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Lessons learned from ten investigations of waterborne gastroenteritis outbreaks, France, 1998–2006

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ABSTRACT

Ten outbreaks of waterborne acute gastroenteritis (AGE) have been investigated in France since 1998. These outbreaks have affected populations of over 1,000 people, with generally high attack rates. The causal agents have been identified in six of these events. Aetiologies involved mainly noroviruses and *Cryptosporidium* sp. The point of entry of the contamination was located in the distribution network in five outbreaks (waste water backflows in four cases and one case of contamination induced by maintenance work) and at the water collection facilities in five other cases. Once the outbreak was detected, epidemiological and environmental investigations and crisis management followed well-established procedures. Further progress in public health surveillance will depend on more complete and rapid detection and reporting. Automated analysis of health insurance data on the reimbursement of drugs for AGE should help make detection more complete. Improved reactivity depends primarily on the operator immediately reporting incidents that indicate a possible massive contamination of the water network to health authorities – in particular complaints from the population, which are the only early-warning alerts in the case of waste water backflows.

Key words | *Campylobacter*, *Cryptosporidium*, France, norovirus, rotavirus, waterborne outbreaks

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ABBREVIATIONS

AGE	acute gastroenteritis
AR	attack rate
CIRE	Cellule Inter-Régionale d'Epidémiologie (Regional Offices of the InVS)
DDASS	Direction Départementale des Affaires Sanitaires et Sociales (local branches of the French Ministry of Health)
GP	general practitioner
InVS	Institut de Veille Sanitaire (French Institute for Public Health Surveillance)
RR	relative risk

INTRODUCTION

Waterborne infectious diseases are a major public health problem in developing countries (Huttly 1990), but events that occurred in Milwaukee, Wisconsin (MacKenzie *et al.* 1994), and Walkerton, Ontario (Hrudey *et al.* 2003), show that waterborne outbreaks can also take place in developed countries and may have a major impact on public health. Estimating the burden of waterborne disease outbreaks is difficult, however, since many go undetected.

At the local level, investigating disease outbreaks is crucial for the implementation of appropriate control measures and prevention of further outbreaks. At the national level, monitoring outbreaks and accidental contamination of drinking water distribution systems, and particularly their causes, makes it possible to prioritize preventive actions and to create better conditions for detecting and investigating outbreaks.

In France, 101 local branches (DDASSs) of the Ministry of Health are responsible for the public health management of outbreaks. Investigations may be led by both the DDASSs

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and the French Institute for Public Health Surveillance (InVS), particularly its regional offices (CIREs).

This paper summarizes the main characteristics of the outbreaks studied in France between 1998 and 2006. The evidence of waterborne transmission, the lack of completeness in detection and delays in reporting are then discussed in order to identify ways to improve detection and investigation.

METHODS

We analysed all available documents concerning waterborne outbreaks investigated between 1998 and 2006: scientific and technical papers (Deshayes & Schmitt 2001; Guyonnet & Claudet 2002; Tillaut *et al.* 2004), published reports (see Appendix) and internal reports of InVS. Available information on earlier outbreaks was too limited to be included. The selection of the different outbreaks examined was based on the level of evidence linking them with drinking water. Several systems based on epidemiological, environmental and microbiological criteria have been proposed for assessing the causal role of water in a disease outbreak (Tillett *et al.* 1998; Blackburn *et al.* 2004). We opted for the system proposed by (Blackburn *et al.* 2004) and used by the Center for Disease Control in the USA (Table 1). Only class I, II or III outbreaks are included in this analysis. For each outbreak we reviewed the investigation procedures: (i) epidemiological investigations; (ii) environmental investigations focusing on the causal factors of the outbreak (environmental, technical or human); and (iii) microbiological analyses of the clinical specimens (principally faeces) and water samples. These investigations yielded information regarding the population exposed, the epidemiological characteristics of the outbreak (period, area and population affected), the causes of contamination, the aetiologic agents, as well as the way the outbreak was reported and the health management actions that followed.

Table 1 | Classification of investigations of waterborne outbreaks according to the strength of the evidence implicating water (from Blackburn *et al.* 2004)

Class	Epidemiologic data	Water-quality data
I	Adequate*	Adequate†
II	Adequate*	Not provided or inadequate
III	Limited‡	Adequate‡
IV	Limited	Not provided or inadequate

*Data provided about exposed vs. non-exposed people (relative risk or odds ratio ≥ 2 or p ≤ 0.05).
†Data provided that did not meet the criterion* or data not provided but ill people without exposures in common besides water.
‡Water processing data adequate (e.g. chlorination failure or mains break) or water microbiology data adequate (e.g. *E. coli* in the water).

