

Report of an Outbreak of
Cryptosporidiosis in the
area supplied by
Milngavie Treatment
Works –
Loch Katrine Water

Produced on behalf of the
Outbreak Control Team by



November 2001

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Produced by Greater Glasgow NHS Board (GGNHSB), formerly known as Greater Glasgow Health Board (GGHB), on behalf of the Outbreak Control Team which included representatives from GGHB, Glasgow City Council, the Scottish Centre for Infection and Environmental Health and the West of Scotland Water Authority. Representatives of the Scottish Executive Water Quality Regulation Team attended OCT meetings as observers and provided technical advice as the regulator of the water authority. November 2001.

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Glossary

CPHM – Consultant in Public Health Medicine
DETR – Department of the Environment, Trade and the Regions
DoE – Department of the Environment
DoH – Department of Health
DWI – Drinking Water Inspectorate
EHO – Environmental Health Officer
ESW – East of Scotland Water Authority
GCC – Glasgow City Council
GGHB – Greater Glasgow Health Board
MAFF – Ministry of Agriculture, Fisheries and Food
MTW – Milngavie Treatment Works
NTU – Nephelometric Turbidity Unit
OCT – Outbreak Control Team
PAG – Problem Assessment Group
SAC – Scottish Agricultural College
SCIEH – Scottish Centre for Infection and Environmental Health
SERAD – Scottish Executive Rural Affairs Department
SE-WQRT – Scottish Executive Water Quality Regulation Team
SPDL – Scottish Parasite Diagnostic Laboratory
UK – United Kingdom
WIC – Water Industry Commission
WOSWA – West of Scotland Water Authority
WTW – Water Treatment Works

1. Summary

This document is a report of the investigation of an outbreak of cryptosporidiosis that affected residents within Greater Glasgow Health Board (GGHB), an area with a population of over 900,000 people, during the spring of 2000. There were 77 cases of cryptosporidiosis notified to GGHB during May and June 2000, including 6 patients requiring hospitalisation and one death in an elderly person. Subsequently, 13 additional cases were confirmed by the Scottish Parasite Diagnostic Laboratory during the same period that had not been reported by the various district laboratories to the health board, providing a total figure of 90 cases. This increase in cases was subsequent to a small increase in turbidity and the detection of a relatively low count of *Cryptosporidium* oocysts detected in a 732 litre sample from the final water (chlorinated although unfiltered) from Mugdock reservoir. This reservoir is just over half of the total water chlorinated at Milngavie Treatment Works which supplies a total population of 703,265.

The banks of Loch Katrine are home to the largest sheep farm in Scotland with roughly 16,000 ewes and lambs. High counts of *Cryptosporidium* oocysts were detected in sheep faeces sampled in the catchment area of this supply, although these appear to be genotypically different from those found in the human faecal specimens. Subsequent epidemiological investigations have confirmed the increase in cases of infection to be a common source outbreak of cryptosporidiosis strongly associated with drinking water from Loch Katrine, supplied via Milngavie Treatment Works.

Membership of the initial Problem Assessment Group (PAG) and Outbreak Control Team (OCT) is listed in Appendix 1. A listing of the meetings held by these groups is in Appendix 2.

2. Background to the Outbreak

2.1 The epidemiology of *Cryptosporidium* infection in the UK

Cryptosporidiosis is an infection caused by a protozoan parasite of the genus *Cryptosporidium*. Human infection is almost always associated with infection by the species *Cryptosporidium parvum*. The infection is characterised by watery diarrhoea usually of 1-2 weeks duration, which can be further prolonged. In the vast majority of infections the illness is self-limiting. In certain immunocompromised individuals the diarrhoea can be very severe and the infection, which can become systemic, potentially life threatening.

There are two main genotypes of *C. parvum* currently described, types 1 and 2. In natural infections, genotype 1 strains are exclusively limited to infection in humans and have been implicated in outbreaks associated with human sewage. A recent example is the second out of three successive waterborne cryptosporidiosis outbreaks occurring in Northern Ireland during 2000 and 2001 where a septic tank serving a family that included an infected case was implicated in the contamination of a public water supply resulting in illness in 180 people (John McKee, personal communication).

C. parvum genotype 2 strains infect both human and non-human hosts including livestock such as cattle and sheep, pets and feral mammals. Surveys of the occurrence of *Cryptosporidium* species in faecal samples demonstrate that most, if not all, mammalian species can be infected with *C. parvum* (Sturdee et al 1999). Cross-transmission of genotype 2 between cattle and humans has been confirmed as has that between sheep and humans, and therefore, cattle and sheep are presently considered the most important reservoirs of human infection (Fayer and Ungar 1986; Current 1986; Casemore 1989^a; Casemore 1989^b; Casemore 1990; Dawson et al 1995).

Companion animals, particularly sick young pets, have been implicated in human infection, although they do not appear to represent a major source of infection (DoE/DoH 1990; Casemore 1990).

Symptomatic infection in livestock appears to be restricted most often to very young diarrhoeic calves and lambs. Infected calves may suffer from severe diarrhoea for up to 14 days and may excrete as many as 10^7 oocysts per gram of faeces (10^{10} oocysts daily) (DoE/DoH 1990). Infected lambs appear to excrete similar numbers of oocysts per gram of faeces (Blewitt 1989). Both calves and lambs can be asymptomatic oocyst excretors. In addition, adult cattle and sheep may act as asymptomatic excretors and may continue to shed oocysts intermittently throughout their lives, thus acting as a reservoir not only for the young of their own species (through faecal contamination of the teat and the general environment) but for humans as well (Kemp et al 1995). Although the concentration of oocysts is much lower in asymptomatic livestock the volume of their faeces (an adult cow excretes 30-40 kg of faeces every day) ensures that the annual contribution to the environment is substantial and therefore both adult and juvenile livestock may transmit the disease to humans both directly or indirectly (by contaminating the ground and water courses).

There are many possible routes of exposure for *Cryptosporidium*. Infection can be spread from animals to humans directly, or indirectly via food, milk or water. More uncommonly, person-to-person transmission is possible resulting in secondary cases, although no formal exclusion of cases or contacts in high-risk groups to prevent secondary transmission is imposed in the U.K.

Perhaps reflecting the importance attached to this infection by government, Cryptosporidiosis has been the subject of three reports from expert committees in the U.K., which are colloquially known as ‘*Badenoch I*’ (DoE & DoH 1990), ‘*Badenoch II*’ (DoE & DoH 1995) and the ‘*Bouchier Report*’ (DETR & DoH 1998), named after the chairmen of their committees. Other useful reviews are given by Meinhardt, Casemore and Miller (1996) and Hunter (1997).

2.2 The cryptosporidiosis scene in Scotland

Reports of cryptosporidiosis in Scotland are submitted from all NHS laboratories to the Scottish Centre for Infection and Environmental Health (SCIEH) as part of national surveillance. Rates for GGHB tend to be substantially lower than the national averages, with the exception of the figures for 1993 (see Table 1).

Table 1

Rates of reported cryptosporidiosis infection per 100,000 per annum for GGHB area and Scotland for period 1988-1999. (Source: Scottish Centre for Infection and Environmental Health).

Year	Region	
	Greater Glasgow	Scotland
1988	4.25	10.71
1989	9.64	23.56
1990	7.89	15.5
1991	9.32	19.22
1992	12.96	18.66
1993	21.84	17.57
1994	9.81	16.85
1995	7.12	14.25
1996	5.05	12.05
1997	8.06	13.46
1998	8.77	17.16
1999	9.05	11.68

The annual reported incidence of *Cryptosporidium* varies considerably between health boards in Scotland, although some health boards have consistently high reporting rates. Some of these differences will reflect different testing and reporting behaviour between laboratories. In addition, rural farming areas characterised by freely grazing animals and private water supplies may be expected to experience more of this zoonosis than urban areas.

2.3 Outbreaks in Scotland, the UK and elsewhere

There have been a number of outbreaks identified in the U.K. over the past two decades, the most commonly identified cause of which was mains drinking water, though outbreaks have also implicated swimming pools and farm visits (CDSC Northwest 1999). A summary table of 25 *Cryptosporidium* outbreaks occurring in the U.K. between 1988 and 1998 and thought by the Bouchier Committee to be associated with drinking water is included in Appendix 3 (DETR & DoH 1998). It reveals that more than 50% occurred despite some level of filtration being in place at the treatment works when filtration is the prescribed method of removing *Cryptosporidium* oocysts from water supplies. It also reveals that more than 50% of these outbreaks occurred in the absence of positive identification of *Cryptosporidium* oocysts in the water samples tested, perhaps reflecting the insensitive testing methodology in existence (DETR & DoH 1998). This table excludes the two recent large outbreaks at Thirlmere reservoir in North Manchester (CDSC Northwest 1999).

The total number of confirmed cases associated with Scottish outbreaks of cryptosporidiosis reported to SCIEH during the five year period 1996-2000 was 420 (see Table 2). If one assumes that approximately 10 cases occurred in the community for every confirmed case¹ reported this would suggest that almost 4,000 cases occurred in reality, including confirmed and unconfirmed/unreported yet symptomatic cases. Of more interest are the estimated numbers associated with larger waterborne outbreaks including the 1998 event investigated in the context of Loch Lomond where 303 cases were confirmed and more than 3,000 would be expected in the community, including both confirmed and unconfirmed/unreported symptomatic cases. The outbreak described in this report would be expected to be much larger than suggested by the number of confirmed cases.

¹ The true number of cases in the community is unknown. However, current evidence suggests that there are at least 10 cases in the community for every reported case (Paul Hunter, personal communication).

