*Epidemiol. Infect.* (1991), **107**, 509–519
*Printed in Great Britain*



# Cryptosporidiosis in the Isle of Thanet; an outbreak associated with local drinking water

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(*Accepted 22 July 1991*)

SUMMARY

An outbreak of cryptosporidiosis occurred in the Isle of Thanet during December 1990 and January 1991. A total of 47 cases ranging in age from 2 months to 85 years were identified in residents from the Margate, Broadstairs and Ramsgate areas, with dates of onset of illness from 3 December to 14 January. A case-control study demonstrated a strong statistical association between illness and the consumption of unboiled tap water from a particular source, with evidence of a dose–response relationship. Although no cryptosporidial oocysts were identified in samples of untreated or treated water taken during the investigation, the results were consistent with the view that the source of infection was treated river water which was used to supplement borehole water.

## INTRODUCTION

At the beginning of January 1991 the Consultant Microbiologist at Thanet District General Hospital (TDGH) informed the Communicable Disease Surveillance Centre (CDSC) of the Public Health Laboratory Service (PHLS) that an increase in cases of cryptosporidiosis had occurred in the Thanet area. Twenty-eight cases had been identified since 11 December 1990, compared with an average

expected number of three per month. A previous outbreak of cryptosporidiosis had occurred between February and May 1989 when 65 people resident in the area were affected. At the time, water was considered to be a possible source (E. Ndawula, unpublished).

Cryptosporidiosis was identified during the 1980s as an emerging public health problem and an important cause of acute, self-limiting gastroenteritis in immunocompetent individuals and a protracted, sometimes fatal infection, in immunocompromised people [1]. Laboratories in the UK began routinely to examine faecal specimens for cryptosporidial oocysts in 1983. Approximately 3000 positive reports from England and Wales were received by CDSC each year between 1986 and 1988. This number increased to 7768 reports in 1989 but fell to 4680 in 1990 (CDSC, unpublished). The Microbiology Department at TDGH has screened all liquid stool specimens for cryptosporidia since 1988 and reported positive identifications to CDSC. The number reported was 3 in 1988, 79 in 1989 and 64 in 1990 (E. Ndawula, unpublished).

Following the recommendations of the Badenoch Report [2] and after consultation with the local Consultant in Public Health Medicine (CPHM) an outbreak control team was convened. This comprised representatives from Canterbury and Thanet Health Authority, Thanet District Council Environmental Health Department (EHD), Southern Water Services, the Ministry of Agriculture, Fisheries and Food (MAFF), South East Thames Regional Health Authority, and CDSC. The local general practitioners had already been informed of the possibility of an outbreak by the CPHM. The outbreak control team decided to carry out an epidemiological and microbiological investigation to identify a vehicle or vehicles of infection.

## THE LOCAL WATER SUPPLY

The East Kent Supply area of Southern Water Services supplies water to the whole of Thanet. The area (320 sq km) includes the towns of Margate, Ramsgate, Broadstairs, Westgate, Birchington, Minster, Sandwich and Deal. The population served is 177300, of which at least 100000 live on the Isle of Thanet. Water is mainly obtained from underground sources. During the spring and early summer, water from the River Stour is also abstracted and treated in two parallel process streams at Plucks Gutter. It is used to supplement the well and borehole water during periods of high demand. Plucks Gutter treatment works was built to take advantage of maximum river flows in the spring and is normally in service for 3 months of the year when treated river water is blended with water from another station along a trunk main leading to a covered service reservoir at Fleete. The treatment works supplies up to 10 megalitres a day and up to 29% of the water held at Fleete. The reservoir has a total capacity of 42 megalitres, sufficient for 24 h use. Water is pumped from Fleete to Ramsgate, Broadstairs and Cliftonville, and fed by gravity to Margate and Westgate.

Due to low rainfall and drought conditions, water was continuously abstracted from the River Stour at Plucks Gutter from March to December 1990. The treatment works was shut down as a precaution in December 1990 when Southern Water Services was informed of the outbreak of cryptosporidiosis.

## METHODS

### *Epidemiological*

*Preliminary investigations* An Environmental Health Officer (EHO) from Thanet District Council carried out preliminary interviews with seven adults and one child. His questionnaire sought information on date of onset of illness, details of nursery, school or work place, contact with domestic and farm animals, the consumption of milk, water and various foods, foreign travel, and illness in other household members. Six of the eight cases reported that they drank several cups of cold tap water per day and seven had contact with domestic pets but only one animal was reported as being sick. None of the patients had travelled abroad in the 4 weeks before onset of illness, or consumed unpasteurised milk.

