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An outbreak of waterborne cryptosporidiosis in Swindon and Oxfordshire

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SUMMARY

An outbreak of cryptosporidiosis resulted in 516 cases in Wiltshire and Oxfordshire. The outbreak caused widespread interest and led to an official inquiry. The majority of cases were in children; 8% of cases were admitted to hospital and the median duration of illness was 3 weeks. The geographical distribution of cases matched the distribution of water supplies from three treatment works and cryptosporidium oocysts were found at these works and in the treated water. Attack rates in electoral wards supplied by the three treatment works were significantly higher than in other wards. The cause of the outbreak appeared to be the failure of normal treatment to remove oocysts. Measures at the treatment works reduced the number of oocysts detected in treated water, after which the outbreak came to an end. The conclusion of the investigations was that cryptosporidiosis is a risk of conventionally treated public water supplies.

INTRODUCTION

Cryptosporidiosis is a recently recognized cause of diarrhoeal illness in man (1–4). In those with normal immunity the infection causes a profuse but self-limiting diarrhoea. In those with immunosuppression, however, infection causes a persistent and potentially life-threatening illness (5–8). Cryptosporidia species are widespread in the environment. The infection is contracted through ingestion of oocysts (9, 10). This can occur following contact with infected animals or by ingestion of contaminated water or foodstuffs (11–16). Person-to-person spread also occurs (17–22). Water-borne infection can result from drinking untreated water or due to contamination of treated water supplies (13–16). The problems that may arise from contaminated public water supplies are demonstrated by this outbreak which occurred in Swindon and Oxfordshire at the end of 1988 and in early 1989. The outbreak became the focus of widespread interest in the United Kingdom among the public and the media leading to a local enquiry and questions in parliament [23]. Concern about the safety of water supplies led to the Badenoch Inquiry and Report, which has far-reaching implications for the water providers, health authorities and local authorities [1].

THE OUTBREAK

A rise in the number of cases of cryptosporidiosis was noticed by microbiologists in Swindon and Oxfordshire in January 1989. Since testing of stool samples began in 1986 at the Oxford Public Health Laboratory (PHL), there had been an average of 4–5 cases per month in Oxfordshire. In December 1988 and January 1989, there were 36 cases in Oxfordshire. Initial investigations of the first cases failed to demonstrate a common factor between cases. The number of cases continued to increase throughout January to February and remained at a high level in March. Mapping of the addresses of early cases suggested an association with water supply. The subsequent epidemiological investigations, described below, tested this association. Investigations by the water authority in late February detected cryptosporidium oocysts in samples from the water treatment works which supplied the affected areas and in the treated water.

The investigation and management of the outbreak was undertaken jointly by representatives of all the interested agencies. These were Swindon and Oxfordshire Health Authorities, Oxford PHL, Thames Water, and Thamesdown, North Wiltshire, Cherwell, Oxford City, South Oxfordshire, Vale of White Horse and West Oxfordshire District Councils. Weekly meetings were held during the course of the outbreak at which control measures were planned. A plan for the distribution of information to the media, the public and to necessary organizations was agreed.

Measures to limit the spread of the disease in the community were agreed and the water supplier undertook measures to remove oocysts from the water supply. The public were advised to boil drinking water for children aged less than 2 years and for the immunosuppressed, because of the greater risk carried by the disease in these groups. Advice was given to hospitals, nursing homes, and other institutions. Advice concerning hygiene and cross-infection was given to the public. Many enquiries were received from businesses, schools and the public. Despite the distribution of information the outbreak generated much anxiety [24]. Immediate control measures applied by the water suppliers included intensive cleaning of the filtration system, changes in procedures for disposal of waters used to wash the filters, and the removal of sediment from storage tanks and service reservoirs.

The incidence of new cases was monitored throughout March and April 1989. The incidence of disease fell to approaching normal levels by the end of April. It was therefore agreed that the outbreak had ceased and control measures advised for the public could be ended. Surveillance of the incidence of cases of cryptosporidiosis and contact between the agencies continued.

THE WATER SUPPLY

Most of Oxfordshire and North East Wiltshire, including most of Swindon, is supplied with surface water drawn from the river Thames at Farmoor. Exceptions are [1] an area around Witney in West Oxfordshire, which is supplied with surface water drawn at the Worsham works from the river Windrush (a tributary of the Thames just upstream from Farmoor); 2) Chalford near Chipping Norton; 3) southern areas of Swindon and 4) southern Oxfordshire which is supplied from underground aquifers. The supply of water from Farmoor to Swindon began in August 1988. This was to meet the increasing needs of the population and industry there.

