

Outbreak of acute gastroenteritis due to a washwater-contaminated water supply, Switzerland, 2008

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ABSTRACT

An operating error in a sewage treatment plant led to severe drinking water contamination in a well-defined district of a suburban municipality of Zurich, Switzerland. Despite the alert issued to the local population on the same day advising people not to consume the contaminated water, cases of acute gastroenteric diseases were subsequently observed. Considerable faecal contamination was detected the day after the incident in water samples taken up to 500 m from the sewage plant. In a retrospective epidemiological study involving 240 persons living in the affected area, 126 cases of acute gastrointestinal illness were documented. The epidemic curve revealed a peak incidence two days after the event. Stool samples from 11 of 20 patients were positive for noroviruses or *Campylobacter jejuni*. Although these microorganisms were not detected in the contaminated water, the subsequently conducted case-control study among the surveyed population showed that consumption of contaminated drinking water was associated with gastrointestinal illness (odds ratio 29.1; 95% confidence interval: 9.8–86.4; $p = 0.001$). The study also revealed the very probable time period of infection. We present the dimension and chronology of this outbreak and discuss the reasons for its localised and temporary spread.

Key words | drinking water contamination, gastroenteritis, operating error, outbreak, sewage plant

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INTRODUCTION

Outbreaks of waterborne disease are rare in industrialised countries (MacKenzie *et al.* 1994; Häfliger *et al.* 2000; Hruđey *et al.* 2003; Nygård *et al.* 2006) but can result in serious public health consequences and may cause significant social and economic costs. The outbreak in Milwaukee in 1993 affecting an extrapolated 400,000 people with cryptosporidiosis incurred US\$96.2 million of outbreak-associated illness costs; one-third in medical costs and two-thirds attributed to productivity losses (Corso *et al.* 2003). In Switzerland, waterborne outbreaks are most often the result of deficiencies in the infrastructure or in the water treatment process (Fretz *et al.* 2005). We present a system change in a suburban municipality of Zurich, Switzerland, on 6 February 2008 that led to considerable contamination of drinking water, followed by an outbreak of gastroenteritis. We conducted microbiological and epidemiological investigations to determine the relation between water contamination and the

incidence of gastrointestinal diseases as well as the extent of this outbreak.

MATERIALS AND METHODS

Outbreak

In the late afternoon of 6 February 2008, an external plumber directly connected the washwater pipe with the drinking water pipe at the sewage plant of a suburban municipality of Zurich, and the highly pressurised washwater flooded the drinking water system. This operating error was facilitated by the fact that the pipes of these two systems were indistinguishable because the drinking water system was not labelled. Washwater (cleaned waste water) is commonly used in sewage plants to flush the cells. Early in the evening, a private

person living close to the sewage plant called the local authority and complained about brown and smelly tap water. The alerted sewage plant manager quickly detected the operating error, restored the system and informed the emergency organisation of the canton of Zurich. The population of the municipality was alerted the same day in the late evening, and a boil-water notice was issued. Flushing of the main drinking water pipes by opening hydrants at the sewage plant and the surrounding area was initiated and continued for two days. Water samples from the possibly affected area were repeatedly collected to identify the extent of microbiological contamination as well as to assess the effect of flushing. As microbiological investigations of drinking water samples from 8 February revealed no significant faecal contamination, the restrictions were lifted on 9 February. Despite the measures taken, several cases of acute gastroenteric diseases were reported by a local newspaper on 12 February.

Environmental investigations

A total of 43 water samples were taken between 7 February and 3 March from different taps in buildings and hydrants within a radius of 2 km from the sewage plant. All these sampling points are connected to the drinking water supply of the municipality, and all but two belong to the same lowest water pressure zone. Samples were analysed for total aerobic bacteria, *Escherichia coli* and *Enterococcus* species with conventional culture methods. These analyses were performed to determine the dissemination of wash-water into the drinking water supply as well as to monitor and to optimise flushing.

One sample taken at the beginning of the pipe flushing and two additional washwater samples collected on 29 February and on 3 March were also tested for noroviruses (NoV) using reverse transcription polymerase chain reaction (RT-PCR). The first sample was also examined for *Salmonella* and *Campylobacter* species by PCR, and one of the latter samples was further checked for *Campylobacter* species by *in vitro* cultivation.

