

Outbreak of *Cryptosporidium parvum* among children after a school excursion to an adventure farm, South West England

M. R. Hoek, I. Oliver, M. Barlow, L. Heard, R. Chalmers and S. Paynter

ABSTRACT

We present the results of an outbreak investigation on a *Cryptosporidium parvum* outbreak among 35 people, (27 students and 8 teachers), who participated in a school excursion to an outdoor adventure farm in South West England, from 22 to 26 May 2006. A cohort study was implemented to investigate possible sources of infection during the farm visit. The most likely transmission route was contact with faecally contaminated surface water following heavy rainfall, or consumption of water from the private well. Disinfection of the water reservoir was by chlorination, to which *cryptosporidium* is resistant. Supplemental disinfection or filtration methods of private water supplies on livestock farms may be needed. This study highlights the fact that epidemiological investigations of outbreaks as a result of environmental exposures are complex but important to inform the public and health professionals of the risks posed by private water supplies and outdoor activities. This is particularly so after heavy rainfall, as this may result in an increased effluent from faecally contaminated land, causing a wide variety of pathogens to wash into surface water and potentially, private wells. This poses risks for public health.

Key words | faecal contamination, heavy rainfall, outdoor activities, private wells, surface water, zoonoses

M. R. Hoek (corresponding author)

I. Oliver

Health Protection Agency, The Wheelhouse,
Bond's Mill, Stonehouse, Glos GL10 3RF,
UK

Tel.: 00441453829740

Fax: 00441453829741

E-mail: HoekMR@gmail.com

M. Barlow

L. Heard

S. Paynter

Health Protection Agency, Sedgemoor Centre,
Priory Road, St. Austell PL25 5AS,
UK

R. Chalmers

Singleton Hospital,
Sketty, SA2 8QA Swansea,
UK

INTRODUCTION

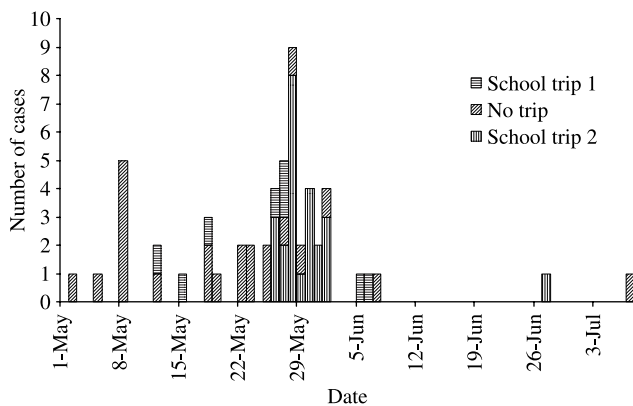
In July 2006, the Cornwall Health Protection Unit was notified of an outbreak of diarrhoea and vomiting among children in a primary school. The school was a non-boarding school, meaning that children went to school in the morning, and went home again in the evening. Two separate school excursions to two different outdoor activity centers had been organised prior to the increase in the number of cases. The excursions were attended by two different groups of children, aged between 10–12 years. The first trip took place between 15–19 May, and the second trip from 22–26 May. The school excursions took place during a prolonged period of heavy rainfall. Cancellation of the school excursions due to the adverse weather conditions had been discussed, but was decided against. Analysis of school data on which children participated in the excursions, combined

with sick-leave data, identified 75 children symptomatic with diarrhoea and/or vomiting between May 1st and July 5th. An ongoing problem of diarrhoea and vomiting at the school due to Norovirus activity was suspected. However, **Table 1** and the epidemic curve in **Figure 1** show a clear increase in the number of children with diarrhoea who went on a school trip to an outdoor activity centre during 22–26 May (School trip 2). Four stool samples sent from those who went on this school trip were found positive for *Cryptosporidium parvum*. A cohort study was implemented of the 27 students and 8 teachers who participated in the second school trip. A standardized postal questionnaire was sent out to record symptoms, medical care, food and water consumption, and participation in the various activities organized during school trip 2.

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Table 1 | Attack rates of diarrhoea and vomiting

	Number	Diarrhoea	Vomiting
No school trip	29	24%	37%
School trip 1	19	5%	58%
School trip 2	27	78%	37%



Note: For 12/19 attendees to school trip 1, no date of onset of disease was available.

Figure 1 | Number of cases with diarrhoea and/or vomiting, May–July 2006.