Table 2**Outbreaks of *Cryptosporidium* infection reported to SCIEH 1996 to 2000 (Scottish Centre for Infection and Environmental Health).**

YEAR	Health Board	Location	Suspected main mode of transmission	Confirmed Cases
1996	TY	School	Person-to-person	5
1996	LN	Specialist farm	Contact with animals	5
1996	HG	Private house (possibly a farm)	Contact with pet lambs	1
1996	GG	Local water supply	Waterborne	7
1998	Various	Public water supply	Waterborne and animal contact	303
1999	AA	Community	Waterborne	9
2000	GG	Public water supply	Waterborne	90
Total				420

The number of affected cases linked to each Scottish event is in keeping with evidence from an international database of 56 cryptosporidiosis outbreaks compiled by Kansas State University suggesting that large outbreaks (e.g. more than 50 confirmed cases) tend to be waterborne and related to large public supplies and that small outbreaks are more likely to result from direct contact with animals, person-to-person spread and small local water supplies. This summary table (address: www.ksu.edu/parasitology/water) included the Milwaukee outbreak in 1993 that was suspected to have caused illness in over 400,000 people (MacKenzie et al 1994). Of these 56 outbreaks, 39 involved drinking water sources and 13 involved swimming pools. Just two involved foodborne infection and another two were drink-associated. The average number of cases per outbreak was greatest with waterborne outbreaks (915). There were no outbreaks listed related to visits to farms and zoos, suggesting that these risk factors tend to be mainly associated with sporadic cases.

A large outbreak of cryptosporidiosis in Central Scotland in April 1998 that was investigated in the context of the Loch Lomond/Balmore Works supply was deemed to be possibly associated with consuming water from the public supply by the Bouchier Expert Group but was never formally attributed to Loch Lomond water, which was unfiltered at the time, by the water authority involved. This outbreak was also included in the Kansas State University list of outbreaks.

2.4 Water supply arrangements

Drinking water supplies in the GGHB area are derived from a variety of sources. The majority of GGHB's population is supplied from Loch Katrine via Milngavie Treatment Works by West of Scotland Water Authority (WOSWA), amounting to 658,588 out of a total population of 911,200 (72.3%). Most of the remainder of the GGHB population is supplied by WOSWA from a range of sources including Loch Lomond via Blairlinnans Works, Dunwan via Picketlaw Works and Daer via Daer Works, *etc.* A small fraction of the GGHB population is supplied by East of Scotland Water Authority (ESW) from Loch Lomond via Balmore Works. The

Loch Katrine supply, all of which is directed through Milngavie Treatment Works, serves a total population of 712,475 (including 53,887 people who live in the Argyll and Clyde Health Board area). Water from Loch Katrine is transported via two Victorian aqueducts starting from the west bank of the Loch at Royal Cottage. Aqueduct 1 was built in 1855 and supplies about 35 million gallons (MG) per day to Mugdock Reservoir. Aqueduct 2 was built in 1885 and supplies about 48 MG/day, 36 MG/day of which serves Craigmaddie Reservoir and 12 MG/day of which also serves Mugdock reservoir. As a result, Mugdock is served by 47 MG/day whereas Craigmaddie is served by 36 MG/day. These flows can be adjusted by opening sluice gates at the inlet of the aqueducts located near Royal Cottage.

Although both these aqueducts are subject to substantial surface water ingress, aqueduct 1 is thought to be more vulnerable to contamination. Figures supplied by WOSWA suggest that the total ingress of water augments the flow carried by aqueduct 1 by as much as 25% (see Appendix 4 for maps of the supply).

Both reservoirs, located at the distal ends of the aqueducts, are unlined ponds in the Milngavie area and are considered as amenities by the local population who uses the area as a park.

2.5 Water treatment at Milngavie Treatment Works

The treatment received at Milngavie Treatment Works (MTW) is rudimentary. The water is subjected to chlorination, pH correction and phosphate dosing as it leaves the two reservoirs at Milngavie via the mains pipes. There are no coagulation and flocculation steps nor is the water filtered to a level that would remove oocysts from parasites such as *Giardia lamblia* or *Cryptosporidium parvum*. Recent evidence suggests that Cl₂ can induce excystation of older environmental oocysts although it has no effect on freshly prepared oocysts (Benton et al 1991). Oocysts from *Cryptosporidium parvum* are therefore expected to resist chlorination at the levels used in a drinking water supply. They require to be mechanically removed either via rapid gravity filtration, slow sand filtration or other technology including membrane filtration.

2.6 Water quality monitoring

Drinking water is monitored for microbiological quality across the West of Scotland Water Authority area by both on-line instrumentation at the various water treatment works and by samples analysed at WOSWA's central laboratories at Balmore Road, Glasgow. Water is sampled at the water treatment works, at service reservoirs and randomly at homes and other premises within the distribution network. Data from these monitoring programmes relating to the period from 1 April onwards were examined to see if there had been any indication of deterioration in water quality.

There was no evidence from coliform and *E. coli* counts of a failure of quality of water during April or May 2000. The raw water entering Mugdock and Craigmaddie reservoirs had been examined for the presence of *Cryptosporidium*

using continuous monitoring utilising *Cuno*² technology since 7 January 1999 and 17 August 1999, respectively. However, the sensitivity of monitoring using *Cuno* filters is understood to be low and therefore any negative results should be interpreted with caution.

The *Cryptosporidium* Direction issued by the Scottish Executive in March 2000 required that monitoring for both oocysts (using *Genera*³ technology) and turbidity of final water on high-risk supplies be conducted on a continuous basis (at 40 l/hour) as of 31 April 2000.

Continuous monitoring for oocysts using *Genera* technology commenced on the Craigmaddie final water on 1 February 2000 and on the Mugdock final water on 27 April 2000. Laboratory analysis of the samples obtained from continuous monitoring using 24 hour samples typically took up to 5 days to process but since 1 May 2000 this should take only 3 days.

Final water turbidity data from spot samples (daily grab samples taken off the system at the point of *Genera* monitoring) are not helpful in identifying, or giving advanced warning of, a *Cryptosporidium* waterborne event on account of the low frequency of sampling from 12 June 2000. At the end of 1994 or at the beginning of 1995 (WOSWA unable to provide exact dates) continuous turbidity monitoring using on-line instrumentation was introduced on both the final and raw supplies at both Mugdock and Craigmaddie over a period of several months (12 different sites on 6 mains - 3 mains from each reservoir before being treated downstream).

² This uses a wound polypropylene cartridge. To release trapped oocysts the wound material is cut into pieces and teased apart by hand prior to vigorous washing.

³ This uses a device which comprises multiple layers of reticulated open cell foam discs, which when compressed act as a filter. Trapped oocysts are released during washing as the discs decompress.

3. Chronology of events

3.1 15-21 May 2000 (Week 20), Week 1 of the outbreak

Identifying the Outbreak

On Monday 15 May, Greater Glasgow Health Board (GGHB) received 7 laboratory reports of *Cryptosporidium* oocysts identified in faecal specimens received from patients living in the health board area. This was in marked contrast to the usual or baseline number received of between 0 and 2 cases per week and in excess of the number received for each of the two previous weeks (week 18 – 3 cases, week 19 – 6 cases). By noon on Thursday, 18 May, it was decided to convene a Problem Assessment Group (PAG) at GGHB. There had been 22 cases reported that week, all of whom were living in the WOSWA supply area, in particular the distribution of the Milngavie Treatment Works (MTW).

Attending the meeting were representatives of GGHB, Glasgow City Council, WOSWA and SCIEH and these are named in Appendix 1. Possible sources of infection were discussed in the light of available evidence including contamination of the water supply at any point from Loch Katrine to the MTW; visits to farms, zoos, safari parks *etc.*; trips to swimming pools; secondary or person-to-person transmission; and foreign acquired infection (person abroad during incubation period). However, there was little evidence from national surveillance by SCIEH of any appreciable increase in cases elsewhere in Scotland except in an area of Argyll and Clyde, part of which also received water from MTW. It was also noted that advice to reduce the risk from farm and zoo visits had been issued every spring by the Chief Medical Officer for the previous three years. Site risk-assessment and turbidity monitoring data was requested of WOSWA staff who agreed to provide this to the health board as soon as possible.

By 5 p.m. on Friday, 19 May, there were 30 cases, the most GGHB has ever had in any one week. Twenty seven of these cases were supplied by MTW. Action taken at this stage consisted of a letter faxed by GGHB to all general practitioners, A&E doctors and hospital medical executives in the health board area on the evening of Friday, 19 May 2000 (see Appendix 5). This action was viewed as in keeping with advice to this effect in the published literature (Meinhardt et al 1996). This advised local medical practitioners of the situation, requested that they encourage suspected cases to submit stool specimens and reminded them of the high-risk groups that should be advised to boil drinking water. These groups, deemed high-risk by the DoH and therefore requiring special advice, following the verdict of a subcommittee of the Bouchier Committee convened in early 1999, had already been highlighted by the Board in a letter to medical practitioners in July 1999 (see Appendix 6).

3.2 22-28 May 2000 (Week 21), Week 2 of the outbreak

A second Problem Assessment Group meeting was held at Shieldhall Treatment Works, Glasgow on Tuesday, 23 May. This consisted of senior representatives of GGHB, Glasgow City, SCIEH and WOSWA and these are listed in Appendix 1.

As of 5 p.m. on Monday, 22 May, GGHB was aware of 44 confirmed cases reported since 1 May, 40 of whom were resident in the supply area for the MTW supply and 25 of whom were over the age of 15 years. In the week 22-28 May (Week 2) 15 more cases had been reported bringing the known total to 54 confirmed cases since 1 May, 48 of whom were on the MTW supply and 37 of whom were above the age of 15 years.