Epidemiological investigations

Initial case series interviews with diarrhoeic patients from the affected area strongly suggested that their illness might

have been attributed to the drinking water pollution. Therefore, an epidemiological investigation was initiated. In order to determine the dimension and the chronology of this outbreak, a descriptive- and an analytical-epidemiological study were performed. In the descriptive-epidemiological study, a set of five copies of a questionnaire to cover a maximum of five persons per household was distributed on 14 February 2008, to each of the 450 households in four different quarters (A–D). Quarters A, B and C are located in the immediate vicinity of the sewage plant; they differ by socioeconomic features: A, modern, middle class apartment buildings; B, old tenement houses; and C, single family detached houses. Quarter D is further from the sewage plant (Figure 1). The populations of these quarters are in the range of 1,500–2,000. The households were identified using the official residents' register. Demographic data (address, date of birth, sex), exposure (time and quantity of consumption of unboiled tap water on 6 and 7 February) and clinical characteristics (onset and duration of illness, symptoms, medical consultations, subsequent disease cases in the household) were recorded.

To further investigate the probable association between consumption of unboiled tap water and gastrointestinal illness, an analytical-epidemiological study (a nested case-control study based on the returned questionnaires) was performed. A case was defined as a person who was randomly chosen from all persons identified in the descriptive study who suffered from diarrhoea and/or vomiting between 6 and 10 February. A control was a person randomly chosen from all persons identified in the descriptive study without any gastrointestinal symptoms. Sample size was calculated using the following parameters: alpha one-sided = 0.05, power = 90%, prevalence in the control group = 50%, minimal detectable odds ratio (OR) = 3.0, and a case/control ratio of 1:1. Epi Info™ Version 3.5.1 (Centres for Disease Control and Prevention, Atlanta, GA) was used for data entry. Sample size calculation, univariable and multivariate analysis were performed using STATA IC 10 (StataCorp, College Station, TX). Statistically significant risk factors identified in the univariable analysis were included in a multivariable logistic regression using stepwise backward procedure.

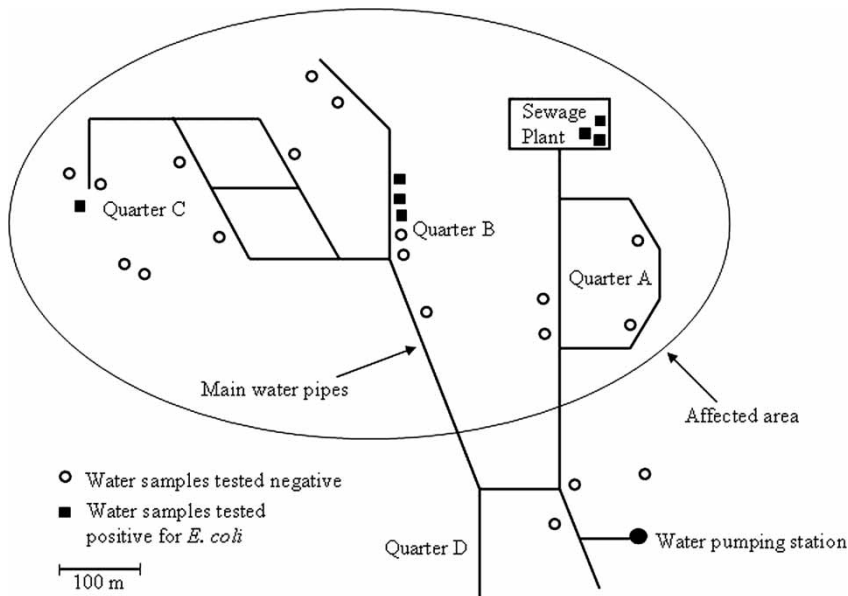


Figure 1 | Schematic of the water distribution system of the affected area showing sample locations (after partial flushing of the system) and locations of samples contaminated with *E. coli*.