RESULTS

Outbreak selection

Since the creation of the InVS in 1998, ten outbreaks of waterborne acute gastroenteritis (AGE) have been investigated in France between 2000 and 2006, of which nine were jointly studied by the DDASSs, CIRESs and InVS (Table 2). No outbreak involving other syndromes (such as hepatitis A or toxoplasmosis) was detected. The definition of AGE may vary slightly between the different outbreaks. A simplified version of the US Foodnet definition (Roy *et al.* 2006) was used in the analytical studies: 'Diarrheal illness (three or more loose stools in a 24-hour period) and/or vomiting'. For the descriptive studies based on the general practitioners' (GPs') questioning (Table 2), either the simplified Foodnet definition was used or the diagnosis of AGE was made by the GP without fixed criteria.

The InVS operates a mandatory reporting-based surveillance system for food borne outbreaks, which includes outbreaks due to contaminated water. Over the period 1996–2005, 5,847 food borne outbreaks were reported, but only 33 were suspected to be linked to tap water (Delmas *et al.* 2006). Out of the ten selected outbreaks, only two were pinpointed by this system. The others were classified as category IV following the Blackburn *et al.* (2004) classification. Seven of the ten outbreaks included in the study display the highest level of likelihood of waterborne transmission according to Blackburn's classification, whereas three meet the class III conditions. In the other three outbreaks, the epidemiological investigations were limited and their waterborne nature, although highly probable, could not be proven formally. We excluded from this study an outbreak of viral infections (rotavirus, norovirus) that took place at the winter sports resort of Serre Chevalier (Hautes-Alpes) in January 2002. Waterborne transmission was initially suspected on the basis of recurrent faecal

Table 2 | Waterborne AGE outbreaks investigated in France, 1998–2006

Outbreak (town, county number)	Date	Source	Treatment	Point of entry of the contamination	Circumstances/causes	Pathogen	Water microbiology (a)	Number of exposed people	Epidemiologic survey design
Sète (34)	Sept 1998	Karstic spring	Disinfection (Cl biox)	Resource	Surface runoff water backflowing into a karstic outlet	*Cryptosporidium* sp.	$F+P_{NS}$	25,000	DS+case-control
Strasbourg (67)	May 2000	Borehole in alluvial aquifer	Disinfection (Cl)	Network	Main repair	Not searched	$F+P_{NS}$	60,000	DS+case-control
Gourdon (46)	Aug 2000	Borehole in karst	Disinfection (Cl)	Resource	Polluted river water entering the karstic aquifer + chlorination failure	Rotavirus + *Campylobacter coli*	F+P++ (rota)	4,900 inhabitants +2,200 tourists	DS+retrospective cohort
Dracy-le-Fort (71)	Sept 2001	Borehole in alluvial aquifer	Disinfection (Cl)	Network	Cross-connection with WWTP effluent network + backflow	*Cryptosporidium hominis*	F+P++	1,100	DS+retrospective cohort
Apprieu et 3 communes voisines (38)	Nov 2002	Borehole in alluvial aquifer	Disinfection (Cl)	Resource	Heavy rains resulting in flooding of the borehole and overflow of the WWTP located upstream of the borehole	Norovirus I & II	F+P++ (rota II)	5,600	DS+retrospective cohort
Divonne-les-Bains (01)	Aug 2003	Karstic springs + borehole in an urban area	Filtration (borehole) + disinfection (Cl)	Network	Cross-connection with WWTP effluent network + backflow	*Cryptosporidium parvum* and *hominis*	F+P++	2,500	DS
Vesoul (70)	Sept 2003	Borehole in karst + alluvial aquifer	Filtration + disinfection (Cl biox)	Network	Cross-connection with industrial network containing contaminated river water + backflow	*Cryptosporidium* sp. + *Campylobacter jejuni*	$F+P_{NS}$	2,000 to 35,000	DS
Pont de Roide (25)	Feb 2004	Well in alluvial aquifer	Disinfection (Cl biox)	Network	Cross-connection with WWTP effluent network + backflow	Norovirus	$F+P_{NS}$	4,800	DS
Arc 1800 (73)	Feb 2006	Three mountain springs	Disinfection (Cl)	Resource	Septic tank emptying or contaminated artificial snow spreading in the catchment area + chlorination failure?	Norovirus I	F+P +	6,100 inhabitants +18,000 tourists	DS
Pulligny (54)	Apr 2006	Three sources: river + alluvial aquifer + karst	Bank filtration (river) + disinfection (Cl)	Resource (river)	Filtration sand replenishment works + chlorination failure	Not found	$F+P_{neg}$	9,500	DS

Table 2 | (*continued*)

