Epidemiol. Infect. (2005), **133**, 593–601. © 2005 Cambridge University Press
doi:10.1017/S0950268805003808 Printed in the United Kingdom

A large outbreak of campylobacteriosis associated with a municipal water supply in Finland

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(*Accepted 15 December 2004*)

SUMMARY

In August 1998, an outbreak of campylobacteriosis occurred in one municipality in northern Finland. A 10% random sample of residents (population 15000) was selected through the National Population Registry for a survey conducted by using postal questionnaires. Cases were defined as residents of the municipality with onset of acute gastroenteritis from 1 to 20 August 1998. Of 1167 respondents (response rate 78%), 218 (18·7%) met the case definition. Drinking non-chlorinated municipal tap water was strongly associated with illness (OR 34·4). The estimated total number of ill persons was 2700. *Campylobacter jejuni* was isolated from stool samples of 45 (61%) out of 74 patients tested. All five isolates tested had indistinguishable PFGE patterns. Water samples were negative for campylobacter and coliforms. Epidemiological and environmental evidence suggested mains repair as the source of contamination. Non-chlorinated ground-water systems may be susceptible to contamination and can cause large outbreaks.

INTRODUCTION

Campylobacter spp. are the most commonly reported bacterial cause of gastroenteritis in developed countries [1]. In Finland, approximately 4000 cases of campylobacteriosis are reported annually; nearly 90% of the tested isolates are *Campylobacter jejuni* [2]. In case-control studies conducted in several countries, drinking unpasteurized milk, eating chicken, barbecuing, drinking untreated surface water and living or working on a farm have been identified as risk factors for sporadic campylobacter infections [3–6].

Although campylobacter infection is usually self-limiting, outbreaks have substantial public health importance. Many patients may seek medical care, and some are hospitalized. Post-infectious complications, such as reactive arthritis [7] and Guillain–Barré syndrome [8] may follow campylobacter infection. The first waterborne outbreaks of campylobacteriosis were reported soon after campylobacter was identified as an important human pathogen in the late 1970s. Since then, outbreaks associated to mains water systems involving both surface water and ground water have been reported [9–16].

Serotyping has been used to subtype campylobacter strains since the 1980s. Recently, new molecular

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Presented in part at the 38th Annual Meeting of the Infectious Disease Society of America (IDSA), New Orleans, 2000.

fingerprinting methods have been developed. Pulsed-field gel electrophoresis (PFGE) has been shown to be a highly discriminatory method for campylobacter, and several distinct PFGE patterns can be found within a serotype [17].

In August 1998, a large outbreak of gastroenteritis occurred in a community in northern Finland. We conducted epidemiological and microbiological investigations to determine the cause, vehicle and environmental source as well as the extent of the outbreak.

MATERIAL AND METHODS

Outbreak setting

Municipality A (population approximately 15000) is located in northern Finland, 20 km north of the city of Oulu. Practically all (99%) residents receive drinking water from the non-chlorinated municipal water supply. On Monday 10 August, the National Public Health Institute (KTL) was notified that during the weekend of 7–8 August 1998, approximately 50 persons had sought care at the municipal health centre because of gastrointestinal symptoms. On 11 August, *C. jejuni* was isolated from stool samples of 15 patients with gastrointestinal symptoms. The wide geographical distribution of cases and preliminary interviews with patients suggested drinking water as the source of the outbreak. A boil-water notice was, therefore, issued on 11 August, and chlorination of water began on 13 August.

Case finding and descriptive epidemiology

A public health nurse recorded on a line list all persons who contacted the municipal health centre because of gastrointestinal symptoms with onset of symptoms from 1 to 20 August. In addition to demographic data and place of residence, information was collected about symptoms and illness onset. Based on these preliminary data, the outbreak was rapidly characterized by age, sex and geography. Fifteen patients were thoroughly interviewed by using a standard questionnaire to generate hypotheses about the source of the outbreak.

Population survey

For the questionnaire study, we selected a 10% random sample of all Municipality A residents aged 15 years and older from the National Population Registry. A case was defined as a resident of Municipality A with diarrhoea (three or more stools during 24 h) or at least two of the following symptoms: fever, abdominal pain, vomiting, nausea; and illness onset from 1 to 20 August. The questionnaire was mailed to participants on 26 August. They were asked about onset and symptoms of gastrointestinal illness and use of health services. Information about consumption of tap water, private well water and bottled water, as well as exposure to mass catering, restaurant foods and poultry between 25 July and 7 August was also collected.