At Farmoor there are two treatment works, Farmoor and Swinford. The water is treated by storage, screening, flocculation, passage through rapid gravity sand filters and disinfection by chlorine just prior to distribution. Polyaluminium chloride (PAC) is the preferred flocculant at Farmoor in winter because it produces a stronger floc in cold weather. The sand filters are cleansed by passing filtered water back through them against the normal direction of flow. This process removes accumulated impurities and is known as backwashing. After settling, the water used for backwashing is returned to the head of the works for treatment.

METHODS

Microbiological investigations

The laboratories involved in the outbreak were the Swindon District Microbiology Department, the Oxford PHL and the Horton General Hospital Laboratory, Banbury. All stool samples submitted to the laboratories and tested for cryptosporidium oocysts were examined using a modified Ziehl-Neelsen method (25–27). Since 1986, the Swindon laboratory had tested for cryptosporidium oocysts in all diarrhoeal samples from children up to 10 years and adults when clinically indicated. The Oxford PHL had the same policy except that children up to 14 years were routinely tested. The Banbury laboratory only tested for cryptosporidiosis when there was a specific clinical indication. During the outbreak the policies of all the laboratories changed to test stools from patients of all ages. This change took place from 30 January in Swindon and from 20 February in Oxford. All stools were routinely examined for other pathogens.

Epidemiological investigations

Case definition. A case of cryptosporidiosis was defined as a person with diarrhoea in the outbreak period, from 28 December 1988 to 28 April 1989, and in whose stools cryptosporidium oocysts were detected.

Epidemic curve. Cases over the previous 2 years were reviewed to establish the background incidence of cases. An epidemic curve, showing the onset of illness in each cases, was plotted. The different initial laboratory testing policies and the extension of testing during the outbreak to cover all age-groups made interpretation of the epidemic curve difficult. To control for these factors, only children up to the age of 10 were included in the final epidemic curve.

Questionnaire survey. All cases, or their parents in the case of children, were contacted by telephone or by post and interviewed using a standard questionnaire. The details sought were as follows:

Age and sex; details of the illness including onset, hospital admission, duration of illness, predisposing causes and contacts; exposure to recognized risk factors including pets, farm animals, unpasteurized milk, foodstuffs, travel, nursery school and playgroup and occupation.

Geographical investigations. Home addresses of all cases were mapped. The suspected association with public drinking water supply was tested by calculating attack rates for electoral wards classified by the source of their water. The electoral wards were classified into: wards receiving water purely from the Farmoor Works i.e. surface water from the Thames; wards receiving water from the Farmoor Works mixed with other sources; wards receiving water purely from Worsham Works, i.e. surface water from the Windrush; wards receiving water from neither Farmoor Works nor Worsham.

Water supply investigations

Thames Water took samples from treatment works and carried out tests on untreated, treated, and stored water supplies. The process for testing for cryptosporidia in water is complex, time-consuming and expensive (28–30). Water is tested by passing 1000 litres through 1 micron pore filters (28–30). The filters are washed, the filtrate centrifuged, and the deposits collected. The re-suspended deposit is stained with monoclonal antibodies for cryptosporidium and examined by fluorescent microscopy [27]. The samples were tested by laboratory staff and stored samples were re-examined by three independent observers. These procedures follow the work of Rose and colleagues (30–31). The method allows for the detection of an oocyst concentration of 0·002 per litre.

Water samples were taken from the treatment works, including water from the filters and water which had been used to backwash the sand filters; storage tanks and reservoirs; the distribution system; and consumers' taps. Samples were taken daily from consumers' taps in the area supplied by Farmoor and Swinford Works. Other tests were repeated weekly from 19 February onwards.

RESULTS

Microbiological investigations.

Between 28 December and 28 April, 516 cases were identified as meeting the case definition; 290 in Swindon and 226 in Oxfordshire. During this time period more than 10% of diarrhoeal stool specimens submitted to the laboratories in Swindon and Oxford were positive for cryptosporidia. Three patients had mixed infections: one had salmonellosis and two had giardiasis in addition to cryptosporidium oocysts.