The Problem Assessment Group discussed the information available at that point which was deemed to provide strong supporting evidence that the outbreak was waterborne and associated with the Loch Katrine supply. A summary of the available *Cryptosporidium* monitoring results revealed that the levels found in the Mugdock reservoir were persistently low in the period running up to the outbreak and that negative results were found in Craigmaddie. It was appreciated early on that issuing a 'boil water' notice would not be appropriate as it was too late to have any effect and that other measures to control the outbreak were limited. The options available to prevent another waterborne outbreak were considered. A summary of the planned upgrading (involving some kind of filtration) at MTW revealed that bringing forward the date of the modernisation would not be an option. The advantages and disadvantages of one of these options, namely informing the public about the unquantifiable risk from tap water every spring during lambing/calving season given that a variable although persistent risk would remain until 2005/6, were discussed. The possibility of enlisting the aid of the Water Industry Commission (WIC)⁴ to canvas the views of the consumer on this issue was raised.

3.3 29 May - 4 June 2000 (Week 22), Week 3 of the outbreak

Twelve more cases were reported to GGHB during the third week, bringing the total confirmed cases from the 1 May to 66. On 30 May, GGHB was made aware of the fact that an elderly person with leukaemia had developed severe cryptosporidiosis-related diarrhoea on 14 May and died on the day of reporting. Cryptosporidiosis was stated as the underlying cause of death on the death certificate. The patient's consultant haematologist reported the death to the Procurator Fiscal.

Up to that point six cases had been admitted to hospital as inpatients as a result of their infection. Their length of stay averaged 4.2 days with a range of 2 to 10 days. The first official Outbreak Control Team meeting was held at GGHB on the morning of Friday 2 June and consisted of the same members who had attended the second PAG (as well as a veterinary epidemiologist from SCIEH). Representatives from the environmental health department of the three other local authorities with cases of illness were invited. Most agreed to maintain contact with the chairman for updates on progress and instruction on how to proceed with the investigation because of the small numbers of cases in each of these local authorities (Appendix 1 lists those people who attended at least one meeting of the OCT).

⁴ The Water Industry Commission is the economic and customer services regulator of the water. They do not handle complaints about the quality of water, which is the responsibility of the Scottish Executive Water Quality Regulation Team.

Debate centred on the advisability of the water authority combining sheep farming and water production. The feasibility of removing the flocks of sheep from Loch Katrine catchment was discussed. It was conceded that the sheep industry was not particularly profitable but formed a traditional part of the management of the catchment. It was agreed that in the interests of public health the removal of the sheep should at least be considered, although it was felt that consideration also had to be given to the livelihoods of 8 shepherds, employed by WOSWA, and their dependants. The fact that 80 rams were routinely moved to Mugdock from Loch Katrine every spring was confirmed by the WOSWA representative who also reassured the OCT that there was no possibility that they could gain access to the water at Mugdock reservoir because of the fencing.

Difficulties experienced by GGHB staff in investigating the outbreak were discussed and in particular the need for WOSWA to offer more timely information and support when an outbreak is identified. More rapid relay of vital water supply details for individual cases was considered essential.

The implications of the *Cryptosporidium* (New Water and Sewerage Authorities) Direction 2000 for this outbreak, issued by the Scottish Executive, and the data required to be provided by the water authority to the health authority, both in advance of, and during an outbreak were also clarified. It was agreed that relevant data included site risk-assessments and turbidity monitoring that had been requested at the first PAG and was still awaited by the OCT.

3.4 5 –11 June 2000 (Week 23), Week 4 of the outbreak

During this week, five more cases were reported to GGHB bringing the total since 1 May to 71. Of these, 63 were living in the MTW distribution, of whom 39 were above the age of 15.

On Tuesday, 6 June the second OCT meeting was held at SCIEH. At this meeting, turbidity data was provided by WOSWA which revealed a small increase in turbidity on 27 April, the day before the first positive result for *Cryptosporidium* oocysts in the water. This small increase in turbidity was not thought to be significant by WOSWA officers at the time of the incident.

A map of cases by residence and date of onset (see appendix 7a) showed that cases were distributed within the MTW supply and were noticeably absent from those geographic areas receiving water from other supplies including Loch Lomond's Balmore and Blairlinnans works (which have both been upgraded to include filtration).

At this point, the first batch of 30 sheep faecal specimens taken from the ground in a fank⁵ at Loch Katrine, following the overnight enclosure of an undetermined number of ewes and their lambs, were reported as negative for *Cryptosporidium* oocysts. The results of two more batches taken in the same fashion were awaited. Opportunities to sample sheep were constrained by husbandry practices and had to fit in with times that the sheep were gathered from the hills. It was not possible to differentiate between faeces from ewes and lambs. It was agreed that a positive result would be useful but a negative result would not negate the likelihood that this was a waterborne outbreak nor that the sheep were the most likely source. The

⁵ A Scottish term for a sheepfold, commonly used to describe a multiply divided pen or enclosure used for sheep.

need for a detailed risk-assessment was considered to determine the prevalence of oocysts in sheep by geographic location, altitude on the hills, flock *etc.*

The consensus view of members of the OCT at this point was that this outbreak was indeed most likely to be waterborne, in the distribution of the MTW and most likely due to the presence of sheep. It was agreed that efforts aimed at risk reduction were required to be made before the spring of 2001 as a priority, or at least in conjunction with any efforts to study in detail the prevalence of *Cryptosporidium* infection in flocks of sheep.

The OCT discussed the issue of consumer representation on any future group convened to investigate the risk of future outbreaks associated with the Loch Katrine supply. Opinions of OCT members about the value of having such consumer representation differed. Likewise, the team was divided on the issue of whether the public should be warned of the increased risk on this supply during the spring to enable them to exercise their right to boil their water or choose an alternative source of drinking water.

3.5 12-18 June 2000 (Week 24), Week 5 of the outbreak

During this week six more cases were reported to GGHB bringing the total from 1 May to 77. Of these, 68 were living in the MTW distribution and 41 were older than 15 years of age. The outbreak was officially declared as having ended on Wednesday, 14 June based on the fact that there were no new cases on 15 and 16 June and the totals of new cases for the following two weeks were just two and one, respectively.

3.6 Third OCT Meeting held 7 August 2000

The purpose of this meeting was to bring together the results of remaining investigations. This included a report of discussions with the consultant haematologist at the Glasgow Royal Infirmary who reported the death due to cryptosporidiosis of the patient with leukaemia, with the Scottish Executive Public Health Policy Unit and with the Department of Health official who will be reviewing the guidelines on issuing a 'boil water' notice to susceptible groups.

The water authority described progress already made toward assessing the risk of future outbreaks involving the Loch Katrine supply. This consisted of the water authority setting up a multi-agency steering group and commissioning the Scottish Agricultural College to initiate baseline studies required to inform the process (including prevalence of *Cryptosporidium* in sheep, sheep management practices, likely points of contamination, relative contribution to contamination by the aqueducts *v* Loch Katrine, *etc.*). Agencies that would be invited to send representatives included GGHB, Scottish Executive Department of Health, Scottish Executive Water Quality Regulation Team⁶ (SE-WQRT), Scottish Executive Rural Affairs Department, Scottish Centre for Infection and Environmental Health,

⁶ The Water Quality Regulation Team at the Scottish Executive has overall responsibility for the regulatory framework for the water industry in Scotland and is responsible for ensuring compliance by the water authorities with specified drinking water quality standards. It holds the DWI function in Scotland.

Glasgow City Council and Scottish Environmental Protective Agency. This group was expected to provide recommendations by December 2000.

3.7 Fourth OCT meeting held on 28 August 2000

This meeting was also attended by the Director of Public Health for GGHB who endorsed the view that the totality and timing of the evidence suggested a waterborne source of the outbreak. WOSWA provided the update of a detailed map showing the distribution of the water supply in relation to the cases which were mapped by date of onset. This suggested that the cases were roughly randomly distributed equally between the two distributions (Mugdock and Craigmaddie) and there was no apparent relationship between date of onset and distribution. Amendments to the first draft of the OCT report were discussed. These included WOSWA's acknowledgement that, contrary to initial reassurances, rams had indeed managed to get through the fence around Mugdock reservoir and that, as a result, the practice of grazing rams around this reservoir in the Spring would be discontinued in future.

3.8 Fifth OCT meeting held on 29 May 2001

This meeting was used to agree the wording and status of the final OCT Report. Members were given one more opportunity after the meeting to bring to the attention of the chairman amendments to, or additional points of fact. It was agreed that representatives were free to refuse to sign up to the report and that they would be asked to provide a short paragraph to that effect explaining their reasons and that their submission would be inserted at the back of the final report.

4. Investigation and Results

4.1 Human Epidemiology

4.2 Water and Environmental

4.3 Human Microbiology

4.4 Meteorological Conditions

4.1 Human Epidemiology

4.1.1 Descriptive

A case definition was determined on the basis of an examination of the time trend for notifications to GGHB. Because the number of cases rose sharply from the baseline of 0-2 cases per week after 1 May and returned to the baseline after 14 June all confirmed cases of cryptosporidiosis reported to GGHB between the 1st May and 14th June 2000 were defined as outbreak cases. There was no effective initiative aimed at finding symptomatic but unconfirmed cases. There were 77 such outbreak cases of cryptosporidiosis reported to GGHB in that 6 week period. An epidemic curve⁷ was plotted using the dates of onset of the 77 cases as well as a 'notification curve' using the dates the cases were reported to the board (see graph in Appendix 7b).

The age breakdown is as follows: Age 0-2 yrs – 10 cases
Age 3-14 yrs – 23 cases
Age >15 yrs – 44 cases

The predominance of cases in the older age bracket is suggestive of a waterborne route, the assumption being that clusters attributed to visits to farms and zoos would predominantly affect school age children and toddlers.

Sixty eight of the 77 cases (88.3%) lived in the catchment for MTW within GGHB while **9** cases lived in the catchment for a range of other supplies within GGHB. However, even though cases occurred who did not live in the distribution of the MTW supply exposure, there was ample opportunity for these cases to be exposed in social or work-related circumstances given that much of central Glasgow is supplied by MTW water.