Outbreak	Number of cases included in the study	Total number of cases (estimate)	Number of hospitalized cases	Number of deaths	Attack rate	Relative risk or odds ratio (b)	Interval start and peak of outbreak (days)	Interval start of outbreak and alert (days)	First signal (c)	Strength of the evidence implicating water (d)	Reference (e)
Sète (34)	92 children < 11 years	> 150 children	> 10 children	0	13% (children)	d/nd 20	1	1	Routine analysis	I	Guyonnet & Claudet (2002)
Strasbourg (67)	53	?	0	0	Low	d/b 2	0	0	*Routine analysis* + increase in AGE in hospital emergency department	I	Deshayes & Schmitt (2001)
Gourdon (46)	1,037	2,600	6	0	37%	d/nd 3.2 d/b 10	10	11	Cluster of AGE cases, GP	I	
Dracy-le-Fort (71)	364	560	0	0	51%	d/nd 2.0 d/b 24	5	5	Cluster of AGE cases, GP	I	
Apprieu (38)	98	2,000	3	0	41%	d/nd 4.6 i/o 20	1	2	Cluster of AGE cases, private person	I	Tillaut *et al.* (2004)
Divonne-les-Bains (01)	387	1,040	2	0	42%	d/b 4	7	9	Customer complaints, water operator	I	
Vesoul (70)	162	200	8	0	5%	NA	2	0	Routine analysis	III	–
Pont de Roide (25)	444	1,000	3	0	20%	o/e 40	1	1	School absenteeism, mayor	III	–
Arc 1800 (73)	114	> 1,000	3	0	High (tourists)	NA	2	2	Analysis, water operator	III	–
Pulligny (54)	231	1,000	0	0	10%	i/o 9	9	18	Routine analysis	I	

(a) F + : sample positive for faecal contamination indicators (*E. coli* or Enterococci); P_{NS}: pathogens not searched; P_{neg}: no pathogen identified; P + : pathogens identified in stool specimens; P++: pathogens in stool indistinguishable from pathogens in water by molecular biology.

(b) d/nd: tap water drinker vs. non drinker; d/b: during vs. before the outbreak; i/o: inside vs. outside the outbreak area; o/e: observed vs. expected according to GP national surveillance (Boussard *et al.* 1996).

(c) If two signals are mentioned, they are given in the order of occurrence and the one which resulted in the alert is underscored.

(d) See Table 1.

(e) See also Appendix.

Abbreviations: Cl, chlorine; Cl biox, chlorine bioxid; DS, descriptive study; GP, general practitioner; NA, non available; WWTP, waste water treatment plant.

contamination of the supply network. However, the epidemiological investigations showed that practically all cases were secondary cases, contracted through contact with other infected people or through a contaminated environment (nursery), and there was no epidemiological evidence supporting a causal link with water.

Type of investigations carried out

Environmental investigations were systematically carried out. Faecal samples were analysed in nine outbreaks. Water samples were analysed for specific pathogens in six outbreaks.

Five analytical epidemiological surveys were conducted between 1998 and 2002: two case-control studies for low attack rate (AR) outbreaks in which the role of water was still unproven and three retrospective cohort studies in the case of high AR outbreaks with a previously established water link. Descriptive studies were always carried out, generally based on information collected from doctors and pharmacists. Comparing the incidence between the contaminated area and a control area provided further indications of the role of tap water in the disease outbreaks.

Exposed population and magnitude of the outbreak

The size of the exposed populations (Table 2) ranged from 1,100 (Dracy-le-Fort) to 60,000 (Strasbourg). The estimated number of AGE cases varied between 200 (Vesoul) and 2,600 (Gourdon). The total number of cases reached at least 9,000, of which about 70 were hospitalized. No fatal cases were recorded. Where age-specific data were available, the highest incidence was observed in children under five years old. At no time did we note a gender-related difference in the incidence rate.

The AR ranged from 5% in Vesoul to 51% in Dracy-le-Fort. The highest rates ($> 40\%$) were observed in outbreaks triggered by waste water backflows.

The relative risk (RR) of AGE associated with exposure to contaminated water ranged from minimum values of 2 (Strasbourg) and 4 (Divonne-les-Bains) to maximum values of around 20 (Dracy-le-Fort, Apprieu).

Six of the investigated outbreaks spread rapidly with a maximum delay of 2 days between the first cases of AGE and the epidemic peak. For four other outbreaks, the dynamic was slower with a delay ranging from 5 to 10 days. The duration of the ascending phase of the outbreak depended on several factors, some of which were well documented (pathogenic agent, point of entry of the contamination, see Table 2) and others less so (distribution of the pathogen concentrations during the exposure period).