Table 1. *Cryptosporidiosis diagnosed in Oxford and Swindon, 1986–8. Number of cases diagnosed each month from March 1986 to December 1988 at the Oxford PHL and Princess Margaret Hospital, Swindon*

Year...	1986		1987		1988	
Month	A	B	A	B	A	B
1	—	—	6	0	1	2
2	—	—	5	0	1	0
3	1	0	6	0	9	2
4	17	3	12	1	1	2
5	8	3	8	0	1	3
6	7	1	5	0	0	0
7	6	1	3	3	2	0
8	5	0	4	2	3	0
9	3	0	4	2	2	1
10	8	0	1	2	3	1
11	12	0	7	2	12	0
12	6	3	1	1	24	2
Annual total	73	11	62	13	59	13

A, Oxford PHL.
B, Pathology Department, Princess Margaret Hospital, Swindon.

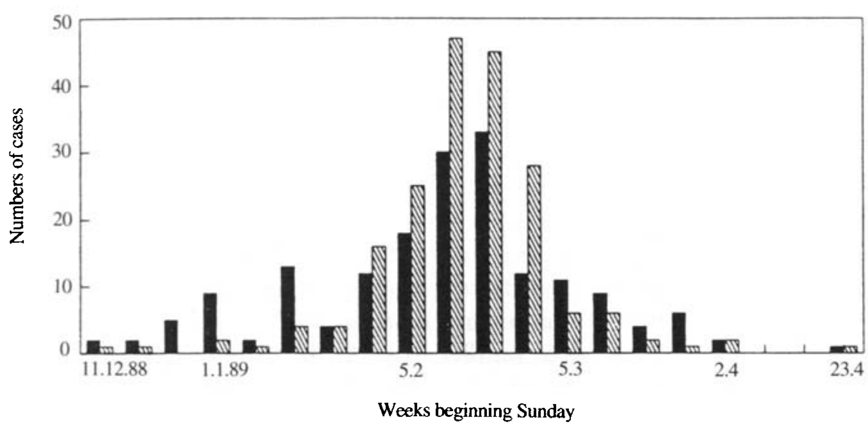

Fig. 1. Epidemic curve: showing the date of onset of illness in children with cryptosporidiosis aged up to 10 years between 28 December 1988 and 28 April 1989 in Swindon and Oxfordshire. ■, Oxon children; ▧, Swindon children.

Epidemiological investigations

Epidemic curve. The cases over the two years prior to the outbreak are shown in Table 1. The epidemic curve for children up to 10 years of age is shown as Figure 1. The majority of cases occurred between 30 January and 28 March 1989. Figure 2 shows the age and sex distribution of 479 patients from laboratory and questionnaire data. 54% of cases were in children aged under 10 years and 37% of cases were aged over 20 years. Among children aged 0–9 years, 62% of cases were in males.

Questionnaire survey. Responses to the questionnaire were received from 407

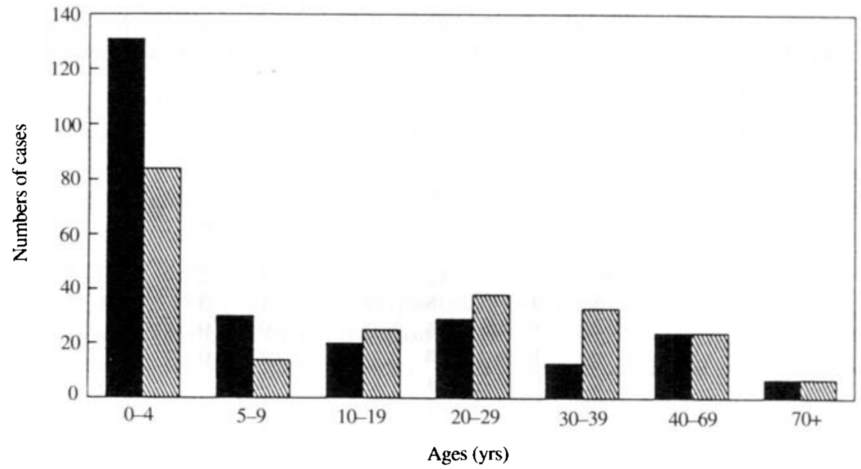

Figure 2. Age and sex distribution of cases of cryptosporidiosis, 28 December 1988 to 28 April, 1989 in Swindon and Oxfordshire. ■, Males; ▨, females.

Table 2. *Duration of illness in 384 cases of cryptosporidiosis, 28 December 1988 to 28 April 1989 in Swindon and Oxfordshire*

Number of days of illness	Number of cases	Percentage of cases (%)
1–7	59	15.4
8–14	123	32
15–21	98	25.5
22–28	56	14.5
29–35	22	5.7
36–42	10	2.6
43–49	3	0.7
50–56	6	2
57–63	2	0.4
64–70	1	0.2
70+	4	1
Total	384	100

people representing 79% of people with cryptosporidiosis during the outbreak. Not all respondents answered all questions. Forty-one patients (8%) were admitted to hospital, in most cases for management of acute diarrhoeal illness. Five patients with HIV infection had persistent and severe diarrhoea [32]. Three other patients had cryptosporidiosis complicating other conditions associated with immunosuppression, due to the condition itself or to its treatment: renal failure, osteosarcoma and dermatomyositis treated with immunosuppressive drugs.