The rate of infection within GGHB, by main water distribution, over the 6 week period May 1 to June 14, was calculated to be:

- Milngavie TW distribution within GGHB: **68** / 653,671 (10.4 per 100,000).
- Non-Milngavie TW distribution within GGHB: **9** / 250,729⁸ (3.6 per 100,000).

Therefore, the relative risk of developing infection for those who lived in the Milngavie distribution within GGHB was approximately three (i.e. three times that of living on the non-Milngavie distribution within GGHB, which provides a statistical association between living in the Milngavie distribution and becoming infected, satisfying one of

⁷ An epidemic curve simply plots the cases by number of cases (y axis) against their date of onset of symptoms (x axis).

⁸ Assuming GGHB pop'n of 904,400 (Mid year estimate for 2000 from 1991 census).

several criteria of causality derived by Bradford Hill in the 1950s). Furthermore, it should still be borne in mind that people living on the non-Milngavie distribution within GGHB might still consume water from the Milngavie distribution as a result of work, social or leisure connections that remain relatively unexplored during the standard interview.

Of these **68** cases living in the area of the Milngavie distribution, **29** (42.5%) received water from Craigmaddie reservoir and **39** (57.5%) received water from Mugdock reservoir.

Within the GGHB Milngavie distribution the rates for the two sub-distributions are as follows:

- Mugdock: **39** / 378,199 = 10.3 per 100,000.
- Craigmaddie: **29** / 275,472 = 10.5 per 100,000.

These rates are remarkably similar. When cases were plotted on a map (provided by WOSWA) by date of onset and by water supply it suggested that cases were randomly distributed in the two distributions in time and geographic area (see map in appendix 7a). Furthermore, the epidemic curves, which plot dates of onset over time, are very similar for the two sub-distributions (see graph in Appendix 7c).

Investigation forms for 73 of the 77 were available providing dates of onset and risk factors. Two cases refused to cooperate, one moved house and his new address was unobtainable, and it was decided not to interview the final case once it was ascertained that they had acquired their infection abroad. The last known date of onset was 2 June.

In terms of ‘other significant risk factors’ reported by outbreak cases, nine cases had visited a farm, zoo or safari park. Six had been living outside the catchment area during the incubation period. Three cases were linked to known cases and were therefore assumed to be secondary transmission. One had contact with an ill animal (a pup with diarrhoea). Six had recently visited a swimming pool. Nevertheless, in total, 52 out of the 77 cases (68%) had no other significant risk factor for cryptosporidiosis other than their water supply. Of these 52 cases with no ‘other significant risk factor’, **49** (94%) received water from the Milngavie Treatment Works. If cases where other significant risk factors have been eliminated are used in the numerator the infection rates by distribution are as follows:

- Milngavie TW distribution within GGHB: **49** / 653,671 (7.5 per 100,000).
- Non-Milngavie TW distribution within GGHB: **3** / 250,729 (1.2 per 100,000).

Therefore, the re-calculated relative risk of developing infection for those who lived in the Milngavie distribution within GGHB was approximately 6 (i.e. six times that of living in the non-Milngavie distribution within GGHB) when only those with no other significant risk factor are considered.

Within the GGHB Milngavie distribution the re-calculated rates for the two sub-distributions, excluding cases with another significant risk factor, are as follows:

- Mugdock: **26** / 378,199 (6.9 per 100,000).

- Craigmaddie: **23** / 275,472 (8.3 per 100,000).

Although these rates diverge slightly, compared to the initial calculated values, they remain not statistically significantly different (P=0.589). If anything, Craigmaddie reservoir rates are higher, contradicting assumptions that suggest aqueduct 1, which is known to be more easily contaminated by ingressing water, was the source of the outbreak.

Of the 52 cases with no significant risk factor, 11 owned a cat, dog or some other well pet. A case-control study was also carried out using the standard outbreak proforma provided in the appendix of the *Bouchier Report* (DETR/DoH 1998) that is included in Appendix 8 of this report. The case-control study was expected to reveal if weaker risk factors like owning a cat or a dog was significantly associated with infection. In addition the case-control study was carried out to assess if a dose response relationship between water consumption and illness could be identified.

Additional cases

In January 2001, it was discovered that 13 additional cases of cryptosporidiosis residing in the Greater Glasgow Health Board area had been diagnosed by the SPDL during the outbreak period although not reported to GGHB by the various hospital laboratories.

Their sample dates and addresses were used to link them with the outbreak although it was not possible at such a late date to obtain other relevant data such as their date of onset of symptoms and other significant risk factors. Nevertheless it was possible to obtain their age and water supply from the GGHB Community Health Index⁹ and WOSWA database, respectively. If these 13 cases are added to the 77 cases originally reported the descriptive epidemiology requires to be amended as follows:

Total number of cases reported during 1 May – 14 June: 90 cases

Age breakdown: 0-2 years – 15 cases (17%)
 3-14 years – 25 cases (28%)
 ≥15 years – 50 cases (56%)

Seventy nine (88%) of the 90 cases live in the distribution of Milngavie Treatment Works and **11** cases (12%) live in the distribution of one of the other supplies for GGHB.

The rate of infection within GGHB, by main water distribution, over the 6 week period May 1 to June 14, was re-calculated for the 90 cases to be:

- MTW distribution within GGHB: **79** / 653,671 (12.1 per 100,000).
- Non-MTW distribution within GGHB: **11** / 250,729 (4.4 per 100,000).

⁹ The GGHB Community Health Index (CHI) is a register of all patients registered with a GGHB General Practitioner and contains basic demographic details including name, address, date of birth and GP's details.

Therefore, the relative risk of acquiring *Cryptosporidium* infection during the outbreak period was 2.75. That is to say that it was almost 3 times more likely that one would acquire cryptosporidiosis if they lived in the Milngavie Treatment Works distribution compared to the risk if they lived in the non-Milngavie Treatment Works distribution within GGHB. This shows that the statistical association is maintained for the 90 cases.

Of the **79** cases living in the Milngavie Treatment Works distribution, **33** (42%) were in the Craigmaddie sub-distribution while **46** (58%) were in the Mugdock sub-distribution.

Within GGHB Milngavie Treatment Works distribution, the rates of infection for the two sub-distributions when these **79** cases are considered are as follows:

- Mugdock: **46** / 378,199 or 12.16 per 100,000.
- Craigmaddie: **33** / 275,472 or 11.98 per 100,000.

These rates for the two sub-distributions are not statistically significantly different. Calculation of rates for the sub-group of cases who do not have a risk factor was not possible for this larger sample. It was decided not to interview the 13 additional cases because it was agreed that interviewing a case to obtain risk factor data and date of onset of illness so many months after their illness had resolved was unlikely to provide accurate data.

4.1.2 Analytical - The Case-control Study

Senior Environmental Health Officers from Glasgow City Council agreed to interview all of their 55 cases. SCIEH advised that a full case-control study should be conducted and that SCIEH would help the Board to interview two controls nominated by each case. Ultimately, it was decided that each case would be asked to nominate 4 controls in order to maximise the number of controls who finally agreed to be interviewed. Glasgow City Council, Legal and Protective Services employed EHOs to work out of hours to interview their cases, which formed the bulk of the outbreak (55 out of 77 cases), and their nominated controls, given that people tended not to be at home during office hours when contacted by SCIEH staff. The case-control study also involved EHOs from East Renfrewshire (6 cases), East Dumbartonshire (9 cases) and South Lanarkshire (7 cases) who interviewed their own cases and nominated controls using a protocol agreed between GGHB and GCC.

The case-control study did not reveal any significant differences in consumption of tap water between cases and controls in that roughly equal percentages admitted drinking tap water, either in their own home, at work/school or elsewhere, without boiling it first. Also of significance was the fact that there was no difference in the recent history of visits to farms or zoos or contacts with animals on a farm between cases and controls. Furthermore, there were no differences in the percentages having attended a public swimming pool or owning a domestic pet, which were virtually identical for cases and controls.

Nevertheless, one important finding was that more of the controls reported drinking bottled water (63/111 or 57%) than the cases (24/72 or 33%) and the difference was statistically significant (P=0.002). This has been found in previous outbreaks (Joseph et al 1991) and raises the possibility that drinking some bottled waters (including protected aquifer natural mineral water) protects against cryptosporidiosis by reducing the consumption of some higher risk surface waters delivered by tap.

4.2 Water and environmental

4.2.1 Water

4.2.1.1 Monitoring of water for oocysts

All positive oocyst detections are investigated and immediately reported (by fax or email) to the relevant health board, local authority and Scottish Executive – Water Quality Regulation Team (see Appendix 9). Determination as to whether the finding is significant is dependent on the Consultant in Public Health Medicine (CPHM). The CPHM may *reactively* conduct an assessment of the relationship of any cases of illness to the water supply (which will inevitably occur some days after the positive finding) or indeed assess the risk of a positive oocyst count in advance of illness being reported with a view to assessing the merit of *proactively* applying a ‘boil water’ notice.

Cryptosporidium oocysts had been identified in final water leaving MTW from Mugdock Reservoir on several occasions preceding the upsurge in reported cases (see Table 3). These results were difficult to interpret as *Genera* monitoring had only commenced on the Mugdock final water on 27 April 2000, the day before the first positive result. *Genera* monitoring of the final water leaving MTW from Craigmaddie Reservoir had started on 7 February and had only shown one positive result on the first day of monitoring (0.6 oocysts/1000L) which was then reportedly followed by more than 3 months of consistently negative results. There was a large variation in the size of the volumes tested over the entire period of recording for these two reservoirs, with several key positive results obtained from sub-optimal sample sizes (less than 1000 L). At the first PAG meeting, it was acknowledged that these positive results could be of relevance to the sharp increase in the numbers of confirmed cases reported to GGHB if a waterborne mode of transmission was being postulated and given a proposed combined transit time, incubation period and reporting delay of more than 14 days (up to 1 week for the oocysts to enter the supply distribution at the tap, an average of 1 week incubation period for illness to develop and up to 1 week for cases to be reported). In fact, the time from the first positive result on final water from Mugdock reservoir on 28 April to the first spike in the number of cases (4) on 1 May as shown on the epidemic curve (based on dates of onset of illness) is in keeping with the fact that the incubation period varies from 1-12 days and the transit time from the treatment works to the consumer’s tap is expected to range from 3 to 36 hours. The fact that the outbreak continued until almost the end of May suggests that the continued presence of oocysts, until the middle of May, albeit at even lower levels, was significant.