To determine the occurrence of post-infectious complications after an outbreak of gastroenteritis, a second questionnaire was mailed on 30 September 1998 to persons who reported new joint or musculoskeletal symptoms after gastroenteritis in the population survey ($n=101$) and to persons who contacted the municipal health centre because of new joint or musculoskeletal symptoms after gastroenteritis from 1 August to 15 September 1998 ($n=13$). Participants were asked about onset and duration of musculoskeletal symptoms, which joints were affected, use of health services and treatment for musculoskeletal symptoms. Probable reactive arthritis was defined as a new joint symptom, including arthralgia, redness, and/or swelling in one or more joints within 1 month of gastroenteritis [18].

Laboratory investigation of patients

Stool specimens were collected from 74 patients who had gastrointestinal symptoms. Twenty-six (35%) specimens were analysed for the presence of *Salmonella*, *Shigella*, *Yersinia*, *Campylobacter*, *Aeromonas and Plesiomonas* spp. as well as *Staphylococcus aureus*, *Bacillus cereus* and *Clostridium perfringens* by routine bacteriological methods. The remaining 48 (65%) specimens were cultured for *Campylobacter* sp. only. For campylobacters, the samples were cultured on Campylobacter blood free selective medium (modified charcoal cefoperazone deoxycholate agar [19], LABM, Lancashire, UK). Growth was confirmed as *C. jejuni* by Gram stain, catalase and hippurate test. In addition, the primary stool cultures of six patients were investigated for enteropathogenic (EPEC) and enteroaggregative (EAEC) *Escherichia coli* by PCR as described previously [20]. Ten specimens were investigated for *Cryptosporidium* and *Cyclospora* spp. and 20 specimens for noroviruses by RT–PCR.

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Antimicrobial susceptibility of campylobacter strains against erythromycin, ciprofloxacin, amoxicillin-clavulanic acid, tetracyclines and clindamycin was tested according to National Committee for Clinical Laboratory Standards (NCCLS) disk diffusion criteria by using standard paper disks (Oxoid, Basingstoke, UK) on Isosensitest agar (Oxoid) supplemented with 5% sheep blood in microaerobic atmosphere at 42 °C for 24 h. If there were any signs of resistance the susceptibility was confirmed by *E* test in the same incubation conditions. Five of the *C. jejuni* isolates recovered from patients were genotyped by PFGE using *Sma*I and *Kpn*I enzymes for digestion of DNA as previously described [21].

Environmental investigation

The municipal water supply was inspected on 12 and 27 August by local authorities in collaboration with the Department of Environmental Health and the Department of Infectious Disease Epidemiology of KTL. Water samples were collected from groundwater wells, a water reservoir and households for microbiological investigation. The first sample collected on 8 August was investigated for coliforms. Subsequent samples of municipal water were collected on 11–13 August and tested for coliforms and campylobacters. Samples taken on 12 August were also investigated for the presence of noroviruses and parasites. In addition, 100-g samples taken from different parts of the filter material used to reduce the iron content of ground water were studied for campylobacters by enrichment and coliforms. The water samples were studied for coliforms on LES Endo medium. The filter material was studied at a dilution of 10^{-1} on Violet Red bile agar (VRB). For campylobacters, water samples of 350–4000 ml volume were filtered through membranes with 0·45 μm pore size and the filters were enriched in Bolton enrichment broth at 37 °C for 24 and 48 h in a microaerobic atmosphere and cultured [22].

Analysis

Attack rates and relative risks (RR) with 95% confidence intervals (CI) for categorical variables, and χ^2 for trend were calculated with Epi-Info software, version 6.04 (CDC, Atlanta, GA, USA). To identify independent risk factors for campylobacteriosis, exact logistic regression was performed with LogXact software, version 5 (Cytel Software Corp., Cambridge, MA, USA). The first model included all participants and the following variables: type of home, drinking unboiled tap water, age and postal code. Another logistic regression model was constructed to include only persons who had consumed unboiled tap water. This model included following variables: type of home, postal code, age, tainted water, and daily dose of unboiled tap water consumed. All variables in the models were associated with illness at $P<0·05$ in univariate analysis.

