovenia	Gastroenteritis (33), bacterial dysentery (8), hepatitis A (2), amoebic dysentery (1), giardiasis (1)	45	n.a.
Spain	Gastroenteritis (97), bacterial dysentery (47), hepatitis A (28), typhoid (27), giardiasis (7), cryptosporidiosis (1), unspecified (1)	208	n.a.
Sweden	Gastroenteritis (36), campylobacteriosis (8), Norwalk like virus (4), giardiasis (4), cryptosporidiosis (1), amoebic dysentery (1), *Aeromonas* sp. (1)	53[5]	27,074 (47)

[1] Discrepancies in data were noted in different sections of the questionnaire
[2] One year of reporting only
[3] Outbreaks associated with drinking water (n = 12) and recreational water (n = 15)
[4] Ten years of reporting only
[5] In one outbreak *Campylobacter* sp., *Cryptosporidium* sp. and *Giardia lamblia* were identified as aetiologic agents (all three are listed in the relevant column)

Water may play an additional role in disease outbreaks through the use of contaminated water in food irrigation or food processing. Such a route was suspected in an outbreak of shigellosis that affected several countries in North West Europe during 1994. The source of the pathogen was identified as lettuce imported from Spain, and irrigation with contaminated water was strongly suspected (Frost *et al*. 1995; Kapperud *et al*. 1995). In North America outbreaks of cyclosporiasis have been associated with raspberries imported from Guatemala; again wastewater irrigation was noted as a possible source of contamination (CDC 1998b). A case-control study in Fuerteventura during an outbreak of vero cytotoxin-producing *E. coli* O157 showed an association with the consumption of raw vegetables (odds ratio 8.4, 95% CI 1.5–48.2) which were believed to have been washed in water from a contaminated private well (Peasbody *et al*. 1999).

6.5 CONCLUSIONS

A good surveillance system requires strong epidemiological and laboratory inputs as well as consideration of environmental factors. Outbreak investigation will only be as strong as the weakest link and it is not enough to only make the connection between the host and agent. The ability to identify the environmental antecedents of an outbreak will enable a move to be made towards developing relevant interventions.

Outbreaks point to a failure in the public health system. However, they are an important source of information, especially on contributory factors, which are often inadequately used to inform disease prevention measures. Suggested additional surveillance tools include monitoring issuances of boil-water advisories and keeping track of pharmacy dispensing.

Lessons have been learned as a result of outbreak intervention and new regulations introduced. In the US, the outbreak of cryptosporidiosis in Milwaukee, for example, led to more stringent EPA standards for acceptable turbidity values. These have become effective in all states and may have contributed to the fact that no outbreaks of drinking water associated with *Cryptosporidium* were reported in 1995–6.

6.6 IMPLICATIONS FOR INTERNATIONAL GUIDELINES AND NATIONAL REGULATIONS

Surveillance of infectious illness and good outbreak investigation does not give an exposure assessment but it does provide important insights into risk factors and major public health events, and can usefully inform the international guideline-setting process. Additionally, lessons learned from outbreaks and routine monitoring should help to define priority microbiological hazards on a country by country basis and drive the setting of location specific health targets. Such systems are also likely to play an important role in deciding upon appropriate management techniques and testing management interventions. This is important at both international guideline and national standards level.

6.7 ACKNOWLEDGEMENTS

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