Following this initial investigation it was agreed that a case-control study should be undertaken to test the hypothesis that cryptosporidial infection was associated with the consumption of cold drinking water supplied by Southern Water Services.

### *Case definition and selection of controls*

Primary cases of cryptosporidiosis were defined as people in Thanet who had had an illness with diarrhoea between 1 December 1990 and 31 January 1991, and confirmation of the presence of cryptosporidial oocysts in a stool specimen. Cases were excluded from the analytical study if they had travelled abroad in the 4 weeks before their onset of illness or if another household member had had diarrhoea in the 4 weeks before their onset. Controls were obtained from the registration data held by the Kent Family Health Service Authority (FHSA), and were matched for the same sex, age group, and general practice or health centre as the case. They were excluded if they had been abroad in the 4 weeks before the onset of illness of their matched case, and if they themselves had had diarrhoea since 1 December 1990. Five names and addresses of controls were obtained per case.

### *Questionnaire administration*

A letter was sent to all cases and controls informing them of the outbreak and requesting their assistance with the investigation. Adult cases or controls and parents of child cases or controls were advised that one of the investigating team would be contacting them to carry out a telephone interview. People for whom no telephone number was identified were asked to make a reverse charge call to CDSC for the interview. If no contact had been made after a minimum of five telephone calls or through a reverse charge call, a visit was carried out to the given address by a Senior Registrar in Public Health Medicine to conduct a personal interview.

The questionnaire for both cases and controls sought information on personal and clinical details, foreign travel, illness in other household members, contact with young or sick pets or farm animals, and a food history which included different types of milk, salad items, meat and cheese. Questions on water related to consumption of cold tap water either at home or outside the home, to untreated, filtered or bottled water, and exposure to recreational water. People were also asked if they had noticed any change in the colour, taste or smell of their domestic

tap water or any problems with their drains or sewers, and to specify the type and timing of any change or problem. Questionnaire data were entered onto a computer, verified and analysed using Epi–Info [3] and Egret [4] software.

For clarity, the descriptive analysis is presented without reference to matching, but all inferential analysis was performed using the appropriate test (Mantel-Haenszel) [5] and estimation procedures (odds ratios and confidence limits) for matched data.

*Microbiological and environmental investigation of the water supply*

Large volume water samples were taken using cartridge filters (1 $\mu$m nominal porosity, Cuno Micro-wynd D-PPPY, polypropylene fibre) according to the method of the Department of the Environment Standing Committee of Analysts (SCA) [6]. Fourteen samples of water were taken from several sites. Southern Water Services obtained a 1000-litre sample of treated water from Plucks Gutter and from the Fleete Reservoir on 28 December 1990. Two samples of treated water (630 litres and 598 litres) were taken from Thanet District Hospital at Ramsgate on 3 January 1991. Further 1000-litre samples were taken from Fleete Reservoir on 3 and 9 January, from the River Stour at the Plucks Gutter intake on 3 January and from the sludge lagoon on 9 January. Southern Water Services provided six further samples of between 96 and 344 litres of finished water from dead-ends. Samples were sent either to the Scottish Parasite Diagnostic Laboratory at Stobhill General Hospital, Glasgow, Ashford Public Health Laboratory (PHL) or to the PHLS Cryptosporidium Reference Laboratory at Rhyl PHL where they were examined using the SCA method. Filters were dismantled in the laboratory using a stout, sharp bladed knife and the fibres teased apart. The entrapped material was eluted in a mechanical agitator, using 0·1 % Tween 80, and recovered by centrifugation. Aliquots of the deposit were then examined both directly, and again after further concentration through sucrose, using immunofluorescence microscopy with monoclonal antibodies, as described in the SCA method [6].

Details of the method of river water treatment and the flow and turbidity charts of the River Stour from Plucks Gutter were obtained from Southern Water Services. A senior Veterinary Investigation Officer from MAFF enquired about the incidence of recent slurries in the River Stour or evidence of cryptosporidiosis in animals in the Thanet area. Information on local rainfall for October–December 1990 was obtained from local meteorological records.