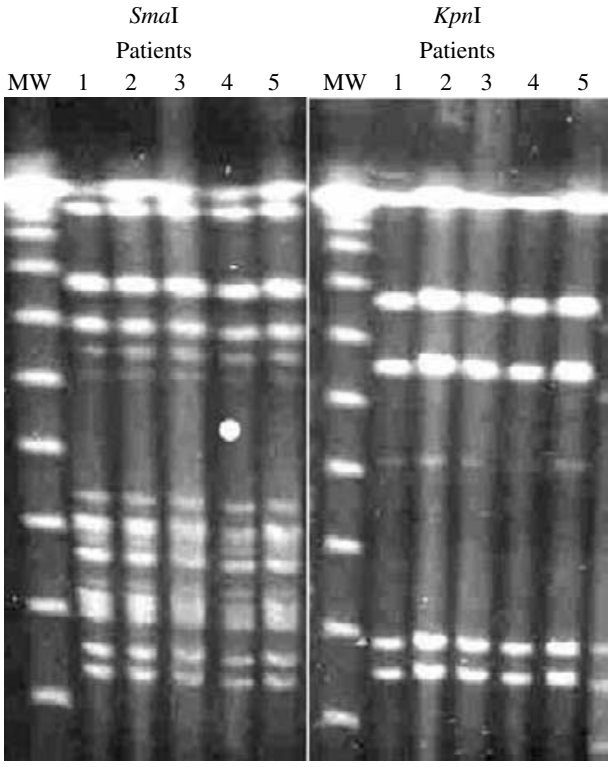

Fig. 1. *Sma*I and *Kpn*I pulsed-field electrophoresis patterns of five *Campylobacter jejuni* isolates from patients. MW, molecular size marker.

RESULTS

Description of the outbreak

A total of 442 persons with gastroenteritis with illness onset from 1 to 20 August, contacted the health centre. All age groups were affected and the median age was 39 years (range 1–89 years); 52% were men. *C. jejuni* was isolated from 45 (61%) of the 74 stool samples tested. All strains were susceptible to erythromycin and ciprofloxacin. All five strains analysed further by PFGE showed an indistinguishable PFGE pattern (Fig. 1). No other pathogens were detected in patient samples.

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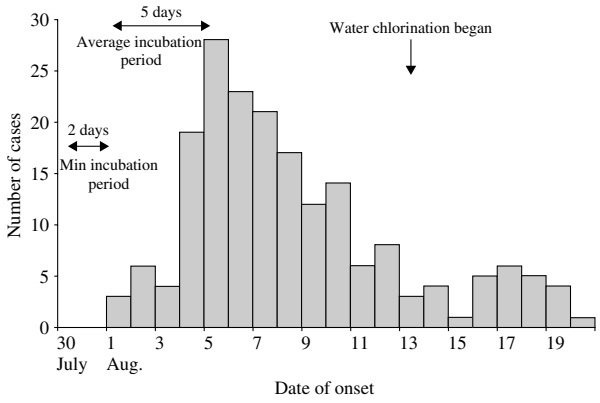

Fig. 2. Cases of gastroenteritis among residents of Municipality A by onset of illness, from 1 to 20 August 1998.

Table 1. *Attack rates (AR) by postal code area according to the population-based survey, Finland, August 1998*

Postal code	Cases	Participants	AR (%)
A	24	155	15·5
B	39	206	18·9
C	115	467	24·6
D	22	145	15·2
E	7	53	13·2
F	8	111	7·2*
Other	3	30	10·0
Total	218	1167	18·7

* $P<0{\cdot}0001$ compared with highest AR.

Population survey

The questionnaire was mailed to 1500 randomly selected residents of Municipality A aged ⩾15 years. In total, 1178 persons participated in the survey (response rate 78%). Eleven participants were excluded from the analysis because they were absent from the municipality during the whole outbreak period or had travelled abroad between 25 July and 7 August. A total of 218 (18·7%) persons met the case definition. Median age of cases was 41 years (range 15–88 years); 57% were women. Forty-one (19%) cases consulted a physician, and seven (3·2%) were hospitalized. Median duration of the illness was 4 days (range 1–35 days) and median duration of the hospitalization 4 days (range 1–6 days). Medication was prescribed to 18 (8·3%) cases, nine of which received antimicrobial drugs. Four cases received erythromycin, three cases ciprofloxacin, and two cases azithromycin. Ninety-eight cases (45·0%) had to be absent from work for a median of 3 days (range 1–15 days). The epidemic curve (Fig. 2) shows that the first cases had illness onset during 1–3 August, then cases increased rapidly with peak incidence on 5 August. Thereafter, the number of cases decreased, and the outbreak was practically over by 13 August, suggesting a point-source outbreak. The attack rate was highest at the centre of municipality close to the water tower (postal code C) and lowest in the eastern part of municipality (postal code F) (Table 1, Fig. 3).