Microbiological investigations of faecal samples

Faecal samples were collected from 15 affected persons with gastrointestinal symptoms and tested for NoV, *Salmonella*, *Shigella* and *Campylobacter* species, enteropathogenic *E. coli*, *Giardia lamblia* as well as for *Cryptosporidium parvum* in specialised diagnostic laboratories using standard procedures. RT-PCR and subsequent sequence analyses were performed to investigate samples for NoV (genogroups I and II). Conventional culture methods, microscopy or PCR were used for the detection of bacteria and parasites.

The microbiological results of faecal samples from five patients that were reported by physicians were also considered.

RESULTS

Environmental investigations

Results of drinking water samples

The sample taken from a drinking water hydrant close to the sewage plant at the beginning of the flushing of the water

system revealed considerable faecal contamination (400 *E. coli*/100 mL water, Table 1).

Neither *Salmonella* nor *Campylobacter* nor NoV was detected in this sample but these analyses were only performed two weeks after sampling.

From the 17 water samples taken on 7 February, only one displayed high faecal contamination with around 300 *E. coli*/100 mL water. This sample originated from a drinking water hydrant situated within a radius of 500 m from the

Table 1 | Features and results of water samples investigated for *E. coli*

Sampling date (2008)	No. of samples taken	No. of samples containing <i>E. coli</i>	Number of <i>E. coli</i> detected (CFU/100 mL)
7 February (1 a.m.)	1	1	400
7 February	17 ^a	1	300
8 February	3	2	2/2
11 February	7	3	390 ^b /98 ^c /2
12 February	12	5	10 ^b /8 ^c /7/4/2
26 February	2	0	–
3 March	1	0	–

^aTwo samples thereof taken within a radius of 500 m from the sewage plant, 1 containing 300 *E. coli*/100 mL.

^bTap sample from laundry located 200 m from sewage plant.

^cTap sample from sewage plant.

sewage plant. In the only other sample taken from within this radius, no faecal contamination was detectable. The other 15 samples were obtained from taps or hydrants which were more than 1 km away from the sewage plant or which were part of another water pressure zone, and they showed no evidence of faecal contamination.

Samples taken one day later (8 February) in the area around 500 m from the sewage plant showed low (2 CFU/100 mL) *E. coli* numbers (Table 1), and the drinking water restrictions were lifted on 9 February. This decision seemed proportionate because of the dramatic and rapid reduction in bacterial numbers within 1.5 days of pipe flushing. However, high faecal contamination was detected again in 2 of 7 samples from 11 February. These two samples originated from two different taps at or close to the sewage plant which had not been flushed after the restrictions were lifted. One day later, faecal contamination at these places was highly reduced (Table 1, b, c). Another three tap water samples taken within a perimeter of 500 m from the sewage plant were slightly faecally contaminated on 12 February. Later, no more such contamination was observed in a few water samples from the affected area.

The results for total aerobic bacteria and *Enterococcus* species were in accordance with the results of *E. coli* (not shown).

Results of washwater samples

The two washwater samples taken three weeks after the incident at the sewage plant were positive for NoV genogroup I. One sample also contained NoV (genogroup II). No *Campylobacter* were detected.

Epidemiological investigations

Descriptive-epidemiological study

Completed questionnaires were returned by 438 persons from 216 (45%) of the contacted 450 households. The response rate of 62% from quarter A was higher than from the three others, and the 240 questionnaires from this quarter were analysed in detail, see Table 2.

For the population of quarter A, the attack rate, defined as the number of households having at least one patient

Table 2 | Comparative data of the descriptive study conducted in quarters A–D

	Quarter A	Quarter B	Quarter C	Quarter D
Return rate of questionnaires (%)	62	36	53	26
Number of households answering (total 216)	117	28	42	29
Number of affected households (% of answering households)	77 (66)	13 (46)	18 (43)	4 (14)
Number of persons answering (total 438)	240	63	81	54
Number of patients (% of answering persons)	126 (53)	23 (36)	31 (38)	5 (9)

suffering from diarrhoea and/or vomiting between 6 and 20 February, was 66% (Table 2).

The median age of this population was 39 years (range 1–81 years), and 66% were women. Thereof, 126 (53%) persons reported an onset of gastrointestinal illness from 6 February onwards. Symptoms included diarrhoea (78%), nausea (58%), vomiting (56%) as well as abdominal pain (55%).