## RESULTS

*Descriptive epidemiology*

Forty-seven cases of cryptosporidiosis were identified by the Microbiology Department of Thanet District General Hospital between 11 December 1990 and 2 February 1991. All patients except one were residents of Thanet with the majority living in Margate, Broadstairs and Ramsgate. Forty-three patients (or their parents) were interviewed by telephone. Their dates of onset of illness ranged from 3 December to 18 January, the majority of cases occurring in the first half of December (Fig. 1). Five cases had been admitted to hospital. The age distribution ranged from 2 months to 85 years, median 17 years (Table 1).

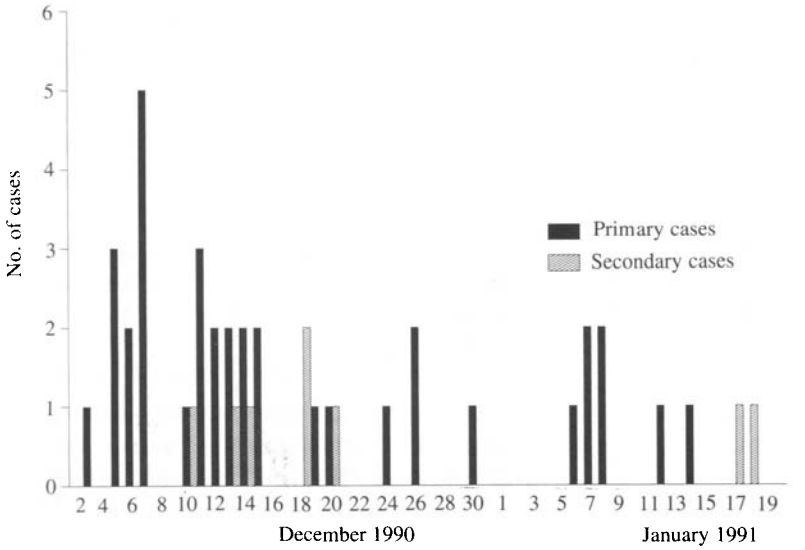


Fig. 1. Cryptosporidiosis in Canterbury and Thanet Health Authority. Date of onset of infection for primary and secondary cases (N = 47; date of onset unknown in 3 cases).

Table 1. *Cryptosporidiosis in the Canterbury and Thanet Health Authority Dec 90/Jan 91; Frequency distribution of cases by age*

| Age–group (years) | All cases |
|---|---|
| < 1 | 4 |
| 1–4 | 13 |
| 5–9 | 3 |
| 10–14 | 2 |
| 15–24 | 5 |
| 25–44 | 13 |
| 45–64 | 3 |
| 65 and over | 4 |
| Total | 47 |
| Median | 17 |
| Minimum age (mths) | 2 |
| Maximum age (years) | 85 |

Altogether 18 of the 47 cases were excluded from the analytical study. Of these, 8 were not primary cases, 1 provided no date of onset, 1 no local GP from which to obtain neighbourhood controls, 2 did not respond, and 6 were reported after the case-control study was completed.

Twenty-nine cases, including six from the preliminary investigation were included in the case-control study. Their ages ranged from 7 months to 85 years (median 27 years) and dates of onset of illness from 3 December to 8 January. Two patients, aged 3 years and 55 years were admitted to hospital. All 29 patients reported symptoms of diarrhoea, 23 reported abdominal pain, 11 fever, 10 vomiting, 19 weight loss and 15 that they had had nausea. Seven cases had a 'flu-like illness in the month before onset of the cryptosporidial infection and five reported that they increased their fluid intake as a result of this 'flu-like illness.

https://doi.org/10.1017/S0950268800049207 Published online by Cambridge University Press

Table 2. *Cryptosporidiosis in the Canterbury and Thanet Health Authority Dec 90/Jan 91; Matched analysis of exposure to different variables by cases and controls in analytical study*