The contamination at the origin of the outbreaks

Nine of the ten outbreaks occurred in areas supplied with treated ground water, and one (Pulligny) with treated river water. In seven water systems, the treatment was limited to disinfection. In three water systems, water was filtered in addition to disinfection. In five outbreaks the contamination entered the water supply distribution network itself, whereas in the other five outbreaks the treatment capacities did not cope with the raw water contamination. Among the latter, one source was river water and four were highly vulnerable aquifers: two karstic aquifers, one small mountain aquifer and one alluvial aquifer known for its poor protection. In two outbreaks, heavy rains resulted in surface runoff that contaminated the source. In the Apprieu area, rain caused a waste water treatment facility to overflow into the river as well as the submersion of the borehole located downstream in the alluvial aquifer. The contamination persisted in the tap water, indicating the absence or failure of adequate water treatment. In one outbreak water was not treated at all, and in the other four outbreaks the treatment was limited to a simple chlorination, which is inadequate against parasites and viruses at the chlorination levels used in France. In two outbreaks the disinfection mechanism had broken down, one such outbreak allowing further exposure of supplied people to pathogenic bacteria (Gourdon).

Considering the five cases of contamination that occurred within the distribution network, four were due to waste water backflows and the fifth (Strasbourg) was the consequence of maintenance work on a water pipe. Backflows were caused by the joint occurrence of: (i) illegal and unprotected connections between a 'soiled' water network and a drinking water network (in three outbreaks, lack of a backflow preventer on the connecting pipe, and in one instance an non-functioning appliance); and (ii) inappropriate operations resulting in excessive pressure in the soiled water network. In three cases, the soiled water was urban waste water treatment plant effluent.

Aetiology and water microbiology

Faecal specimens were analysed in nine outbreaks. A single causal agent was found in six of these (noroviruses in three outbreaks and *Cryptosporidium* in the other three cases), while two outbreaks involved two agents (*Cryptosporidium* + *Campylobacter* and *Campylobacter* + rotavirus).

Faecal contamination of the tap water was evidenced in all nine outbreaks, with indicator bacteria *Escherichia coli* (*E. coli*) or enterococci identified in samples taken shortly before or during the outbreak. In six outbreaks water samples were examined for specific pathogens. In five outbreaks, the causal agent identified in the faecal samples was also found in the water samples. In four outbreaks, the strains identified in faecal and water samples were typed and compared using molecular biology and were found to be indistinguishable.

Initial signals, reporters and reporting times

Four investigations were launched following a reported cluster of AGE cases and six following an environmental signal.

The clusters were reported to the DDASS by GPs in two outbreaks (Gourdon and Dracy-le-Fort), by an individual end-user in Apprieu, and by the town mayor in Pont-de-Roide. The GPs had identified the clusters of cases, respectively, in a geriatric health facility (Gourdon) and in a hotel (Dracy-le-Fort) and notified these clusters as suspected food borne outbreaks which are mandatorily notifiable. No outbreak was reported by GPs on the grounds of an excess of clinical cases observed in the community. In Pont-de-Roide, the outbreak was revealed by school absenteeism, which prompted the mayor to notify the authorities. In the Strasbourg outbreak the AR was low but the number of cases peaked during the weekend. This concentrated those seeking medical care in the hospital emergency department, which facilitated the outbreak detection by emergency medical staff.

Environmental signals included unusual water source pollution events due to accidents or adverse weather conditions which exceeded water treatment capacities, water processing failures, substandard bacteriological analyses of tap water, and consumer complaints of bad taste, smell or colour suggesting an organic pollution. In five outbreaks, investigations were launched because of the substandard results from regulatory water quality monitoring by the health authorities (four outbreaks) and by the water company (one outbreak, Arc 1800). In the case of Divonne-les-Bains, the water supply operator informed the DDASS following the accumulation of various signals: complaints by consumers, substandard analyses and AGE cases over the previous week.

Considering all ten outbreaks, reporting took place on average 5 days after the beginning of the outbreak. The delay was shorter when the signal that motivated the official alert was environmental (average delay 1 day after the onset of the outbreak) rather than medical (8 days). In four out of five outbreaks, the reporting of an excess of AGE cases coincided with the peak of the outbreak or the following day. In the extreme case of Pulligny, the outbreak was detected 9 days after its peak. Even though environmental signals were reported earlier than public health signals, alert-inducing environmental reports tended to coincide with the epidemic peak (3/5), or at best with the beginning of the outbreak (2/5). These delays were due to the nature of the signal; that is, substandard bacteriological water analyses, the results of which are obtained by culture after a 2-day incubation period.

Control measures

In all cases, the health authority officer took steps to restrict tap water consumption on the day the signal was reported, but the water supply was never cut off. In two instances, the water supply operator, on his own initiative, issued a public announcement informing the population that the water was safe (Divonne-les-Bains, on the day before the epidemic peaked) or that the restrictions had been lifted, in contradiction to the information issued by the health authorities (Arc 1800).