The farm centre

The outdoor adventure farm is a well-established residential centre, operated by experienced staff. The children's activities supervised by the school staff included art and craft activities, while moorland exploration and several water based recreational activities, including a water slide, were led by the County Council youth service. Participants were housed in dormitories with shared bathroom facilities, and food was served in the main house, where wash hand basins with hot and cold water, liquid soap, cloth, and paper towels were available.

Cryptosporidium parvum

Cryptosporidiosis is a gastrointestinal disease caused by microscopic parasites of the genus *Cryptosporidium*. Farm animals are a natural host of *Cryptosporidium parvum*, and in particular, sheep and lambs are known to shed large quantities of oocysts during lambing season which generally starts the 1st of March and ends 31st of July (Smerdon 2003). Heavy rain can cause the oocysts to be washed off the

land and accumulate in large quantities in surface water, and streams (Chevallier *et al.* 1992; Benedetto *et al.* 2005). The parasite is very resistant to chlorine based disinfectants. *Cryptosporidium* can be found in soil, food, water, or surfaces that have been contaminated with infected human or animal faeces, and is one of the most common causes of waterborne disease. In humans, asymptomatic infections are common. In those who are symptomatic, diarrhoea is the most common symptom, which may be profuse and watery, and is generally preceded by anorexia and vomiting in children. The diarrhoea is associated with abdominal cramps and pain. General malaise, fever, anorexia, nausea, and vomiting occur less often. Symptoms generally begin 2 to 10 days (average of 7 days) after infection, and last about 1 to 2 weeks.

METHODS

Microbiological investigation

Four stool samples were sent in from those who participated in school trip 2 and who had symptoms of illness. All samples tested positive for *Cryptosporidium parvum*, and one was also positive for *Campylobacter*, using microscopy and auramine modified acid fast stain colouring.

Environmental investigation

On the 12th of June, a site visit was carried out by members of the South West Peninsula Health Protection Unit, the *Cryptosporidium* Reference Unit and the Environmental Health Department of North Cornwall District Council, to identify possible routes of transmission. During the visit, a number of potential sources of infection and transmission routes were detected. Lambs and calves, the likely source of infection, grazed the fields around the farm. The animal health department did not undertake testing of animals on the farm, because farm animals are a natural host, and have high carriage rates of *Cryptosporidium parvum* in farm (Stanley & Jones 2003; Robinson *et al.* 2006). Therefore, testing would not add new valuable information. Possible transmission routes included a pond and a stream in which the students had played, which was vulnerable to run off

from grazed fields. The fields where activities had been organised were contaminated with sheep and cow faeces, including a sloping field where a waterslide had been set up.

Another possible transmission route was the private water supply on the farm. The farm has a well situated in a field below the farmhouse. The water from the well is pumped into a reservoir on a hill above the farmhouse. The well was not fenced off from livestock. Instead, a low wall of cement blocks and a cover of corrugated roofing material, held down by weights, protects the well from effluent and prevents animal interference. However, cracks at ground level were visible through which plant roots could be seen growing into the well. In addition, livestock faeces were present beside the well wall and rabbit faeces on the well cover. The water reservoir on top of the hill is routinely disinfected by batch dosing of sodium hypochlorite. This chlorination was assessed by the Environmental Health Department only weeks before the outbreak and found to be satisfactory. The reservoir had been routinely emptied, cleaned, and chlorinated just before the site visit of the health protection unit. The well water was tested on the 12th and 19th of June, and was negative for indicator bacteria.

Epidemiological investigation

A retrospective cohort study was undertaken to investigate possible associations between illness and all activities organized during the farm visit. Standardized questionnaires regarding symptomatology, medical care, food consumption, and participation in any of the activities organised during the excursion, were sent to the school for distribution to all attendees, children and teachers, of the school trip to the outdoor adventure farm from 22–26 May. Completed questionnaires were then entered into an Access database. Descriptive and single variable analyses were undertaken using STATA.

Inclusion criteria

A confirmed case was defined as any person from the school, participating in the second school trip to the outdoor adventure farm from 22–26 May. Presenting with diarrhoea (3 or more loose stools within 24 hours), for at

least two days, and a faecal specimen positive for *Cryptosporidium* between May 22nd and June 9th 2006. A probable case was defined as any person from the school who participated in the farm visit, presenting with diarrhoea, of at least two day duration, between May 22nd and June 9th 2006.

Exclusion criteria

Any case with a household member who had diarrhoea and/or vomiting in the 1–7 days before onset of diarrhoea and/or vomiting in the case, and cases with a disease duration of less than two days.