Table 3

A summary of positive results on final water from Mugdock reservoir during the outbreak period from the start of monitoring.

Date of positive results during the outbreak	Oocyst count per 10 litres	Oocyst count per 1000 litres	Sample volume (litres)
28 April 2000	0.07	7.0	732
3 May 2000	0.008	0.8	1300
9 May 2000	0.02	2.0	620
12 May 2000	0.01	1.0	845
16 June 2000	0.008	0.8	1220

However, these levels of *Cryptosporidium* recorded in the final water from Mugdock were not concluded by WOSWA to be particularly significant at the time of reading or in light of the outbreak brought to their attention when compared to those reported by water authorities in England and Wales. For example, North West Water Authority has regularly obtained counts of 1 or 2 oocysts and as many as 4 oocysts per 10L grab samples during non-outbreak situations (100, 200 and 400 oocysts per 1000 L, respectively). However, a 10L grab sample taken fortuitously during an episode of contamination may provide much higher counts than a 24 hour sample that included a short episode of contamination because of dilution. In addition, different supplies provide different baseline oocyst levels and variation in the inherent viability and virulence of these oocysts and therefore results need to be interpreted with baseline levels in mind. Finally, the sensitivity of monitoring on the Mugdock water would reasonably be expected to improve over time with increasing experience of the technology.

Oocysts isolated from the final water were sent to the SPDL although it was appreciated that most of the small number of oocysts isolated using *Genera* testing would be stained and therefore unsuitable for genotyping. Nevertheless, it was agreed that all slides would be kept for this analysis in case genotyping of such stained oocysts becomes possible in the future. By the time this report went to press in the autumn of 2001, no oocysts obtained from *Genera* monitoring proved to be suitable for genotyping.

Continuous daily monitoring of the final water from Mugdock reservoir commenced on 27 April 2000, the day before the first and highest positive result and has continued until the time of writing. Turbidity measurements made on samples of water obtained during changing of the *Genera* filter only commenced on 12 June 2000 and are therefore of little use for this investigation. However, they may be informative as a baseline for investigating future outbreaks.

Continuous daily oocyst monitoring of the final water from Craigmaddie reservoir commenced on 1st February 2000. Unfortunately, the monitoring of Craigmaddie water had stopped on March 14 because of operational problems and only restarted on 10 May 2000 where it continued until the time of writing. Unfortunately, this suggests that no *Genera* monitoring of roughly half of the final water from Milngavie Treatment Works was conducted for more than 8 weeks encompassing the entire period of suspected exposure (i.e. the end of April or beginning of May) and half the outbreak period (see Table 4).

Table 4

A summary of positive results on final water from Craigmaddie reservoir from the start of monitoring (1 February 2000) to the end of the outbreak.

Date of positive results during the period from 1 February 2000 to 15 June 2000	Oocyst count per 10 litres	Oocyst count per 1000 litres	Sample volume (litres)
1 February 2000	0.006	0.6	1664
14 March 2000	Cessation of monitoring		
10 May 2000	Re-establishment of monitoring		
31 May 2000	.01	1	890

4.2.1.2 Turbidity monitoring

Daily

Daily turbidity measurements were conducted on grab samples taken at the time of changing the *Genera* filters starting on 7 February on the Craigmaddie final water until 3 March when it was stopped. This recommenced on 12 June 2000. Daily turbidity was not measured on Craigmaddie final water using this method during the high-risk period.

Continuous

Continuous turbidity measurements revealed a blip in turbidity (as registered by all 4 needles on the trace equipment) on final water from Mugdock on April 27 where it rose from 0.59 NTU¹⁰ to 0.81 NTU (on Pen 4) and stayed modestly elevated at about 0.75 NTU until 4 May (see Appendix 10). In the absence of any other increases this is suspected to be the relevant contamination event associated with the outbreak peaking two weeks later. Equivalent continuous turbidity measurements on water from Craigmaddie suggest more sustained increases on 21 April and 10 May, with no obvious blip as seen on the Mugdock final water, but are more difficult to interpret in the absence of concomitant oocyst monitoring.

4.2.2 Environmental - Sampling and testing of sheep faeces

In the absence of evidence of the presence of other livestock, the sheep reared on the catchment of Loch Katrine were considered to be the most likely source of a waterborne outbreak of cryptosporidiosis in the distribution of Loch Katrine water. The results of tests of sheep faecal specimens were expected to be useful if they proved positive particularly if the bulk of the human specimens were of Genotype 2 but a negative result would not provide evidence against the hypothesis that the outbreak was waterborne nor that sheep were the most likely source. Unfortunately, the OCT was never made aware that the shepherds themselves were allowed to retain small personal stocks of cows and that these grazed in a high-risk lochside park. As a result these animals were never tested for *Cryptosporidium* oocysts and by the time this information

¹⁰ The unit of measurement of turbidity used was the NTU or Nephelometric Turbidity Unit. A water authority is expected to define, for each treatment works, the value and duration that constitutes a significant deviation in turbidity of the final treated water irrespective of its relationship to the regulatory standard which is 4 NTU.

was revealed by the subsequent steering group convened by WOSWA the animals had been removed from Loch Katrine and could not be tested. Their possible role in the outbreak could, therefore, never be accurately assessed.

Test results from SAC

The Scottish Executive Rural Affairs Department (SERAD) agreed to fund, through SAC, animal sampling for *Cryptosporidium*, using the standard protocol for diagnosing clinical disease in livestock. On three separate occasions SCIEH collected approximately 30 faecal samples recovered from the ground within pens where ewes and their lambs had been held overnight. Samples were taken from sheep in this fashion from separate hills around the Loch Katrine area: 1st June – 29 samples from sheep from Letter Hill and taken from a pen at Edra Farm; 4th June – 31 samples taken from sheep from Strone and taken from a pen at Edra Farm; 15th June – 23 samples from sheep from a nearby hill and taken from a pen at Gengyle. These specimens were sent to the Scottish Agricultural College laboratory at Auchincruive, Ayrshire. All 83 samples received were reported as negative for *Cryptosporidium* oocysts on direct microscopy after staining, using the their standard protocol for examination of animal faeces.

Test results from Chester Public Health Laboratory

GGHB was subsequently offered 30 free tests for *Cryptosporidium* oocysts in sheep faeces by the Director of the Public Health Laboratory (PHL) in Chester. Faecal specimens from 30 lambs born in the spring were collected by SCIEH staff at GGHB's request, obtained from rectal sampling of lambs from Stronachlacher Hill on 14 July. Chester PHL reported that 25 of these 30 were positive for *Cryptosporidium* oocysts on direct microscopy. These 30 specimens were then sent on to the *Cryptosporidium* Reference Laboratory in Swansea where it was confirmed that 29 were in fact positive for *Cryptosporidium* oocysts using two different staining techniques (modified Ziehl Neilsen and phenol auramine) on direct microscopy. The 30th sample was subjected to a pre-microscopy concentration technique and immunofluorescence staining and was also found to be positive. High counts of oocysts were observed from roughly one third (10/30) of these positive smears (R. Chalmers, personal communication).

Comparative testing

Two further duplicate batches of 30 samples each from lambs of two flocks were submitted to both SAC and Swansea on the 25 August and the 7 September, respectively. SAC did not report any positives, whereas Swansea identified oocysts in 19 of the 60 samples using direct microscopy. The sensitivities and specificities of the protocols used by both laboratories are being further investigated. Subsequently, the Swansea reference laboratory subjected all 90 sheep faecal specimens received from 13 July onwards to more sensitive fluorescent monoclonal antibody testing which revealed that higher proportions were positive for *Cryptosporidium* oocysts than had been detected with previous techniques (see Table 5).

Genotyping results available from mid-October 2000 pertaining to all 90 of the samples received by PHLS Swansea have demonstrated that the parasite oocysts present in the sheep were different, in at least one DNA locus studied, from those in the human cases. Specifically, the sheep specimens were positive for *Cryptosporidium* oocysts that do not appear to be of the *C. parvum* species and may be a previously unidentified species. These study results have recently been accepted for publication (Chalmers et al, in press). This finding does not diminish

the likelihood that the sheep were still the most likely source of the outbreak. Such is the complexity and uncertainty surrounding the genotyping of *Cryptosporidium* that it is difficult to know how to interpret this finding. It also suggests that more detailed prevalence and DNA fingerprinting studies of the various flocks at Loch Katrine may be needed to assess the epidemiology of *Cryptosporidium* at this location and in general. Finally, it begs the question of whether other livestock, at either Loch Katrine, or along the aqueducts might have been the source of the contamination.

Table 5

A comparative summary table of Loch Katrine sheep sampling results during 2000.

Date	Farm	Source	No Samples	Percentage positive for <i>Cryptosporidium</i> oocysts			
				SAC		Swansea	
				Direct microscopy	Direct microscopy ¹¹	Fluorescence microscopy ¹²	Genotyping
1/6/00	LetterHill	Ewes and Lambs	29	-ve	N/A	N/A	N/A
4/6/00	Strone	Ewes and Lambs	31	-ve	N/A	N/A	N/A
15/6/00	Glengyle	Ewes and Lambs	23	-ve	N/A	N/A	N/A
13/7/00	Stronachlacher	Lambs-rectal swab	30	N/A	29/30 +ve	30/30	Not type 1 or 2
25/8/00	Stronachlacher	Lambs	30	-ve	12/30 +ve	19/30	Not type 1 or 2
7/9/00	Edra	Lambs	30	-ve	7/30 +ve	18/30	Not type 1 or 2

N/A Samples sent to SAC were disposed of after testing and therefore could not be submitted to the Swansea laboratory for a comparative study of quality control.