The emergency steps taken to clean the water network involved chlorine shocks and flushing of the pipes. A complete purge was necessary in the case of contamination by *Cryptosporidium*, on which chlorine is inactive. This operation was particularly lengthy and delicate in Dracy-le-Fort because of the complexity of the water distribution system there: a meshed network alternatively gravity-fed by several reservoirs located at the periphery of the network and pump-fed from the treatment plant.

The actual steps taken to prevent recurrences are not precisely known, since they were implemented after publication of the investigation reports. Of ten documented AGE outbreaks, additional treatments (UV disinfection) were imposed on the operator in the case of two cryptosporidiosis outbreaks, even though one of them did not involve contamination of the source (Divonne-les-Bains). Physical protection of the borehole from flooding was advised in the case of Apprieu, and a river banking project is currently being considered.

DISCUSSION

Comparison of outbreak descriptive data

Comparability of impacts and risks

Comparing impacts expressed as total number of cases or AR is difficult since the case definitions may differ according to clinical characteristics and to the investigator's territorial and temporal delimitation of the outbreak. Epidemiological investigations conducted in France usually restrict public health impact assessment to the enumeration of AGE cases that seek treatment, which underestimates the number of symptomatic cases. In the three outbreaks for which population surveys were carried out 52% (Gourdon), 54% (Dracy-le-Fort) and 30% (Apprieu) of the sick consulted a doctor. The proportion of people seeking medical care is known to vary according to the severity of the illness, that is, according to the pathogen and physical state of the infected person, but also according to social factors such as level of education (Tam *et al.* 2003). This complicates any attempt to deduct the actual number of symptomatic cases from the number of cases that seek medical care.

Estimating the incidence of AGE also depends on the geographical delimitation of the exposed population when defining cases. The AR may be artificially lowered if the presumed area of exposure exceeds the area actually supplied with contaminated water. In the case of contamination by back siphonage the fraction of the supplied population exposed to the contaminated water often remains unknown. This probably explains the low AR (5%) estimated for the Vesoul outbreak; a large area was considered to have been exposed whereas the contamination probably occurred only in a small part of this area. The temporal delimitation of an outbreak is determined by comparing the incidence rate during the outbreak with baseline data from non-epidemic situations. Since there are no fixed criteria (Craun *et al.* 2006), the beginning and end of an outbreak may be estimated differently, in particular the latter, which for some pathogens can be obscured by cases with a long incubation period or secondary cases.

The estimation of the RR associated with exposure to drinking water not only depends on the way cases are defined but also requires the risk to be defined for exposed and non-exposed persons. Four options coexist in the investigations considered: (i) the risk observed in persons who say they do not drink tap water (cohort studies); (ii) the risk observed in control areas at the time of the outbreak; (iii) the risk observed in the exposed area before the outbreak; or (iv) the expected risk estimated from data sources such as the GPs' sentinel surveillance network (Boussard *et al.* 1996). Method (iv) introduces a substantial uncertainty regarding the estimation of the RR, due to the natural variability of the incidence rate in endemic situations. Definition (i) cannot give results comparable to those derived from definitions (ii) and (iii) since exposure is defined differently (drinking tap water as against residence in the contaminated area). Definition (i) moreover introduces classification errors due to the existence of unrecognized exposures to tap water that tend to result in an underestimation of RR. In Dracy-le-Fort, for example, given the contamination level of the tap water with *Cryptosporidium* (estimated at around 1,000 infectious oocysts per litre), using water to wash vegetables or brush teeth could have been infective, but was not classified in exposure.

International comparison

The comparison and interpretation of results from different countries is impeded by differences in outbreak definitions, epidemiological and microbiological investigation procedures and time frames used for recording data. Reviews of waterborne outbreaks (enteric pathogens) have been published for the United States (Kramer *et al.* 1996; Levy *et al.* 1998; Barwick *et al.* 2000; Lee *et al.* 2002; Blackburn *et al.* 2004), England and Wales (E&W) (Smith *et al.* 2006) and Canada (Schuster *et al.* 2005). In Canada, the inclusion criteria and study period differ too much from our own data to allow valid comparisons to be made. The paper on England and Wales is essentially focused on the pathogens involved in the outbreaks, whereas those concerning the United States also look into environmental and technology-related determinants.

Using available data for the period 1998–2006, the average incidence rates of investigated waterborne outbreaks were 10.1 per year for the USA, 4.5 for E&W and 1.1 in France. This represented 3.4×10^{-3}, 8.6×10^{-3} and 1.9×10^{-3} outbreaks per year and per 10^5 inhabitants, respectively, and an incidence rate of waterborne outbreak related AGE cases of 13.8 (0.24 if the Milwaukee outbreak is excluded), 1.04 and 0.18 per 10^5 inhabitants, respectively.