The duration of illness is shown in Table 2. The median duration of illness was 3 weeks. Illness was reported in one or more of the other household members at the time of the onset of their illness for 49% of cases. These persons were not all investigated by examination of stool samples.

Results of questions about exposure to recognized risk factors are shown in Table 3. The results did not indicate any common factor. One percent had drunk

Table 3. *Exposure of cases to factors associated with cryptosporidiosis, 28 December 1988 to 28 April 1989 in Swindon and Oxfordshire*

Risk factor	Percentage exposed (%)
Swimming pool	24
Contact with	
dog	28
cat	29
farm animals	5
Unpasteurised milk	1
Under 5 years at playgroup	42

Table 4. *The incidence of cryptosporidiosis and attack rate by wards classified according to the water supply between 28 December 1988, and 28 April 1989 in Swindon and Oxfordshire*

Water supply source	Number of cases in area supplied	Population in area	Attack rate per 10000 population (95% CI)
Farmoor and Swinford	370	385450	9·6 (8·6–10·6)
Worsham	21	25275	8·3 (4.7–12.9)
Farmoor, Swinford mixed with other	45	110341	4·1 (2·9–5·3)
Not Farmoor, Swinford or Worsham	45	220031	2·0 (1·4–2·7)
Total	481*	741097	

* Addresses were not available for 35 cases.

unpasteurized milk, 24% had recently used a swimming pool and under 30% reported contact with farm animals or domestic pets. Of the children below school age, nearly half attended playgroups but there were no clusters associated with playgroups or schools. The occupations of adults were varied with no predominance of agricultural workers or animal handlers.

Geographical investigations. The cases' home addresses were mapped. The cases in Swindon Health Authority were concentrated in the area supplied by water from the Farmoor water works, whereas the Oxfordshire cases were scattered more widely through the county. When the suspected association with public drinking water supply was tested by calculating attack rates for electoral wards classified by the source of their water, the incidence of cryptosporidiosis in wards supplied with water from Farmoor and Worsham was higher than in other wards. The results are shown in Table 4.

Water supply investigations

From February 1989 to the end of April 1989, 1439 water samples were tested. On 19 February samples of treated water at Farmoor works contained 0·66 oocysts per litre. The water which had been used to wash the sand filters was also tested and contained up to 10000 oocysts per litre. Samples were taken from customers taps in areas supplied by Farmoor and Swinford and 34% of samples collected

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between 20 February and 5 March were found to contain oocysts in the range 0·002–24 oocysts per litre. Between 5 and 20 March only 5 % of samples contained oocysts. Oocysts remained detectable in a small number of samples until 15 April. Two samples from the Worsham works were positive. Samples from other works and distribution systems were tested and found to be clear.

DISCUSSION

This was a large outbreak affecting over 500 people and lasting over 4 months. The possibility of such an outbreak resulting from the contamination of the public water supply is of great concern. It is not surprising that this outbreak, associated with a conventionally treated public water supply, led to widespread public anxiety, media interest and to the Badenoch Inquiry [1].

Although the majority of cases diagnosed during the outbreak were in young children, over a third of diagnosed cases were in adults. It is usually stated that cryptosporidiosis is more common in children [7]. This may reflect a greater susceptibility to the infection, or a greater likelihood of visiting the family doctor with a diarrhoeal illness and having a stool sample tested and hence being diagnosed as having cryptosporidiosis. Laboratory testing policies are based on the increased likelihood of finding cryptosporidiosis in children's stools. This may lead to a greater observed incidence in children as adults are not routinely tested. The predominance of male children is an unexplained finding but reasons suggested for increased incidence in children could also apply here.

The number of patients admitted to hospital and the median duration of illness suggest this is not a trivial disease. The advice given to the public to boil the water was aimed at those considered most vulnerable, i.e. the very young and the immunosuppressed. The effect of the boiling notice in reducing illness is uncertain, and it may have contributed to public anxiety. The decision to issue a boiling notice is complex and it is not certain that the same decision would be made in different circumstances. When boiling notices are issued, it is important that preparations are made to deal with the consequences of the action [24].