4.3 Human microbiology

It was agreed that current genotyping methods would not offer conclusive results pinpointing the aetiology of this outbreak since the methodology was still under development. Genotyping the *Cryptosporidium* oocyst from the human faecal specimens referred to the SPDL would enable classification into two groups (Genotype 1: human only and Genotype 2: human/animal with type 2 being provisionally further divided into 26 subtypes). This would help establish whether there was just one outbreak or more than one coinciding outbreaks and whether the ultimate source of the *Cryptosporidium* infection was of human origin (Type 1).

All human stool specimens that were found to be positive for *Cryptosporidium* oocysts at the local NHS district general hospital laboratories, were reported by these laboratories to be sent routinely to the Scottish Parasite Diagnostic Laboratory (SPDL) for genotyping as per existing guidelines. Ultimately, forty seven human faecal specimens had been received by the SPDL that were sufficient in quantity to be genotyped, out of a possible 77 cases. Forty six of these were Type 2 *Cryptosporidium parvum*, suggesting that this outbreak could be of either human or animal origin. One was Type 1 *C. parvum* and this was re-tested and confirmed to

¹¹ Using modified Ziehl Neilsen and phenol auramine.

¹² Using a concentration technique and monoclonal antibody

be Type 1 and, therefore, possibly not part of the outbreak. Of the 13 additional cases that were identified as having been reported to SCIEH but not the health board, 11 were Type 2 *C. parvum*, one was Type 1 *C. parvum* and one was untyped.

4.4 Meteorological conditions

Anecdotally, it was reported that there was a prolonged dry spell during the first three weeks of April 2000 in the West of Scotland followed by heavy rainfall on the 26 April in the Stirlingshire and Trossachs area. This heavy downpour occurred the day before the blip in turbidity on water from Mugdock on 27 April and two days before the first positive *Cryptosporidium* oocyst measurement on water from Mugdock reservoir on 28 April (0.07 oocysts per 10 L).

The Glasgow Meteorological Office confirmed that April 2000 was a very distinctive month weather-wise as a result of two successive depressions with cyclonic features leading to copious, and in some places, recording-breaking rainfall from the 19-24 April in Central Scotland and from 24-27 April in the East, respectively (The Scotsman, May 2000).

Daily rainfall

Daily rainfall data from Stronachlacher produced and provided by WOSWA suggests that the outbreaks affecting GGHB of 1993 (presumed to be Loch Katrine), 1998 (Loch Lomond) and 2000 (Loch Katrine) are all characterised by a combination of a dry spell followed by heavy rainfall. However, using 24 hour figures, this relationship is not clear-cut and could not be used to predict if, when or where an outbreak would occur. It is further complicated by the fact that lambing/calving occurs earlier at the lower altitudes found around the more southerly ends of the aqueducts and therefore aqueduct-related outbreaks would be expected to occur between one and two weeks earlier in the year. Nevertheless, the heavy rainfall of 26 April noted anecdotally was supported by the daily figures provided by WOSWA where substantial rain fell at Stronachlacher on 26 April resulting in a count of 22.8 mm by 9 am on 27 April. However, short, sharp so-called cellular storms lasting a few hours and striking geographically distinct patches (within 5 miles), may not be evident from looking at the 24 hour totals. It was postulated that a key causal factor involved in the development of a cryptosporidiosis outbreak, over and above the timing following a dry spell and coinciding with the peak lambing/calving period, could be the amount of rain falling during a short period of time (over a matter of a few hours), and in the relevant geographic, high-risk area. This may not be reflected in the total counts (in mm) in a 24 hour period obtained from set daily measuring stations.

Hourly rainfall

Unfortunately, according to SEPA (West), measurement of hourly rainfall data only commenced at Loch Katrine in September 1993. In addition there are gaps, due to technical failures, in the hourly data collected at Loch Katrine including the critical period during April 2000.

Hourly rainfall data obtained for Sloy, Inveruglas on the west Loch Lomond coast, for 1998 revealed that there was a prolonged dry spell from 20:00 hours on 8 April until

06:00 hours on 21 April at which time it started to rain until 09:00 hours on 22 April, producing a total of 18.2 mm over 27 hours. At no point however was the rainfall particularly excessive, with a maximum hourly total of just 1.8 mm and the heaviest spell producing just 8.4 mm falling over a 5 hour period. The increase in reported cases of infection associated with the Loch Lomond outbreak in 1998 started in the week commencing 27 April.

Overall, the missing data notwithstanding, hourly data suggests that heavy hourly rainfall is not a necessary factor, that short geographic distances are important and that what is relevant is the timing of heavy showers after a prolonged period of drought and coinciding with lambing or calving.

The association between extreme precipitation and waterborne disease outbreaks in the United States over a period of 46 years was described recently (Curriero et al 2001). Outbreaks of waterborne disease due to surface water contamination, including cryptosporidiosis, showed the strongest association with extreme precipitation (above the 95 percentile) during the month of the outbreak ($P=0.002$).

5. Media response

The GGHB Press Office agreed to take inquiries from the media regarding the outbreak. A press release and background information sheet was developed by the GGHB representative after taking advice from all participating agencies. It was agreed that any requests for technical information regarding water would be passed to WOSWA Press Office. It was agreed that the GGHB representative would act as the spokesperson for the OCT but all media inquiries would be handled by GGHB press office. Only if absolutely necessary would the GGHB CPHM deal with media calls after vetting by the press office. A press release was issued on 2 June (see Appendix 11) and a press holding statement which was retained at the Board was compiled on 6 June.

6. Discussion

6.1 The Cause of the Outbreak

From the outset, SCIEH and GGHB representatives were of the opinion that the epidemiological evidence suggested, based on published PHLS guidelines, a strong association between the outbreak and the water supply from Loch Katrine (CDSC 1996). Ultimately, the entire OCT was unanimous in that appraisal. Criteria for estimating the strength of association between human illness and water, outline that if the pathogen found in human case samples is also found in water samples while the descriptive epidemiology suggests an association, this is sufficient to suggest a *strong association* between the outbreak and a suspected water supply (CDSC 1996; Stanwell-Smith 2000). This remains despite the fact that the oocysts identified in the water from Mugdock can not currently be classified in terms of genus or genotype, and therefore their pathogenicity in humans remains unknown (Fairlie 2000).

The very close similarity of the infection rates per 100,000 and the profile of the epidemic curves for the two distributions within the MTW supply (see appendix 7c), suggests that the site of contamination was not within one or other of the aqueducts, but in the Loch itself. Aqueduct 1, which supplies an average of about 35 million gallons/day to Mugdock reservoir, is older and considered more vulnerable than aqueduct 2 which supplies an average of about 12 million gallons/day to Mugdock reservoir and an average of about 36 million gallons/day to Craigmaddie reservoir (see maps in Appendix 4). Even accounting for a variable amount of flow of water from aqueduct 2 to aqueduct 1 through a connecting tunnel at the distal end of the aqueducts and for variable flow rates through the two aqueducts, it is difficult to conceive a combination of flow dynamics, given the similarity in size of the two reservoirs, that would enable almost identical infection rates in the two sub-distributions if only one aqueduct was contaminated. The small difference in volumes between the two reservoirs¹³ sheds no further light on the likely explanation. It is unlikely that one episode of contamination affected both aqueducts equally unless it involved the Loch supplying both aqueducts. WOSWA reported that in response to heavy rain noted on 26 April 2000 the reservoir levels at Milngavie were observed to be rising rapidly and the decision was made to adjust the sluice gates at Royal Cottage at Loch Katrine to reduce the daily total flow by about 9 million gallons (see Table 6). The turbulence in flow that this may have caused is not thought by WOSWA to be a suspect cause of the subsequent rise in the oocyst count because such adjustments are frequently made with no apparent effect on oocyst counts.

¹³ The volume of Mugdock reservoir is 2,500 megalitres while that of Craigmaddie reservoir is 3,000 megalitres.

Table 6

Summary table of flow rates into Mugdock and Craigmaddie reservoirs via aqueducts 1 and 2 at the time of adjustment on 28 April 2000.

Date	Total flow from Loch Katrine (MG/day)	Total flow into Mugdock reservoir (MG/day)	Aqueduct 1 flow into Mugdock (MG/day)	Aqueduct 2 flow into Mugdock (MG/day)	Aqueduct 2 flow into Craigmaddie (MG/day)
26 April	82.29	46.33	34.58	11.75	35.96
27 April	82.74	46.78	35.03	11.75	35.96
Sluice gates at Royal Cottage adjusted (aqueduct 1 more than aqueduct 2) on 28 April to reduce total flow by 9 MG/day					
28 April	73.84	39.71	32.35	7.36	34.13
29 April	73.12	39.44	32.35	7.09	33.68

On 27 April there was a small increase of about ½ NTU in the turbidity of Mugdock water. Although this increase would normally have been considered an insignificant deviation by WOSWA’s technical staff, in view of the positive oocyst result the next day and the subsequent outbreak it was retrospectively deemed to be important by the OCT. It would appear that a small increase in turbidity immediately preceding a positive, albeit low oocyst count can be associated with illness and that these parameters need to be taken more seriously. In fact, the *Bouchier Report* states, ‘...it may be that at large water treatment works alarms should be set to be triggered by any increase in turbidity in the final water of greater than 50% of the normal average or suitably representative value...’ and that ‘instruments capable of detecting changes of less than 0.1 NTU’ should be used on high-risk sites. However, it was pointed out by WOSWA that there was no proactive action that could have been taken in light of the turbidity and oocyst counts given that the current treatment works is incapable of removing oocysts. That is, other than to issue a ‘boil water’ notice to a population of more than 700,000 people with all the difficulties that would incur.