The pathogens involved in the various outbreaks are detailed in Table 3. Methods of analysis for the main viruses responsible for waterborne outbreaks are too recently developed to make comparisons with earlier years and allow conclusions to be drawn about the relative importance of causal agents of waterborne outbreaks over time. Data from the USA concerning the years 1999–2002 indicate that noroviruses represent 18% of the causal agents. These data are probably more reliable than estimates from earlier years but the proportion of viral aetiology in waterborne outbreaks, especially norovirus, is probably still underestimated.

In E&W, bacteria can represent up to 60% of aetiologies in private facilities as against only 4% in public ones (Smith *et al.* 2006). Such a discrepancy is most likely explained by the absence or failure of disinfection in private facilities. In properly equipped and operated water treatment systems, parasites emerge as the dominant aetiology. *Giardia* is found more often in North America than in Europe.

The frequency distribution of outbreaks according to the point of entry of the contamination in the drinking water system does not differ significantly in the USA and France. French data are, however, too scarce to ascertain whether the rise in the proportion of network-originating contaminations documented in the USA (Craun *et al.* 2006) also occurs in France.

Table 3 | Aetiologic pathogens in waterborne outbreaks in the USA (Kramer *et al.* 1996; Levy *et al.* 1998; Barwick *et al.* 2000; Lee *et al.* 2002; Blackburn *et al.* 2004) and in England and Wales (Smith *et al.* 2006)

	USA (1993–2002)		**England & Wales (1992–2002)**	
	Number of outbreaks	**Aetiology frequency (%)**	**Number of outbreaks**	**Aetiology frequency (%)**
Hepatitis A virus	0	0	0	0
Calicivirus	10	10	0	0
Rotavirus	0	0	0	0
Adenovirus, astrovirus	0	0	1	2
Enterovirus	0	0	0	0
Total viral agents	**10**	**10**	**1**	**2**
Cryptosporidium	9	9	28	57
Giardia	13	13	1	2
Total protozoan agents	**22**	**22**	**29**	**59**
Campylobacter	7	7	13	27
Salmonella non typhi	3	3	0	0
Shigella	5	5	0	0
Yersinia	1	1	0	0
E. coli shigatoxin producing (STEC)	10	10	3	6
Vibrio non cholerae	1	1	0	0
Total bacterial agents	**27**	**27**	**16**	**33**
Unknown aetiology	42	42	3	6
Total	**101**	**100**	**49**	**100**

Public health perspectives

The true impact of outbreaks in France

Developed countries recognize the incompleteness of their surveillance and detection systems for waterborne diseases and their inability to propose an estimate of the overall impact based on the data obtained (Craun *et al.* 2006). However, some indications can be given as to the proportion of outbreaks that have been avoided in France through prevention and the residual proportion of the risk that cannot be easily avoided.

The ten events documented are not representative of the outbreaks that occur in France. They involved medium-sized distribution networks (supplying over 1,000 end-users) whereas incidences of accidental microbiological contamination of distribution networks recorded through regulatory drinking water monitoring mostly affect very small distribution units (Table 4). The discrepancy between the high frequency of microbiological contaminations and the absence of outbreaks recorded in small distribution networks stems from the difficulty of detecting small-scale outbreaks. In contrast to the French situation, there is in the USA as in England and Wales a real capacity to detect, investigate and report on outbreaks linked to small-scale distribution systems, even at the individual home level (Kramer *et al.* 1996; Levy *et al.* 1998; Barwick *et al.* 2000; Lee *et al.* 2002; Blackburn *et al.* 2004).

On the other hand, nothing is known of the outbreaks that have been avoided through prevention. The analysis of drinking water contamination data in France between 1991 and 1994 (Appendix, Ref. 9) shows that backflows were involved in 20% of pollution events and 50% of outbreaks. This difference suggests that contamination affecting the source – and therefore leaving some time for prevention – is less likely to result in outbreak than contamination arising within the network. This observation justifies the role of preventive actions by the operators and DDASSs.

In order to prevent outbreaks caused by contamination of the source, DDASSs' approach is to promote the setting up of an alarm system or even automatic water pumping shut-down devices governed by turbidity and free chlorine sensors. Less frequently, operators are invited by DDASSs to install an alarm on the chlorine demand, which surges in reaction to an abnormal presence of organic matter.

Suppressing connections between drinking water networks and networks containing effluent from waste water treatment plants is the first priority for DDASS action to prevent backflow-related outbreaks.