| Variable | Response | * Case | † Control | Odds ratio | *P* ‡ value |
|---|---|---|---|---|---|
| Tapwater (daily) | > 1 cup | 19 | 33 | 8·7 | 0·002 |
| Water consumed outside the home | yes | 15 | 23 | 5·2 | 0·01 |
| Bottled water | yes | 0 | 16 | 0·1 | 0·034 |
| Water filter | yes | 0 | 8 | 0·3 | ns |
| Changes in water | yes | 8 | 15 | 1·8 | ns |
| Blocked drains at home or work | yes | 3 | 6 | 2·3 | ns |
| Swimming pools | yes | 5 | 16 | 0·8 | ns |
| Rivers | yes | 2 | 1 | 3·8 | ns |
| Contact with pets | yes | 6 | 7 | 3·7 | ns |
| Sausages | yes | 23 | 66 | 1·3 | ns |
| Lettuce | yes | 16 | 51 | 0·7 | ns |
| Fresh raw vegetables | yes | 22 | 56 | 1·6 | ns |
| Unpasteurized cheese | yes | 0 | 10 | 0·2 | ns |
| Unpasteurized milk | yes | 0 | 0 | — | — |
| Sheep's milk | yes | 0 | 0 | — | — |
| Goat's milk | yes | 0 | 0 | — | — |
| Untreated water | yes | 0 | 0 | — | — |
| Contact with farm animals | yes | 0 | 0 | — | — |

* Cases (Nmin = 25, Nmax = 29). † Controls (Nmin = 74, Nmax = 80). ‡ ns (*P* value > 0·05).

The duration of illness associated with cryptosporidial infection ranged from 3 to 40 days, median 16 days. Several of those affected reported being unable to carry out normal daily activities for up to 28 days, median 3 days. Adults reported a more severe and protracted infection than children, including a higher proportion of nausea, 'flu-like symptoms and fever. Adults (⩾ 15 years) also reported more frequently than children that their illness lasted between 2 and 3 weeks.

One hundred and fifty-four controls were provided by Kent FHSA. Twenty-two were excluded for the following reasons: 10 because of no response from their matched cases, 1 did not meet the criteria of local residence, 2 were the wrong age or sex, 7 had had diarrhoea themselves since 1 December 1990, 1 had travelled abroad in the 4 weeks before the onset of their matched case's illness, and 1 refused to be interviewed.

*Analytical epidemiology*

Twenty-nine cases and 80 controls (range 1–4 per case), were included in the case-control study. Preliminary matched analyses were performed on the questionnaire variables to assess any significant association between the individual variable and the risk of disease. Of the 18 risk factors investigated, there were five variables to which no-one in the study had been exposed and these were excluded from the matched analysis. The only variables reaching significance in the matched analysis ($P < 0·05$) were consumption of cold tap water drunk both at home and outside the home and the consumption of bottled water, the latter having a protective effect against the risk of infection (Table 2).

A new variable was created, defined as any quantity of water consumed from

https://doi.org/10.1017/S0950268800049207 Published online by Cambridge University Press

the Fleete reservoir, and its effects estimated from an analysis which excluded cases or controls that drank water outside this supply area. Analysis of the daily exposure of more than one cup of Fleete water within individually matched case and control sets showed that consumption was significantly associated with illness, with an estimated odds ratio of 9·4 ($P < 0{\cdot}001$).

The distribution of cases and controls according to the amount of Fleete tap water consumed was examined. Matched analysis using a test for dose response showed a chi-squared test for trend which was highly significant ($P < 0{\cdot}001$). The chi-squared test for non-linearity was not significant, demonstrating an increasing risk of illness with a linear increase in consumption of Fleete water (Table 3).

*Microbiological and environmental results*

Cryptosporidial oocysts were not identified in any of the water samples. The River Stour water is treated by flocculation with an aluminium sulphate coagulant, flotation and filtration. The water is then passed through an activated carbon filter, superchlorinated and dechlorinated prior to entering the distribution system. River water was abstracted at Plucks Gutter treatment works on two occasions in January 1990. Abstraction recommenced on 26 March 1990 using both process streams and continued uninterrupted until 26 November 1990 when one was shut down to repair its mechanical dosing pump. This stream was reopened on 11 December 1990 and Plucks Gutter remained in service until 29 December 1990 when Southern Water was informed of the outbreak of cryptosporidiosis. The proportion of water from Plucks Gutter in the Fleete Reservoir varied from 11 to 29% during the month of November. It reduced to 15% for the last 4 days in the month following the closure of one process stream.

The River Stour's gauged monthly mean flow, measured in cubic metres per second (cumecs) for the months September, October and November 1990 were 1·3, 2·1 and 3·4 cumecs, respectively. River flow was low from July but rose at the end of October when daily readings of 5·6, 10·2 and 6·1 cumecs were recorded on 28–30 October. In November the daily river flow returned to around 2·0 cumecs except for readings from the 26–30 November which were 7·2, 13·6, 15·0, 9·4 and 6·9 respectively.