Legal framework

The *Cryptosporidium* Direction issued by the Scottish Executive Water Quality Regulation Team (SE-WQRT) required continuous monitoring to be operational by 1 May 2000. In fact, continuous monitoring had commenced on final water from Craigmaddie on 1 February 2000 and on that from Mugdock on 27 April 2000. Water tested by *Genera* technology showed that *Cryptosporidium* oocysts were present in the Mugdock supply on four occasions during the outbreak period. The highest level at 0.07 oocysts per 10 litres measured from a suboptimal sample size of 732 litres on 28 April occurred the day after a small increase in turbidity in that same reservoir. This positive result preceded the peak in the epidemic curve by 12 days. WOSWA pointed out that all of these values were considered low, particularly in light of the fact that in England and Wales 1 oocyst/10 litres is the level at which prosecution by the Drinking Water Inspectorate (DWI)¹⁴ would be

¹⁴ The DWI regulates public water supplies in England and Wales and as such is responsible for assessing the

considered. However, in Scotland, all results no matter how low are reported immediately to the relevant health board CPHM, local authority environmental health officer and SE-WQRT to allow assessment of the situation. In Scotland, there is no official investigation level but the regulations do not permit any element, organism or substance at a concentration which would be detrimental to public health and the SE-WQRT has stated that zero counts are the target, any positive result posing a risk to the public health. The fact that *Cryptosporidium* levels are notably excluded from the Water Regulations in Scotland implies that no specific level would automatically result in prosecution of a water authority by the SE-WQRT, which holds the DWI function in Scotland. Water authorities in Scotland can, however, be prosecuted if it can be demonstrated that the water was unwholesome and the level of oocysts in the water supply was at a concentration that was detrimental to public health. This is in marked contrast to the situation in England where the DWI would have difficulty prosecuting if the standard of 1 oocyst/10 litres had not been breached. In any proceedings for the offence of supplying *unwholesome* water it would be a defence to show that all reasonable steps had been taken and all due diligence exercised for securing that the water was fit for human consumption.

Monitoring of oocysts in the water

The presence of 29 (43%) cases of infection in the distribution area served by Craigmaddie reservoir in the absence of positive results for oocyst in water from Craigmaddie reservoir was initially considered to be an argument against this being a waterborne outbreak. This generated significant debate about the importance of negative values obtained by *Genera* which led members of the OCT to question the current scientific basis for linking a quantitative assessment of oocyst concentration in the water with the level of risk to the public health. Members concluded that a positive result was useful but a negative result was not. Such is the insensitivity of the *Genera* technique currently that the only real evidence of an increased risk of GI infection with waterborne *Cryptosporidium* was provided when an outbreak was actually identified and this could obviously occur, in retrospect, with lower levels than had previously been thought to be problematic or even in the presence of zero counts. This had already been demonstrated by the fact that in more than 50% of other UK waterborne cryptosporidiosis outbreaks described in the *Bouchier Report* no oocysts were detected (DETR/DoH 1998) (see appendix 3). However, as it was later discovered that no *Genera* monitoring had actually be conducted on the water from Craigmaddie reservoir for an 8 week period encompassing the suspected exposure period and most of the outbreak period (March 14 – 9 May), this entire argument became obsolete. The *Bouchier Report* (DoH/DETR 1998) makes it clear that episodes of contamination are short-lived events lasting in the order of hours, hence the need for continuous monitoring on high-risk supplies. The *Cryptosporidium* Direction made continuous monitoring mandatory on such a supply from 1 May 2000.

quality of drinking water south of the border, taking enforcement action (including prosecutions) if standards are not being met, and appropriate action when water is unfit for human consumption. They also receive complaints from the customer about the quality of water.

Low sensitivity and specificity of oocyst monitoring

Ultimately, it was appreciated that, as a whole, the oocyst monitoring data was of limited use in providing a baseline level or in providing an explanation of the outbreak. Firstly, the utility of *Genera* monitoring on an unfiltered supply has been called into question as this technology was primarily designed for filtered supplies. However, to all intents and purposes, Loch Katrine raw water is sufficiently unpolluted that *Genera* monitoring of the chlorinated product should be informative. Secondly, monitoring on Mugdock only commenced on 27 April, the day before the first positive result which implies that a significant episode of contamination could have occurred earlier that week. Thirdly, there was no monitoring on final Craigmaddie water for 8 weeks during the suspected exposure or outbreak period. Fourthly, several samples were suboptimal in that they were less than the 1000 L samples advised by the *Cryptosporidium* Direction (40 L/hour for 24 hours). Given that significant contamination episodes probably last a matter of hours (DETR/DoH 1998) it is possible that aborted sampling could miss or grossly underestimate the extent of such events. Finally, any increasing trend may be attributable in part to ascertainment bias given that the ability to detect oocysts with newly introduced *Genera* technology would be expected to improve over time.

Quantity or burden of oocysts

The concentration of 0.07 oocysts per 10 litres observed on 28 April, could equate with a theoretical 2½ million oocysts passing through the Milngavie Treatment Works supply on 28 April, given that 360 million litres (equivalent to about 82 MG) of water pass through the treatment works in just one day. Even if 50% were non-viable, given the low infective dose of *C. parvum* - as few as 10 oocysts swallowed have been shown to cause illness in healthy human volunteers (Fayer and Ungar 1986), and as few as 5 oocysts have been shown to cause illness in gnotobiotic lambs¹⁵ (Blewett et al 1993)- there is no obvious reason to suppose that an outbreak could not occur in association with levels of 0.07 oocysts per 10 litres or even lower. Indeed, no evidence came to light during the investigation to suggest that such a count, particularly if measured on a sub-optimal sample size, was trivial.

¹⁵ A gnotobiotic lamb is a newborn lamb that has yet to fully colonise its gut with normal commensal organisms.

Variable pathogenicity of oocysts

More recent human volunteer studies indicate that the ID50 for *Cryptosporidium* varies from isolate to isolate, being 87 oocysts for the Iowa (bovine, genotype 2) isolate of *C. parvum* (DuPont et al., 1995), 1042 oocysts for the UCP (bovine, genotype 2) isolate, and 9-10 oocysts for the TAMU (equine, genotype 2) *C. parvum* isolate (isolated from a human exposed to an infected foal and passed in calves) (Okhuysen et al., 1999). The TAMU isolate differed significantly in attack rate (86%) from Iowa (52%) or UCP (59%) with a trend towards a longer duration of diarrhoea (94.5h compares with 81.6h (UCP) and 64.2h (Iowa)). No information was available on the specific isolate obtained in the human faecal specimens during this outbreak to make judgements on expected, or comparisons with these, virulence or attack rates. What this does suggest is that not all *C. parvum* are equally pathogenic to humans and some experts would suggest that many genotypes are not pathogenic to humans at all (J. Wastling, A. Tait, personal communication).

WOSWA representatives were of the view that homogeneous mixing of oocysts does not occur in environmental water samples. They are probably correct in this assessment, however, this would imply that other samples taken from a different *Genera* monitor on the same day (i.e. from a different batch of 1,000 litres from the same reservoir over the same 24 hours) might have been higher or lower. The fact is, there was no accurate way of counting the total burden of oocysts that passed through MTW on 28 April but there is no more justification or evidence to underestimate the count, than overestimate it.

6.2 *Cryptosporidium* and sheep

It is increasingly evident from scientific research that clinically well sheep can carry *C. parvum* to varying extents in terms of inter- and intra-flock prevalence. Faecal oocyst counts can vary with the season and the status of the flock, for example, excretion rate increases during the peri-parturient period (Scott et al 1994).

The asymptomatic ewe can infect her lamb during suckling as a result of a periparturient rise in oocyst counts and peri-udder contamination (S. Wright, personal communication; Ortega-Mora et al 1999). An infected lamb can develop clinical illness if infected between 1 and 3 weeks of age and can produce huge numbers of oocysts in a small faecal dropping, in the order of one million oocysts per gram of faeces resulting in an output of 10^{10} oocysts in a 7-10 day period (Blewitt 1989). The udder acts as the main locus of transmission during suckling both from infected ewe to lamb and between sibling lambs (Anderson 1982), although environmental contamination by faecal droppings during grazing is another less likely possibility (S. Wright, personal communication; DoE/DoH 1990).

The three batches of 30 sheep dung specimens picked up off the ground during the first two weeks in June and sent to SAC yielded entirely

negative results. Unfortunately, there was no way of knowing whether the samples were predominantly from ewes or their lambs or whether droppings from all the animals housed overnight were included. This was initially interpreted by the OCT to mean that the samples may not have been representative of sufficient numbers of animals at higher risk of carrying the infection. Although cryptosporidiosis can cause diarrhoeal illness in sheep none of the animals tested appeared to be suffering from diarrhoea.

However, the fourth batch of 30 lamb dung specimens taken in mid-July from Stronachlacher and sent to the Chester PHL, all of which were ultimately reported as positive for *Cryptosporidium*, and 29 of which were positive using direct microscopy alone, clearly confirms the presence of oocysts, albeit of a reportedly different genotype, in sheep on the banks of Loch Katrine and would suggest that a high carrier rate for this type exists at least for some flocks. Although the positive samples were collected 4-6 weeks after the initial negative samples and were from the opposite side of the Loch the discrepancy between the Swansea reference laboratory and the SAC results provided the stimulus for a review of the protocol used by SAC and a quality-assurance study.