Table 4 | Distribution of waterborne AGE outbreaks and accidental faecal contamination of drinking water according to distribution network size, 2004–2005 (from Sise-eaux database, Ministry of Health)

	Distribution network size (number of supplied people)					
	0–100	**100–500**	**500–2,000**	**2,000–10,000**	**≥ 10, 000**	**Total**
Number of water systems	8,228	7,487	5,636	3,839	985	26,175
Total supplied population (millions)	0.3	1.9	5.9	16.5	36.1	
Number (n) of occurrences of accidental faecal contamination of drinking water*	903	489	145	73	20	1,630
Regulatory average yearly number of samples (f)	5	6	8	17	30	
Estimated number (N) of occurrences of accidental faecal contamination of drinking water†	65,919	29,748	6,616	1,567	243	104,093
Distribution of accidental faecal contaminations	63.3%	28.6%	6.4%	1.5%	0.2%	100.0%
Number of investigated outbreaks	0	0	1	5	4	10
Distribution of investigated outbreaks	0.0%	0.0%	10%	50%	40%	100.0%

*An accidental faecal pollution of drinking water is said to occur when the sum of *E. coli* and enterococci counts (CFU $100ml^{-1}$) from samples collected one day at one distribution unit exceeds a threshold of 50.

†The number (N) of accidental faecal contaminations of drinking water is estimated as the observed number (n_{fc}) of accidental faecal contaminations of drinking water divided by the frequency ($n_{sd}/365$) of sampling days within the year: $N = n_{fc}/(n_{sd}/365)$. The duration of the drinking water contamination is assumed to be one day.

Towards more sensitive surveillance and more reactive detection

With the possible exception of the Pont-de-Roide outbreak, which coincided with the winter outbreak of viral AGE, it is unlikely that outbreaks with high AR (>20%) have passed unnoticed by GPs. However, only two of the six high AR outbreaks were notified by doctors. A third outbreak (Divonne-les-Bains) was reported by a GP to the municipal authorities rather than to DDASS, which delayed the investigation.

Since a capture–recapture study (Gallay *et al.* 2000) showed that fewer than 21% of the AGE cases due to food borne outbreaks (including waterborne outbreaks) are reported to health authorities, it can be assumed that the sensitivity of the GP reporting-based surveillance for waterborne outbreaks does not exceed this level. An outbreak detection method based on real time on-line analysis of drug reimbursement data from the national health insurance system may in the future help to improve the detection of outbreaks and the sensitivity of surveillance (Appendix, Ref. 7). The sensitivity of a drug reimbursement-based surveillance for the clinical AGE case collection should be rather high in France since the following conditions are met: (i) a high proportion of AGE cases consult their GP (the rates range from 30 to 54% according to the aetiology and social factors); (ii) French GPs almost systematically prescribe drugs to AGE cases; (iii) the combinations of drugs prescribed for AGE are sufficiently specific (specificity estimated to 86%) to identify AGE cases (Beaudeau *et al.* 2006); and (iv) most importantly, 99% of the population living in France are covered by the national social security system and reimbursement data are centralized in one data base. Despite the different factors lowering its sensitivity, the overall sensitivity of this system remains better (24–43%) than reporting by GP, whereas its specificity is almost as good. A statistical power study which took into account both the overall sensitivity of the system and the imperfect mapping of the district areas (the smallest space unit for drug reimbursement data availability) by the drinking water service areas, has shown that this mechanism will be unable to pinpoint outbreaks occurring on distribution networks supplying less than 500 end-users and outbreaks associated with a RR related to living within the exposed area of less than about 10. Nonetheless this limit concerns no more than 2.2% of the French population (Appendix, Ref. 8). Taking into account the minimum processing time of 3 working days needed by the national health insurance to handle medical care data, this mechanism may enable the authorities to take action and prevent additional infections in the case of slowly developing outbreaks. Four out of ten outbreaks belonged to this category, since it took between 5 and 10 days from the start of the outbreak to the peak. Another limit of the drug reimbursement data-based surveillance is the long-term constancy which may be challenged by possible changes in drug reimbursement policies. As suggested by the lack of published work, it is not likely that usage of AGE-related drug consumption data is relevant for countries other than France, because consultation and drug prescription rates for AGE may be lower, and in many countries such a social security system covering a large majority of the population and centralizing reimbursement data in a short period of time, does not exist.

Along the spectrum of possible environmental signals (e.g. accidental pollution, treatment failure, substandard analysis, consumers' complaints), only the results of regulatory water quality monitoring triggered official alerts. However, the frequency of these analyses is low, except in the case of very large distribution networks. According to the French Public Health Code, eight analyses per year are required for networks supplying between 500 and 2,000 people, as against 174 or more for networks supplying 100,000 people and over. It is therefore not surprising that only one outbreak (Pulligny) was preceded by the detection of faecal pollution by regulatory monitoring.