RESULTS

Of the 35 questionnaires sent out, 26 were received, response rate: 74%. Two cases were excluded from the analysis because they reported a family history of diarrhoea and vomiting within 1–7 days prior to onset of symptoms, a further four cases were excluded for they had either no diarrhoea, or a disease duration of only one day. Seventeen of the 20 remaining respondents matched the case definition. Three respondents with no history of disease were used for comparison. The attack rate among respondents was 85%. Fourteen students and six teachers were included in the study. The attack rate among students was significantly higher than among the teachers (Table 2).

Symptoms among cases included diarrhoea (100%), abdominal pain (84%), fatigue (63%), and vomiting (58%). Nine cases sought medical advice (47%), and two cases were hospitalized (11%). The reported duration of illness ranged from 2 to 37 days, with a mean of 9.4 days. The epidemic curve, shown in Figure 2, suggests that exposure to *Cryptosporidium parvum* took place in the first three days of school trip 2, 22–26 May. The shape of the curve and the fact that all cases fall within the minimum and

Table 2 | Attack rate among attendees

	Number	Attack rate
Students	14	100%
Teachers	6	50%

maximum known incubation period indicate a point source outbreak.

Single variable analysis of the completed questionnaires indicates several possible associations with illness. In Table 3, the exposures are classified according to the type of exposure. Some activities involved contact with surface water, of which wading in the stream and crawling through a drainage pipe were most significantly associated with illness. None of the activities that took place in the barn were significantly associated with illness. However, when the activities in the barn were grouped, a significant association became apparent. A waterslide was set up on the ground of a sloping hill, which was contaminated with animal faeces, but was not significantly associated with illness. Only one person, a teacher, reported to have consumed solely bottled water, all other participants to school trip 2 reported to have been drinking tap water. Nonetheless, this teacher was also symptomatic. Multivariate analysis did not reveal more information as a result of high participation rate in the activities and the high attack rate among the participants, resulting in a very small number of people in the comparison group.

DISCUSSION

The identification of the outbreak was delayed by an ongoing problem of diarrhoea and vomiting at the school, probably due to increased Norovirus activity in the wide community, and could offer a possible explanation for the diarrhoea and vomiting among children who did not participate in school trip 2. The main challenge with this outbreak investigation was the multitude of possible risk factors. Many activities involved exposure to either surface

water or animal faeces, which are both known risk factors. Thus, there may have been more than one source, although the epidemic curve in Figures 1 and 2, suggest a common point source of infection. The high attack rate, combined with the high participation rate in the activities further complicated the investigation, and limited the usefulness of the epidemiological investigations such as the use of multivariate analysis.

Although *Cryptosporidium* can spread readily from person to person, the setting, the shape of the epidemic curve, plus the fact that the agent isolated was *Cryptosporidium parvum*, as opposed to *C. hominis*, all suggest that cases were infected through a common transmission route, and from an animal source. Single variable analysis indicates that potential sources were contact with contaminated surface water, consumption of contaminated drinking water, and direct contact with animal faeces in the barn.

The association between illness and having spent time in the barn may however be due to the fact that all participants were at some point during the week present in the barn. This would explain why individual activities in the barn did not show a significant association with disease, but when the activities were grouped, the barn was associated with disease. Although the barn was not used to house animals, there has been possible exposure to *Cryptosporidium parvum*, as sheep and lambs were able to enter the barn and sheep droppings were present.

The private well is another possible source of infection, and cannot be excluded as a risk factor. The only form of disinfection of the water reservoir was by chlorination, to which cryptosporidium is resistant. The negative testing result of the well water reduces the probability that the drinking water was the source of infection. Simple chlorination of private water supplies on livestock farms may be inadequate to prevent disease outbreaks such as the one described in this paper, particularly after heavy rainfall. Heavy rainfall may cause contamination of private well water through subsurface or preferential flow which can carry oocysts and other pathogens (Kisteman *et al.* 2002; Darnault *et al.* 2003). Supplemental disinfection or filtration methods of private water supplies may be needed. A dose-response effect calculation of illness and consumption of well water could not be performed as neither children nor

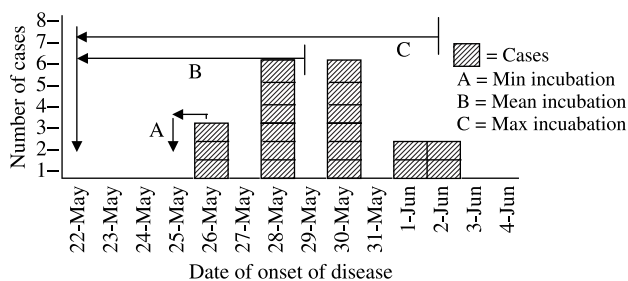


Figure 2 | Incubation periods for *Cryptosporidium* outbreak ($n = 20$).