Further, the epidemic curve shows that the first persons fell ill on 6 February. The number of cases sharply increased with a peak incidence on 8 February. Afterwards, the number of new cases dropped sharply, with two minor further peaks on 11 and 13 February. After 14 February, one single additional case was reported (Figure 2).

Case-control study

An initial study sample size of 142 persons (71 cases and 71 controls) was computed. According to the definitions for cases and controls, study persons were randomly chosen among all persons who returned the questionnaire within the descriptive-epidemiological study. The univariable analysis revealed the consumption of tap water on 6 or 7 February 2008 (OR 13.5; 95% confidence interval (CI): 5.6–33.2; $p = 0.001$), the consumption of tap water on 6 February only (OR 10.1; 95% CI: 4.4–23.7; $p = 0.001$), and the consumption of tap water on 6 February between 4 and 10 p.m. (OR 19.4; 95% CI: 7.6–50.9; $p = 0.001$) as statistically significant parameters associated with the gastrointestinal illness. Furthermore, the use of tap water for washing

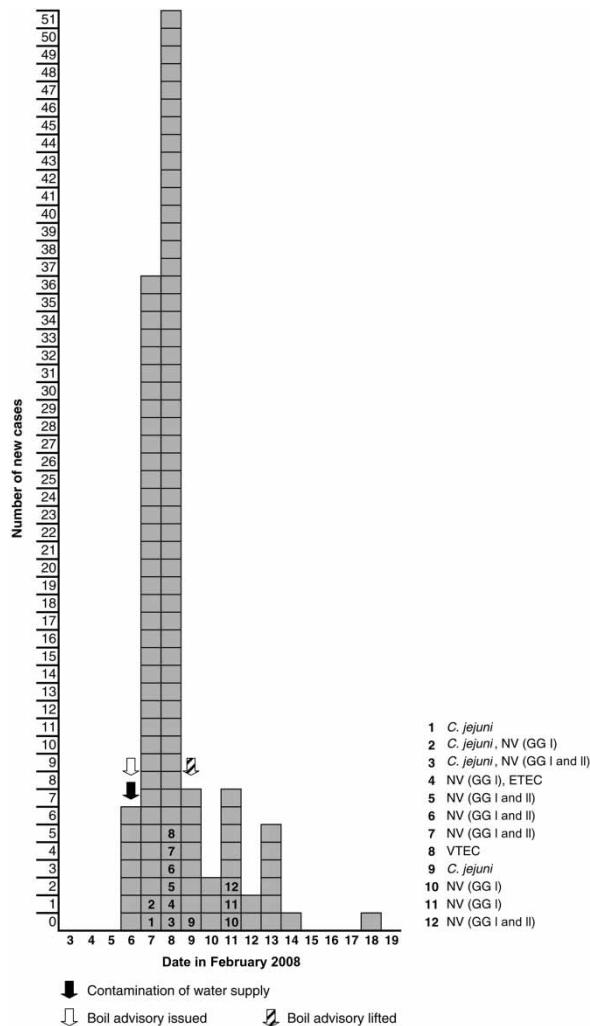


Figure 2 | Epidemic curve showing the number of cases of gastroenteritis as well as the detected pathogens in stool samples of persons from quarter A (ETEC, enterotoxigenic *E. coli*; VTEC, verotoxin-producing *E. coli*).

raw vegetables and fruits on 6 February (OR 5.4; 95% CI: 2.3–13.1; $p = 0.001$), and the consumption of up to 0.5 L of tap water on 6 or 7 February was associated with illness (consumption of 0–0.2 L: OR 3.1; 95% CI: 1.3–8.0; $p = 0.010$; consumption of 0.2–0.5 L: OR 4.4; 95% CI: 1.6–13.0; $p = 0.002$; Table 3).

The following two risk factors previously identified in the univariable analysis remained in the multivariate model: the consumption of tap water on 6 February between 4 and 10 p.m. (OR 29.1; 95% CI: 9.8–86.4; $p = 0.001$) and the usage of tap water for washing raw vegetables and fruits during the whole day (OR 8.5; 95% CI: 2.9–25.2; $p = 0.001$; Table 4).