The under use of other environmental signals is another reason for the failure to detect all outbreaks. Respective risks related to contamination of raw water, to treatment failures or to operating accidents are difficult to assess in the absence of detailed context-specific knowledge. For instance, the assessment of the risk related to the bursting of a main has to take into account both the soil water saturation and the distance to the next sewer line (LeChevallier *et al.* 2003). Also, chlorination failures result in a risk the level of which depends upon the microbial contamination of raw water often related to weather conditions and upon the presence and functioning of other treatment processes such as filtration or re-chlorination at tanks. The reporting of operation incidents to DDASSs is currently under debate in order to find a balance between the public health advantage and the burden of false alarms. Things are very different in the case of complaints from water end-users. Numerous complaints mentioning an odour of sewage are suggestive of waste water backflows and must be reported without delay to the health authority, which is the only body qualified to order environmental and epidemiologic investigations. The public health issue at stake is important because (i) the microbiological contamination induced by waste water backflows is very high and gives rise to obvious public health risks; (ii) such events are often listed among causes of AGE outbreaks (4/10); (iii) they coincide with consumer complaints to the local town hall; and (iv) there is no other early environmental warning of an imminent outbreak.

CONCLUSION

Whereas waterborne disease outbreaks have been better detected and investigated from 1998, further efforts are needed to achieve faster and more comprehensive reporting.

The systematic use of the drug-reimbursement database should facilitate the assessment of impacts on health, limited to the number of care-seeking AGE cases and, ultimately, the detection of outbreaks. However, this being a medical signal, detection will still be posterior to the emergence of disease.

The most promising source of improvement as regards reactivity – in order to halt exposure and prevent the development of the outbreak or limit the number of cases – is to pay more attention to environmental signals, in particular complaints from the population suggesting tap water contamination.

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APPENDIX | French outbreak reports and drinking water assessment reports quoted in the text. English summaries are included in the reports

Ref.	Title	Authors, date	Organisation	Website
1	Surveillance et investigation d'épidémies de gastroentérites aiguës survenues dans un centre de vacances de Serre Chevalier de 2001 à 2005	Armengaud, A., 2006	Cire Sud & InVS, Marseille	InVS*
2	Investigation d'une épidémie de gastro-entérites aiguës sur la zone de Pulligny (Meurthe-et-Moselle)	Diulius, D. & Mantey, K. 2006	Drass Lorraine, Ddass de Meurthe-et-Moselle, Cire Est & InVS, Saint-Maurice	InVS*
3	Epidémie de gastroentérites en Isère, novembre 2002.	Tillaut, H., Encrenaz, N., Checlair, E., Gomez do Spirito Santo, E. & Beaudeau, P. 2004	Drass Rhône-Alpes & InVS, Saint-Maurice	InVS*
4	Epidémie de gastro-entérite liée à la pollution du réseau de distribution d'eau potable de la commune de Divonne-les-Bains, Ain, août-septembre 2003	Gofti-Laroche, L. & Schmitt, M. 2003	Cire Rhône-Alpe, Drass Rhône-Alpes & InVS, Lyon	InVS*
5	Epidémie de gastro-entérites à Cryptospridium, Dracy-le-Fort, Saône et Loire, Septembre 2001.	Di Palma, M., Carbonel, S., Beaudeau, P., Checlair, E. & Gallay, A. 2003	Drass Bourgogne, Cire Centre-Est & InVS, Saint-Maurice	InVS*
6	Epidémie de gastro-entérites à germes multiples liées à la consommation de l'eau de distribution. Gourdon, Lot (46). Août-septembre 2000	Cournot, M., Hemery, C. & Gallay, A. 2001	Drass Midi-Pyrénées, Cire Sud-Ouest & InVS, Saint-Maurice	InVS*
7	Détection précoce automatisée des épidémies de gastro-entérites d'origine hydrique à partir des données de vente ou de remboursement des médicaments. Etude de faisabilité: choix des données sanitaires et des départements pilotes	Beaudeau, P., Mouly, D. & Lauzeille, D. 2006	InVS, Saint-Maurice	InVS*
8	L'eau potable en France, 2002–2004	Anon. 2006	Ministère de la Santé et des Solidarités, Paris	Min†
9	Pollutions accidentelles des eaux d'alimentation en France	Nedellec, V., Jouan, M., Ledrans, M. & Tricard, D. 1996	Réseau National de Santé Publique & Ministère du Travail et des Affaires Sociales, Saint-Maurice	–

*InVS: www.invs.sante.fr/
†Min: Official website of the Ministry in charge of Health, www.sante.gouv.fr/