The investigation into other possible causes of cryptosporidial outbreaks (apart from waterborne) revealed no common factors. The mapping of the home addresses of cases suggested an association with the supply of surface water drawn from the Thames. This was most striking in Swindon. It was not possible to investigate all exposure to water in each case, for example water supply at place of work or school. The postulated association with water supply was confirmed by finding higher attack rates in wards supplied from Farmoor and Worsham and by the identification of oocysts in treated water and at the works.

The epidemic curve showed the highest rates of onset of illness occurred in early to mid February. The percentage of water samples containing oocysts had fallen to very low levels by mid March. Given an incubation time of between 2 days and 2 weeks, it is possible that the measures taken at the treatment works to remove oocysts from the water were rapidly effective as the epidemic declined as the water cleared.

The significance of finding cryptosporidium oocysts in water is unclear [30]. Neither the viability nor the species of oocysts can be established using existing methods. The normal level of cryptosporidial contamination of untreated water supplies and of treated water is unknown [30–33]. It is of concern that relatively high concentrations of a pathogen can build up in a treated public water supply.

It was observed that attack rates in Swindon were higher than those in Oxfordshire. A possible explanation for this is that the population in Swindon, which had received surface water from Farmoor for the previous year only, had had less exposure to cryptosporidia and hence a lower level of immunity.

During the outbreak, the question of how the cryptosporidium oocysts entered the waterworks was frequently considered. Cryptosporidium oocysts are present in the agricultural environment, originating from the faeces of cattle and sheep, and so will be found in surface waters [34, 35]. Two other outbreaks in the United Kingdom, thought to be associated with waterborne spread, were noted to follow a period of heavy rainfall (16, 36). There was a spell of heavy rain in November 1988. Heavy rain would lead to surface water draining off pasture into the rivers, carrying cryptosporidium oocysts. The mild winter of 1988 led to longer periods of grazing on the land by livestock and could have allowed viable oocysts to survive in large numbers. Cold temperatures decrease the viability of oocysts [7, 9, 10]. A combination of mild weather, increased grazing and heavy rainfall could have led to an unusually high concentration of oocysts entering the water treatment works in water abstracted from the Thames.

Cryptosporidium oocysts are resistant to chlorine at levels used in water treatment but filtration can remove oocysts from water [7, 9, 10]. The large number of oocysts found on the filters at Farmoor demonstrated the ability of the filters to trap oocysts. When the number of oocysts entering the treatment works is high, filtration will not be sufficient to prevent some oocysts passing through the works so contaminating the treated water.

Waterborne outbreaks have been reported elsewhere [12–15, 36, 37]. A waterborne outbreak associated with a filtered public water supply occurred in Carroltown, USA [13]. There was evidence of pollution by farm effluent of the river from which water was drawn for treatment by filtration. The implication was that conventional treatment may be inadequate for heavily contaminated water. In other waterborne outbreaks, there were faults in the water treatment or distribution which could explain how oocysts contaminated the drinking water [14, 15, 37]. In the outbreak in Swindon and Oxfordshire, no faults were found in the treatment works nor in the parameters of water quality that are routinely monitored. We conclude, therefore, that cryptosporidial infection is a risk of treated water supplies using existing methods and that techniques of abstraction and treatment must be further researched and developed to prevent waterborne outbreaks.

The management of the outbreak involved the cooperation of many agencies. Regular meetings took place between senior officers, who formed an outbreak control team. Prior planning for such an incident would have improved communication at the very early stages. It was agreed after the outbreak that those with responsibility for public health and water quality should plan together how such incidents in the future would be handled.

The concern generated by the outbreak led to the Badenoch Inquiry into cryptosporidium in water supplies [1]. Our conclusions, concerning the risk of conventionally treated supplies and the need for planning, were presented by representatives of the outbreak control team in the evidence given to the Inquiry. The Badenoch Report made a number of far-reaching recommendations concerning surveillance and control of waterborne cryptosporidial infection and the need for further research. All health and local authorities and water companies are now charged with developing outbreak plans to deal with cryptosporidiosis outbreaks and with providing appropriate advice to the public. Water companies have been given instructions regarding means of minimizing the risk of oocysts passing into public water supplies [1, 38]. The designation of cryptosporidiosis as a notifiable disease would aid the implementation of the recommendations of the Badenoch Report.

Following the experience of a large outbreak of cryptosporidiosis in Swindon and Oxfordshire, it must be accepted that, until techniques of water treatment are improved or new techniques developed, cryptosporidiosis will remain a risk of public water supplies.

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This paper expresses the views of the authors which are not necessarily those of their employing organizations.

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