Microbiological investigations of stool samples

NoV were detected in 9 of the 15 stool samples examined for microorganisms, and genogroup I was identified in all cases. Additionally, five of them also contained NoV belonging to genogroup II (Figure 2). Two of these samples were also positive for *Campylobacter* spp., and a positive signal for enterotoxigenic *E. coli* was detected by PCR in one of them. A further sample was positive by PCR for shigatoxin-producing *E. coli*. Detection of *Campylobacter* spp. was reported by physicians in two of five stool samples.

DISCUSSION

Our investigations, particularly the epidemic curve (Figure 2) as well as the attack rate of 66% of households with illness in quarter A, substantiate an outbreak of gastroenteritis in this district one day after an incident at the sewage plant when washwater polluted the drinking water supply. The case-control study revealed the time frame between 4 and 10 p.m. on 6 February 2008, as the very probable time period for infection. The association identified between consumption of tap water during the time period of the water system failure (i.e. during the faecal contamination of the drinking water system of the district) and gastrointestinal disease was strongly supported by further risk factors identified, such as the general consumption of tap water on either 6 or 7 February and the usage of tap water for washing raw vegetables and fruits on 6 February.

The epidemic curve displays a steep up slope, a more gradual down slope and a rather large width, which indicates a point-source outbreak caused by infection of multiple pathogens. This assumption is supported by the microbiological results of stool samples of the affected persons which revealed that different pathogenic microorganisms caused the observed gastrointestinal illness.

The attack rates of households with illness of 43–66% in quarters A to C suggest that this waterborne outbreak, like other similar incidents (MacKenzie et al. 1994; Häfliger et al. 2000; Gallay et al. 2006), has affected many people. In order to assess the effective dimension of an outbreak, a response rate of 80% is desirable, but this was not achieved in the studied area. As *E. coli* was detected only in drinking

Table 3 | Results of the univariable analysis of the case-control study

Exposure	Cases			Controls			OR	[95% CI]	Fisher's exact <i>p</i>
	Total	Exposed	(%)	Total	Exposed	(%)			
Consumption of tap water, 6 or 7 February	71	59	83.1	71	19	26.8	13.5	[5.6–33.2]	0.001
Consumption of tap water, 6 February	71	55	77.5	71	18	25.4	10.1	[4.4–23.7]	0.001
Before 4 p.m.	71	19	26.8	71	12	16.9	1.8	[0.7–4.5]	0.223
Between 4 and 10 p.m.	71	54	67.1	71	10	14.1	19.4	[7.6–50.9]	0.001
Between 10 and 12 p.m.	71	8	11.3	71	3	4.2	2.9	[0.6–17.5]	0.208
Usage of tap water for washing of food intended for raw consumption (e.g. salad, vegetables, fruits), 6 February	66	37	56.1	63	12	19.1	5.4	[2.3–13.1]	0.001
Consumption of tap water, 7 February	71	7	9.9	71	2	2.8	3.8	[0.7–38.2]	0.166
Between 0 and 6 a.m.	71	5	7.1	71	1	1.4	5.3	[0.6–254.3]	0.209
After 6 a.m.	71	2	2.8	71	1	1.4	2.0	[0.1–121.4]	1.000
Amount of consumed tap water, 6 or 7 February:									
0–0.2 L	71	24	33.8	71	10	14.1	3.1	[1.3–8.0]	0.010
0.2–0.5 L	71	23	32.4	71	7	9.9	4.4	[1.6–13.0]	0.002
0.5–1 L	71	8	11.3	71	2	2.8	4.4	[0.8–43.5]	0.097
> 1 L	71	2	2.8	71	0	0	n.a.	[0.5–n.a.]	0.497

water samples around 500 m from the sewage plant and these data correspond well with the high attack rates of households with illness from quarters A to C, the extend of washwater contamination was most likely restricted to this area. The most probable reason for this limited dispersal of washwater was a water pumping station situated outside this perimeter which delivered uncontaminated ground water into the system at high pressure (Figure 1).