Table 3 | Single variable analysis, association between activities and illness

Activity	Cases		Comparison group		Risk ratio	CI	P value (Fisher's exact test)
	Participated	Not participated	Participated	Not participated			
Exposure to surface water:							
Bridge clues/walking through stream	2	15	0	3	1.20	0.98–1.48	1.00
Fell in the water during pond crossing	5	12	0	3	1.25	0.97–1.61	0.54
Cross the pond on a surfboard	13	4	1	2	1.39	0.78–2.50	0.20
Crawling through drainage pipe	13	4	0	3	1.75	0.92–3.23	0.03
Wading in stream	14	3	0	3	2.00	0.90–4.45	0.02
Exposure to the barn:							
Story telling in barn	14	3	2	1	1.17	0.64–2.12	0.51
Fun & drama activities in the barn	10	7	1	2	1.17	0.79–1.74	0.57
Blindfolding in the barn	1	16	0	3	1.18	0.97–1.44	1.00
Art activities in barn	12	5	1	2	1.29	0.79–2.12	0.27
Clay handicrafts in barn	9	8	0	3	1.38	0.96–1.97	0.22
Face painting in barn	13	4	1	2	1.39	0.78–2.50	0.20
Drawing in the barn	13	4	1	2	1.39	0.78–2.50	0.20
All barn activities	15	2	0	3	2.50	0.85–7.31	0.01
Exposure to the waterslide:							
Waterslide	13	4	1	2	1.39	0.78–2.50	0.20
Exposure to other activities:							
Water balloon fight	10	7	1	2	1.17	0.79–1.74	0.57
Emergency training	2	15	0	3	1.20	0.98–1.48	1.00
Lunch in the field	15	2	2	1	1.32	0.58–3.00	0.40

teachers were able to recall the quantity of water consumed for each day during their stay at the farm.

The heavy rain during the lambing season may have caused the accumulation of large quantities of oocysts in surface water, and has been observed in other studies (Handysides 1999; McGuigan 2005; Ihekweazu *et al.* 2006; Nichols 2006). During surface water activities, many students fell into the water, waded in the water, and splashed surface water in their faces. Public awareness of the of the risk of infection from environmental sources, and knowledge of simple interventions - such as avoiding swimming in or ingestion of surface water prone to effluent from grazed fields, and hand washing before meals - needs to be improved.

Valuable information was gained during the site visit by the health protection unit, and is recommended in this type of situation. Although only minimal microbiological testing

was undertaken, the visit enabled a clear assessment of the various environmental risks posed by many of the activities on the trip, and by a thorough examination of the private water supply. Standard risk assessments for school trips and similar activities need to include assessment of environmental risks

Meetings were held with the health and safety staff of the county council, who are responsible for performing the risk assessment for school trips, to increase awareness of environmental risks of outdoor activities. The farm owners were recommended to prevent animals from entering the barn where activities are being held, to provide clean running water, liquid soap, and disposable paper towels rather than shared cloth towels for hand washing, and were advised on improved methods of disinfection of the well water by both the Environmental Health Department and Cryptosporidium Reference Unit.

This outbreak is another example in the growing body of evidence linking environmental contamination with outbreaks of infectious disease. Such outbreaks are often found to be due to contamination of fields, surface water, or wells, with animal or human faeces. Environmental contamination is an often-underestimated risk, and public perception needs to be raised to reduce the risk of infection to those undertaking outdoor activities.

CONCLUSIONS

This study highlights the fact that epidemiological investigations of outbreaks as a result of environmental exposures are complex but important to inform the public and health professionals of the risks posed by outdoor activities, particularly after heavy rainfall. As heavy rainfall may cause contamination of surface water through increased effluent of grazed land, and contamination of private well water through subsurface or preferential flow which can carry oocysts and other pathogens. Disinfection of private water reservoirs by chlorination alone may not be sufficient to eliminate all pathogens. Supplemental disinfection or filtration methods of private water supplies, particularly on livestock farms and outdoor activity centres in close proximity of grazed fields are recommended.

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