Drinking unboiled tap water was significantly associated with illness (Table 2) (RR not calculable, $P<0{\cdot}001$). Among those who drank municipal tap water, drinking tainted water, i.e. water that had an abnormal colour, taste or smell was also associated with illness (RR 1·6, 95% CI 1·2–2·2). Persons aged 15–64 years were more likely to report illness than persons aged ⩾65 years (RR 1·8, 95% CI 1·2–3·0). The attack rate was higher among participants living in an apartment building (33·3%) than among participants living in a townhouse (24·9%) or in a house (17·0%) (Table 2). The risk of illness increased significantly with increasing daily consumption of unboiled tap water (Table 3). Other exposures were not significantly associated with illness.

In exact logistic regression, drinking unboiled tap water (OR 34·4, 95% CI 6·2–infinite), living in an apartment building (OR 2·8, 95% CI 1·4–5·6), age ⩾65 years (OR 2·2, 95% CI 1·1–4·9), and living in postal code area C (OR 1·8, 95% CI 1·3–2·6) were all independently associated with illness (Table 2). In the logistic regression, including only those who had drunk unboiled tap water, age ⩾65 years was not any more significantly associated with illness ($P=0{\cdot}15$).

Of 218 persons with gastroenteritis in the population survey, 101 (46%) reported new joint or musculoskeletal symptoms after gastroenteritis. Eighty-five persons (75%) returned the second survey on musculoskeletal symptoms; 76 (89%) of them had joint or other musculoskeletal symptoms following gastroenteritis. The median interval between onset of gastroenteritis and onset of symptoms was 10 days (range 1–27 days). Twenty-seven persons consulted a physician because of musculoskeletal symptoms. Neck pain and lower back pain were the most common symptoms; 30 persons had joint swelling and pain – consistent with reactive arthritis (Table 4).

Environmental findings

The water was pumped from ground-water wells located in three different sites (Fig. 3). At well A which

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Table 2. *Exposures associated with gastroenteritis among participants in the population-based survey, Finland, August 1998*

Exposure	Cases	Total	AR (%)	RR (95% CI)	*P* value	OR (95% CI)*	*P* value*
Unboiled tap water							
Yes	213	936	22·8	Not calculable	<0·001	34·4 (6·2–infinity)	<0·001
No	0	81	0				
Tainted water†							
Yes	33	94	35·1	1·6 (1·2–2·2)	0·004		
No	175	805	21·7				
Age (years)							
15–64	202	1016	19·9	1·9 (1·2–3·0)	0·01	2·2 (1·1–4·9)	0·03
⩾65	16	151	10·6				
Type of home							
Apartment building	20	60	33·3	2·0 (1·3–2·9)	0·003	2·8 (1·4–5·6)	0·004
Townhouse	48	193	24·9	1·5 (1·1–2·0)	0·01	1·4 (0·9–2·1)	0·15
House	142	836	17·0	Ref.			
Postal code area							
C	115	467	24·6	1·7 (1·3–2·1)	<0·001	1·8 (1·3–2·6)	<0·001
Other	100	670	14·9				

AR, Attack rate; RR, relative risk; OR, odds ratio; CI, confidence interval.
* Exact logistic regression model.
† Abnormal colour, taste or smell.

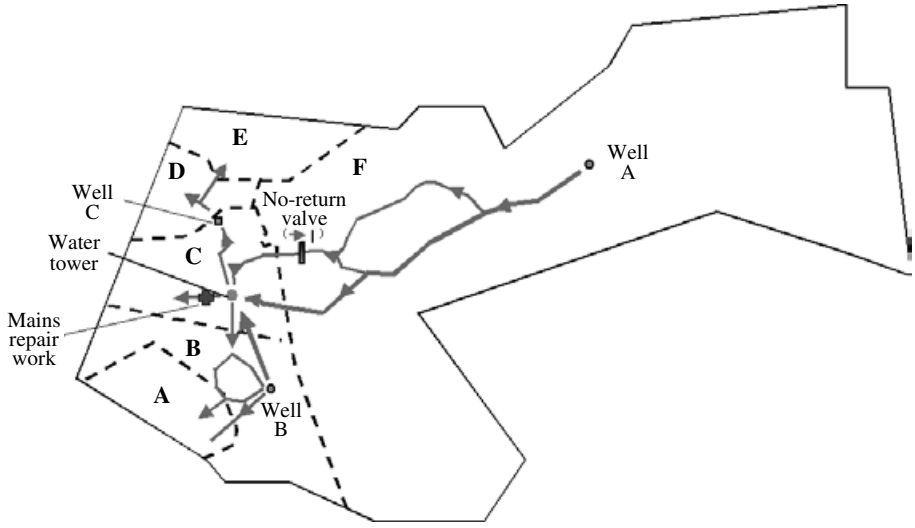

Fig. 3. Map of Municipality A presenting the water supply system and postal code areas (A–F) in the municipality. Arrows indicate direction of water flow in the municipal supply.