Reports of gastrointestinal illnesses of affected persons have further been confirmed by the positive results of 12

stool samples containing various pathogens, especially NoV and *Campylobacter jejuni*. These microorganisms are common agents of waterborne outbreaks (Häfliger *et al.* 2000; Gallay *et al.* 2006; O'Reilly *et al.* 2007; Jakopanec *et al.* 2008). They may cause single source outbreaks (O'Reilly *et al.* 2007) or may be part of gastrointestinal illnesses with multiple aetiologies, mostly caused by an influx of waste water into a water supply system (Häfliger *et al.* 2000; O'Reilly *et al.* 2007) as described here. Neither NoV nor *Campylobacter jejuni* could be detected in the water sample taken when flushing was initiated. These investigations were only performed two weeks after sampling and these two agents are notoriously difficult to detect, particularly in small sample sizes (Hänninen *et al.* 2003). However, the chronology of the system error at the sewage plant and the onset of illnesses as shown by the epidemic curve (Figure 2) as well as the lack of a documented food-borne outbreak at the same time in this area, support the presence of these pathogens in the contaminated drinking water supply.

Table 4 | Results of the multivariate analysis of the case-control study

Exposure (Feb 6)	OR	[95% CI]	<i>p</i>
Consumption of tap water, between 4 and 10 p.m.	29.1	[9.8–86.4]	0.001
Usage of tap water for washing of food intended for raw consumption (e.g. salad, vegetables, fruits), 6 February	8.5	[2.9–25.2]	0.001

Additionally, the later detection of NoV in two washwater samples confirms this statement.

NoV genogroup I was the major causative agent of this outbreak. This genogroup has been isolated from all stool samples positive for NoV. Further, in five of these nine samples, NoV genogroup II was also detected. A person-to-person spread was not obvious from answered questionnaires or from the epidemic curve (Figure 2). The lack of secondary cases and the dominance of NoV genogroup I in waterborne outbreaks have already been described (Häfliger *et al.* 2000; Maunula *et al.* 2005; Chan *et al.* 2006; Hewitt *et al.* 2007). The postulated difference in virus stability (Maunula *et al.* 2005; Lysén *et al.* 2009) as well as the observed 100 times lower viral load of faecal samples containing NoV genogroup I (Chan *et al.* 2006; Hewitt *et al.* 2007) may explain the characteristics of such outbreaks.

In many waterborne outbreaks, the cause of pollution is unclear or water as the polluting source can only be assumed in environmental investigations (Kuusi *et al.* 2004; Gallay *et al.* 2006; O'Reilly *et al.* 2007; Ter Waarbeek *et al.* 2010). Safety measures to be undertaken in order to prevent such outbreaks are difficult to devise. The source of the waterborne outbreak described here was maintenance work, an incident rarely documented in the literature to date (Andersson 1991; Laing 2002). Measures to prevent such cases include the clear labelling of drinking water pipes which is easy to realise and is regulated by Swiss law.

Despite the fact that the operating error was detected and corrected within a few hours and the boil-water notice was issued on the day the incident occurred, 126 people living in quarter A near the sewage plant were identified as suffering from gastrointestinal symptoms. The emergency organisation attempted to install safety measures as soon as possible. As the first complaint by a private person was recorded in the early evening, it was beyond the organisation's power to prevent the inhabitants from consuming drinking water for dinner. Nevertheless, reaction times to implement adequate measures have to improve.

CONCLUSIONS

Drinking water pipes have to be clearly labelled and strictly separated from other water systems. As already claimed by

Beaudeau and colleagues (Beaudeau *et al.* 2008), prohibiting connections between drinking water supplies and networks containing effluent from waste water treatment plants is a top priority to prevent such backflow-related outbreaks. Persons working with water supplies need comprehensive instruction on safety measures. Contingency plans to quickly and reliably alert potentially affected persons have to be introduced and sustained. Furthermore, implemented safety measures have to be monitored in order to guarantee their effectiveness. In particular, pipe flushing has to be sustained until pipes at households containing contaminated water are drained. Otherwise, a recontamination of the water supply may occur. This report illustrates the value of combined approaches of microbiological diagnostics, molecular genotyping and descriptive as well as analytical statistics to elucidate the context of waterborne disease outbreaks.

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