The Margate area experienced a maximum rainfall of 39·1 mm and 33·3 mm on the 26 and 27 October with a total for the month of 91·2 mm. Corresponding figures for November were 25·2 mm and 13·9 mm on the 24 and 25 November, with a monthly total of 83·8 mm. Total rainfall during December was low at 44·4 mm.

Turbidity charts for both streams at Plucks Gutter provide a continuous record of the treated water turbidity in Nephelometric Turbidity Units (NTU) over 7-day periods. Turbidity increased between 26 and 28 November when readings from number two stream rose from < 1 NTU on the morning of 27 November to 2 NTU at 7 a.m. on 28 November before returning to base line levels on Friday 30 November. This increase in turbidity corresponded with the increase in the flow of the River Stour for the same time period. The treatment works at Plucks Gutter automatically shuts down if the turbidity level reaches 3 NTU. MAFF reported that the area surrounding Plucks Gutter was mainly arable land and land used by farmers for sheep grazing. No incidents of recent water slurries in the River Stour or animal infections were known to have occurred in November or December 1990.

Table 3. *Cryptosporidiosis in the Canterbury and Thanet District Health Authority Dec 90/Jan 91; Dose response of daily consumption of Fleete water by cases and controls in analytical study*

| | Number of cups per day | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 1–2 | 3–5 | ⩾ 6 | NS* | Total |
| Case | 2 | 6 | 9 | 9 | 3 | 29 |
| Control | 35 | 23 | 18 | 4 | 0 | 80 |

* NS. Not stated.

Chi-square test for trend = 23·63 ($P < 0·001$); Chi-square test for non-linearity (2df) = 1·41 ($P = 0·68$).

No routine monitoring of cryptosporidial infections in animals is carried out in Thanet and incidents are only identified if the Veterinary Investigation Centre is contacted for advice.

*Control measures*

Plucks Gutter treatment works was closed by the water company on 29 December 1990. Two cases of cryptosporidiosis occurred with onset in the middle of January, and were reported after the case-control study was completed. They were outside the incubation period for this outbreak and are assumed to be part of the expected monthly incidence for Thanet.

## DISCUSSION

The results of the investigation indicate that this outbreak was associated with the consumption of contaminated drinking water. The supportive evidence includes the temporal acquisition of infection as shown by the epidemic curve, the age distribution of the cases, the matched case-control analysis and the data on the water supply. In waterborne outbreaks of cryptosporidiosis, the whole population is at risk and all ages are affected, as was evident in this outbreak. The median age of those affected increased from 17 to 27 years after the children who were exposed to secondary infection within households had been excluded from the case-control study.

Cryptosporidium is now the fourth most important cause of laboratory confirmed diarrhoea after campylobacter, salmonella and rotavirus [7] with almost 5000 cases reported to CDSC from England and Wales in 1990 [8]. A direct zoonotic source could not account for this number of infections. Although contact with pets was reported by some of the cases in this outbreak, such contact is unlikely to be the source of a widespread community outbreak. Routes of transmission such as person-to-person spread, food and water have been investigated in other community outbreaks [1].

Contaminated water as a source of infection has been demonstrated either epidemiologically and/or microbiologically in outbreaks of cryptosporidiosis investigated in the USA and the UK. The first recognised waterborne outbreak was in 1984 in Texas [9] and was followed by another in Georgia, USA in 1987 [10] where approximately 13000 people were thought to have been infected. In the

UK, the first outbreak of cryptosporidiosis in which oocysts were detected in treated water occurred in Ayrshire in 1988 [11]. Contamination of water after treatment was shown to be the cause of the outbreak. A second outbreak, in 1989 with over 500 confirmed cases in the Oxford and Swindon area was identified as waterborne when oocysts were found in raw water from the reservoir, backwash samples of filtered water and potable water [12]. Issues raised by the Oxford and Swindon outbreak were addressed by a Government Report in 1990 [2]. Outbreaks where water was the suspected source have occurred in Sheffield [13], North Humberside [14] and Loch Lomond [7]. An outbreak associated with recreational water has also been reported [15]. Suspected waterborne outbreaks have been investigated in Blackburn, Cardiff, Frimley, Yarmouth and Bristol (CDSC, unpublished).