was constructed in 1995, 1800 m³/day was pumped from six abstraction wells. Well A was located on a sand ridge formation about 10 km east of the centre of municipality. In the vicinity of well A gravel had been excavated from several places, reducing the thickness of earth layers protecting ground water. The surroundings of each abstraction well were protected with a steel metal fence (10 m × 10 m). Well B, constructed in 1959 produced 700 m³/day from one abstraction well. The closest houses were ~1 km from well B. A farm field was located ~150 m from the well, and a ditch from a cattle farm passed the well at a distance of 10 m. Well C produced only 20 m³/day from one abstraction well. The water tower was located in the centre of the municipality, and was filled at night from both wells A and B. The capacity

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Table 3. *Dose–response relation between the amount of daily consumption of unboiled tap water and attack rate (AR) of gastroenteritis, Finland, August 1998*

Glasses/day	Cases	Total ($n=879$)	AR (%)
0	0	63	0
1–3	33	251	13·1
4–6	83	347	23·9
⩾7	86	278	30·9

χ^2 for linear trend = 43·48; $P<0·0001$.

Table 4. *Characteristics and symptoms of 76 persons who reported musculoskeletal symptoms after gastroenteritis*

Symptom or characteristic	Number of persons (%)
Neck pain	50 (75)
Lower back pain	48 (74)
Arthralgia only	39 (61)
Limitation of joint movement	31 (49)
Swelling and pain	30 (46)
Achilles tendinitis	18 (31)
Female	42 (55)
	Median (range)
Age (years)	50 (14–85)

of the water tower reservoir was 1700 m³. Small holes were found on the roof of the water tower with connection to the water reservoir. Roosting birds (mainly seagulls) were observed, and bird stools found on the roof of the tower.

The eastern part of the municipality (postal code F) received drinking water directly from well A, while other parts received their water through the water tower. The water was not chlorinated and water quality was monitored regularly for coliforms.

During mains repair work close to the centre of municipality on 29 July, sewage water had flooded and probably mixed with mains water. After the incident, the pipes were thoroughly flushed in order to prevent contamination of the main water system.

Initial samples from the water supply were negative for coliforms. Subsequent water samples from various points of the water system from 11, 12 and 13 August were negative for campylobacter and indicator bacteria. Noroviruses or parasites were not detected in water samples.

DISCUSSION

In this community-wide outbreak associated with consumption of non-chlorinated drinking water from a ground-water supply, we found that almost one fifth of the population in the affected municipality fell ill with gastroenteritis. In addition to a strong association between illness and consumption of municipal water, the risk of illness increased with increasing daily consumption of unboiled tap water. *Campylobacter jejuni* was isolated from a majority of the investigated stool samples, and the studied strains had indistinguishable PFGE genotypes indicating a common source of infection. Together with the temporal association and a plausible contamination mechanism from mains repair work, these findings provide strong evidence that the outbreak was waterborne [23].

The epidemiological evidence shows that the municipal water supply was the source of the outbreak. The response rate was close to 80%, making significant selection bias unlikely. Because of the short delay in distributing the questionnaires, respondents were likely to accurately recall their exposure to water and other investigated risk factors. Media publicity during the outbreak with speculations about tap water as the cause of illness may have resulted in recall bias of exposure to municipal tap water. However, the dose–response relation between the amount of water consumed and illness strengthens the conclusion of water as the vehicle.

The population survey design of our study enabled direct calculation of attack rates and accurate assessment of the total number of residents with gastroenteritis in the community. When the results from the large random-sample population-based survey were extrapolated to the whole population, the estimated total number of ill in the municipality was 2700. Besides this high overall disease burden, 4% of the survey participants had consulted a physician, 0·6% were hospitalized, and 8·4% were absent from work because of illness. In addition to acute gastrointestinal illness, reactive arthritis is a relatively common complication of campylobacteriosis [7]. In our survey, nearly half of the cases reported some musculoskeletal complaints after gastroenteritis. Thirty participants in the second survey reported new joint swelling and pain, fulfilling the criteria frequently used for reactive arthritis [7]. Although reactive arthritis following campylobacter infection is usually mild, this complication substantially increased the disease burden and use of health services in this outbreak.

This is among the largest waterborne campylobacter outbreaks reported. Other major waterborne outbreaks have been reported from the United States [9], Sweden [13] and Denmark [16] with estimated numbers of cases ranging from 2000 to 3000. Several other outbreaks with smaller or poorly defined numbers of cases have been reported [10–12, 14, 15]. Attack rates in the previous outbreaks have varied from as low as 2–4% [9, 11, 24], considerably lower than in our study, to 56–88% [11, 14, 16]. High attack rates have been associated with longer contamination periods of the water, while in the outbreaks with low attack rates the contamination has lasted for only a few days.

Isolation of campylobacter from water has rarely been reported in outbreak investigations [11, 25]. The concentration of bacteria in the water may be low, and the strains may lose their culturability over time [26], making isolation difficult. The water supply may also be contaminated for only a short period or intermittently. The epidemic curve in this outbreak strongly suggests a point-source outbreak and that exposure to contaminated water lasted only 1–3 days. Samples from the supply were obviously taken after the contamination was already over. The indistinguishable PFGE patterns from patient strains also indicated a common source.

The environmental investigation revealed several risk points in the water system. The mains repair work on 29 July is the most plausible source of contamination on the basis of epidemiological and environmental evidence as well as temporal association. The work was done close to the centre of the municipality and water tower where attack rate was highest. It probably caused a cross-connection between sewage water and drinking water. According to the epidemic curve, contamination during the construction work is temporally compatible with the epidemiologically determined exposure period in the outbreak. Previously, cross-connection has resulted into community-wide waterborne outbreaks [16, 27].

Due to the excavations close to well A, the filtration layers of earth between surface and ground water were less than 1 m causing a risk for the contamination of ground water. Previously, heavy rainfall has been associated with waterborne campylobacter outbreaks, and in one of these outbreaks identical campylobacter strains were isolated from a nearby farm and from human cases [28]. However, in the present outbreak the attack rate in the eastern part of the municipality receiving water directly from well A was lower than in other parts of the municipality. All samples taken either from abstraction wells or filters of well A were negative for faecal indicator microbes as well as for campylobacters. Taken together, the findings indicate that the source was not well A.

Bird faeces from the roof of the water tower could have contaminated the reservoir through the detected holes. Previously, a water system with an open-top storage tank was probably contaminated from bird faeces causing an outbreak in a boarding school [12]. However, there is a large dilution effect in the reservoir (1700 m^3). It is, therefore, unlikely that this mechanism would have caused such a large, community-wide outbreak. Furthermore, all campylobacter strains isolated from patients were indistinguishable by PFGE, while bird faeces would probably have contaminated the reservoir with several different strains.

Ground water has been regarded as a safe source of drinking water, and therefore, unlike surface water, it is less likely to be adequately chlorinated and monitored for contaminants, and may be an important source of waterborne outbreaks. In Finland, 87% of the population obtains drinking water produced by public waterworks. The majority (58%) is produced from ground water or by using artificial ground-water recharge technology. The approximately 1400 ground waterworks usually serve small communities with less than 500 consumers [29]. During 1998–9 seven outbreaks linked to public water systems were registered in Finland, and six of these were ground-water systems. Moreover, in other countries, e.g. the United States, approximately 130 million people receive water from ground-water sources [30], and small water systems that serve fewer than 3300 people collectively provide water to 40 million people [31]. The safety of groundwater systems should be improved by chlorination or disinfection of water with ultraviolet light devices.

This outbreak highlights the importance of thorough epidemiological investigation of waterborne outbreaks. The microbe is often isolated only from patients but not from the water source. Therefore, public health authorities have to rely on epidemiological evidence when deciding on control measures during and after the outbreak and improvement of the safety of the water system after the outbreak to prevent similar incidents in the future.

ACKNOWLEDGEMENTS

We thank Anja Siitonen from the Laboratory of Enteric Pathogens of KTL and Outi Lyytikäinen from the Department of Infectious Disease

Epidemiology of KTL for constructive comments on the manuscript, and Jukka Ollgren from KTL for statistical advice. We also thank Marja Laasonen, Olli Laitinen and Jukka Sipilä from Haukipudas Municipality for their valuable work in this outbreak investigation.

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https://doi.org/10.1017/S0950268805003808 Published online by Cambridge University Press