In the present study the epidemiological investigations showed a strong statistical association between cryptosporidiosis and the consumption of drinking water supplied by Southern Water Services. The results also showed that drinking bottled water reduced the risk of infection. Although the number of cases identified is relatively small in comparison with some other outbreaks, their degree of morbidity was high. Ten percent of the cases were admitted to hospital and 20 of the 29 cases in the analytical study reported symptoms which lasted for 8 days or more, and 7 patients stated that their symptoms were still continuing at the time of interview, up to 1 month after onset of illness.

No microbiological evidence for the presence of oocysts was found in either the river water or the treated water supplied by Southern Water Services but the epidemiological evidence strongly suggests that oocysts were present in the water consumed by the cases.

Plucks Gutter treatment works was built to operate for only a short period each year during the spring, to take advantage of maximum river flows, but because of drought conditions in 1990 it remained open to abstract water for most of the year. While no major incidents of slurry contamination were recorded, it is possible that accidental contamination of river water occurred during the autumn when slurry was washed off farmland. A combination of environmental factors at the end of November would have increased the potential for contamination: heavy local rainfall, the river in spate, one process stream at the treatment works shut down because of mechanical problems and a coincidental rise in turbidity of the water from the second process stream. The incubation period for cryptosporidiosis is estimated to be 3–11 days but cases are known to occur up to 25 days after exposure to infection [16]. The epidemic curve for the primary cases in this outbreak is consistent with exposure to contaminated water at the end of November.

Treatment works have to adjust to a wide range of quality in abstracted river water. River water may contain a large number of faecal bacteria, especially after rainfall. Turbidity monitoring indicates changes in the quality of water and should detect any significant quantities of suspended particles. Low turbidity is not necessarily indicative of an absence of oocysts, as turbidimeters are insufficiently sensitive to detect oocysts and other particles in the 1–10 micron range [17]. However, a small deviation in turbidity levels can suggest disturbance in treatment efficiency. Plucks Gutter shuts down automatically when turbidity

reaches 3 NTU but since the outbreak the treatment works has been adapted to close down when turbidity reaches 1 NTU. This corresponds with current policy elsewhere [18].

Current methods of water purification have evolved from systems which were originally designed to eradicate faecal bacteria. Oocysts are assumed to enter untreated water supplies through accidental agricultural pollution, heavy rainfall and the resultant run off from agricultural land into rivers or reservoirs, often in the autumn. The practice of disposing of animal and human excreta on to the land via slurry spreading may lead to infection by contamination of water courses and reservoirs. Contamination may also arise from the discharge of sewage effluent. Normal water treatment processes may not be able to cope with a sudden discharge of large numbers of oocysts into the untreated water. Cryptosporidial oocysts are unaffected by chlorination, leaving physical methods of removal such as filtration and flocculation as the only current effective means of treatment [19].

The routine monitoring of treated water for cryptosporidiosis is not recommended by the Badenoch Committee owing to its cost, the shortcomings in the current methodology of water sampling and also the lack of information on the infective dose of *cryptosporidium* for humans [17]. Recent veterinary studies indicate that the infective dose in lambs is less than 10 oocysts and is probably one oocyst (DP Casemore, unpublished). It is not clear how this data should be extrapolated to humans. All the samples taken by Southern Water Services for this outbreak were negative for the presence of oocysts, as were the weekly 1000-litre samples of treated water from Plucks Gutter taken from May to August 1990. However, negative results may not imply absence of oocysts. Results from analysis of filter samples by the standard SCA method generally yield results which give recovery efficiencies of approximately 10% or less (DP Casemore, unpublished). Only a small proportion of Plucks Gutter treated water was sampled and negative results should be considered in the light of the known inefficiency of the method of testing [20].

This study of the outbreak of cryptosporidiosis in Thanet has demonstrated the importance of local surveillance of cryptosporidiosis. Once the outbreak was recognised, prompt intervention by the water company and close liaison between themselves, the local CPHM, EHD, and CDSC prevented the occurrence of further cases of infection.

## ACKNOWLEDGEMENTS

We would like to acknowledge the willingness with which Southern Water Services and in particular Mr R. Collett, provided assistance and information in this outbreak investigation. We would also like to thank the following people for their help: Ms J. Hollyer, CDSC; Dr C. Dulake, Ashford PHL; Dr H. Smith, Scottish Parasite Diagnostic laboratory, Stobhill General Hospital, Glasgow; Rhyl PHL; Dr P. Savage, Kent FSHA; Mr P. Gayford, MAFF; and Dr M. Fletcher, The Central Surgery, Birchington, Kent.

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