The latter suggests that the SAC laboratory may have experienced difficulties identifying oocysts in the dung of asymptomatic animals using direct microscopy, possibly because their experience is in dealing with ill animals with much higher counts. In a recent, unpublished study from Cumbria, about 10% of more than 1,700 samples taken from the ground of livestock and animals were positive on direct microscopy and about 1% gave counts calculated to be more than 10^5 oocysts per gram (A. Sturdee, personal communication). The Cumbria study suggested that, using insensitive methods, prevalence of infection tends to be low while the use of more sensitive methods on the same material, including concentration and immunofluorescence antibody test (IFAT), frequently provides positive results. This raises some concerns about relying entirely on the Scottish Agricultural College to undertake the studies necessary to ensure the risk reduction required by the Scottish Executive before the spring of 2001, particularly if prevalence studies are to play any role. Prevalence/carrier rate studies conducted other than during the high-risk period in April and May will require expertise in terms of detecting oocysts in solid dung and perhaps even more sensitive methods of detection including those preceded by techniques aimed at concentrating the oocysts.

The epidemiology of *Cryptosporidium* infection is complex and poorly elucidated. Genetic fingerprinting of *C. parvum* isolates from cattle surveyed in Scotland shows clearly that mixed infections are relatively common (i.e. the presence of one or more genotypes co-existing in the same host). One question that must urgently be addressed if we are properly to interpret the results of genetic fingerprinting of parasites recovered from outbreaks and potential sources of that outbreak, is that of the stability of individual genotypes. If the predominance of a particular genotype in a host is only transitory, then collection of material from potential sources would need to be performed as soon as possible after an outbreak. If on the other hand, genotypes are very stable, then associations made by genotyping may be robust even if collection was some considerable time after the outbreak in question. Establishing which of these two scenarios is the case will be particularly important with mixed infections, where the predominance of one or other genotype could fluctuate without

the need for exposure of the host to another infection (J.M. Wastling, A.Tait, personal communication).

The limited faecal sampling from sheep at Loch Katrine does not preclude the possibility that other flocks of sheep at Loch Katrine or those grazing above the path of the aqueducts are carrying Type 2 *C. parvum*. Furthermore, the fact that a small collection of cattle was kept by the shepherds in the lochside grazing fields which are considered high-risk areas and that they were not tested before their removal implies that there was a potential for other domestic livestock kept at Loch Katrine to be the source of this event and that their role will remain undefined. Even if a flock of sheep or a herd of cattle was identified on a high-risk area to be carrying *C. parvum* Type 2, the state of microbiological techniques, including genotyping, available to the OCT in the spring of 2000 did not permit an exact match to be made between the pathogen's oocyst found in sheep or cow dung specimens, the final water and that found in stool specimens submitted by ill people. It was concluded that the OCT would likely not obtain forensic-level proof of the cause of this outbreak and members should not await such absolute proof before finalising a report of its conclusions.

Currently the Scottish Executive Chief Scientists Office is supporting research on the development of a new genotyping method that has greater resolution than those currently available. These methods, developed at the University of Glasgow in conjunction with SPDL and SCIEH, have the potential to define sources of human infection with greater certainty by using DNA fingerprinting methods adapted from forensic science. The isolates from the Glasgow outbreak will be typed using the new system and results will be made available to the team in the long term. However, further investment in this area is required in both the development of further genotypic markers and in understanding the population structure of *C. parvum* in humans and animals, including questions relating to genotype stability (J.M. Wastling, A.Tait, personal communication).

In conclusion, the descriptive epidemiology, including the timing of the outbreak and the equal infection rates, implicates Loch Katrine sheep as the most likely source of the contamination causing this outbreak, the contradictory genotyping results notwithstanding.

6.3 Additional Supporting Evidence

Additional supporting evidence that this was a waterborne outbreak is provided by the absence of a sustainable alternative explanation and supporting descriptive epidemiological data obtained from routine data sources.

The outbreak was not explained by secondary transmission, visits to zoos, farms or safari parks, *etc.*; pet ownership; or trips to swimming pools, *etc.* It is possible that some of the cases were caused by other factors but this could not be quantified. Typing of the parasite may in the future help identify which cases are linked in outbreak situations. Cases in this outbreak were characterised by a strong tendency to reside in the distribution of the MTW, be older than 15 years of age, and have no obvious risk factor other than their water supply. Forty four cases (57.1%) were older than 15 years old and not likely to be involved with visits to farms or zoos organised by the school services.

The absence of a rise in cases across the rest of Scotland suggests that there was not an increase, generally, in exposure to *Cryptosporidium* due to the normal recognised routes such as springtime animal contact. A large urban outbreak in the spring affecting one water supply area and no other is therefore likely to be waterborne.

Data provided by South Lanarkshire Council

South Lanarkshire Council (SLC) (total population 306,860) reported that, having examined the past 2 years of data, most of their cases of cryptosporidiosis occurred in a small neighbourhood in the Rutherglen area within GGHB (Toryglen/Bankhead and Kirkhill) which receives water from MTW and most of their cases occurred in the three months April to June. This data was submitted by SLC Environmental Health Services at the third OCT and revealed that although only 22,450 of their population (7.3%) receive water from MTW in South Lanarkshire, 14 out of 18 cases (82%) of cryptosporidiosis they had between April 1998 and June 2000 were living in that same area.

Correlation between number of cases and population receiving suspect water by local authority

WOSWA provided data on the populations that receive water from MTW by local authority (LA) within GGHB. This showed a rough correlation between the percentage of cases within GGHB by LA with the percentage of the GGHB population receiving water from MTW (673,281) by each LA (see Table 7). For example, there were no cases of infection reported from North Lanarkshire which is in keeping with the fact that only 3 people receive water from MTW in that same council area despite the fact that North Lanarkshire Council residents living within GGHB total 16,220. The investigation revealed several anomalies in practice that might have explained the lack of reported cases in the West Dunbartonshire Council area (WDC). Two hospitals receive faecal specimens from more than 10,000 people living in WDC who also receive water from MTW. It was subsequently discovered that one of these did not routinely test faecal specimens for *Cryptosporidium* oocysts and the other one did not routinely report results positive for *Cryptosporidium* to GGHB. Efforts were subsequently made by the health board to ensure consistency of practice across all hospitals serving the health board area and that all hospitals test for *Cryptosporidium* routinely as per guidelines issued by the Public Health Laboratory Service at Colindale.

Table 7

Populations of GGHB receiving water from Milngavie Treatment Works by unitary authority and the distribution of 90 cases of cryptosporidiosis reported to GGHB during spring 2000 by unitary authority. Total population of GGHB taken to be 911,200.

Unitary <i>authority</i>	No. of cases reported to GGHB by specific LA	% of cases in each LA	Population by LA within GGHB	Population by LA within GGHB supplied by MTW	% of GGHB population supplied by MTW by LA
Glasgow City	65	72.2	619,680	571,151	86.7
E. Dunbartonshire	10	11.1	109,570	48,202	7.3
S. Lanarkshire	8	8.9	56,560	22,450	3.4
E. Renfrewshire	7	7.8	63,050	6,479	1.0
W. Dunbartonshire	0	0	46,120	10,303	1.6
N. Lanarkshire	0	0	16,220	3	0.0
Total	90	100%	911,200	658,588	100%

6.4 Analytical epidemiological evidence

On the basis of advice from SCIEH, it was agreed that even if a case-control study did not reveal a statistically significant association between drinking tap water from Loch Katrine and illness this would not prove that there had not been a waterborne outbreak, particularly in light of the fact that increasing immunity to cryptosporidiosis may develop from chronic low level exposure. The OCT accepted that the descriptive epidemiology pointed to a waterborne outbreak and that the results of any analytical study were over and above this conclusion. Reference was made to a published paper (Tillett et al 1998) that suggested an outbreak with a majority of cases in older age groups, preponderance of cases in one water supply with concomitant positive oocyst results on water samples was sufficient to attribute an outbreak to waterborne transmission.

The results of the case-control study do not offer either supportive or contrary evidence to directly implicate consumption of tap water as the cause of illness. Nevertheless, of interest is the strongly statistically significant difference in bottled water consumption between cases and controls with cases substantially less likely to have consumed bottled water in the recent months before the outbreak. The limitations of case-control studies in the context of waterborne outbreaks of cryptosporidiosis have been discussed (Hunter 1998).

There is much evidence to suggest that if an outbreak occurs in association with a supply that is intermittently contaminated the attack rate for any outbreak tends to be low because of prior immunity and any case-control study conducted may fail to provide statistically significant odds ratios for consumption of tap water (Hunter and Quigley 1998; Hunter 2000^b). This finding is so consistent that experts are advocating abandoning case-control studies on the grounds that they are unlikely to provide additional evidence supporting that revealed by the descriptive epidemiology and consume scarce resources in terms of time and effort (Paul Hunter, personal communication).

6.5 *Cryptosporidium* (New Water and Sewerage Authorities) Direction 2000

This Direction, issued by the Scottish Executive in March 2000, required water authorities to comply with its recommendations by the end of 2000. One of these requirements was for site risk-assessments (involving assignment of risk code) to be made available to interested parties including health authorities. Another requirement was for continuous monitoring of turbidity on high-risk sites. WOSWA acknowledged that Loch Katrine/Milngavie Treatment Works was assessed as a high-risk site.

The SE-WQRT acknowledged that their risk-assessment model does not take into consideration the number or density of livestock on the raw water catchment area. The model was intended to take a precautionary approach and assign a high-risk score to the presence of any livestock on the catchment. The Drinking Water Inspectorate web site (www.dwi.gov.uk) contains several protocols relating to the implementation of the *Cryptosporidium* Regulations (which apply to England and Wales). In Annex B of the guidance on Risk-assessment, it stipulates that whether livestock are sparsely or intensively grazed *and their location* requires to be assessed as well as the adequacy of water company control of the catchment area. It could be argued, at least in England and Wales, that any water company that allows large numbers of livestock to roam the catchment area that they own, *close to an impounding reservoir*, has increased the risk from *Cryptosporidium* and neglected to control its catchment area. The fact that there is no specific mention, in the DWI guidance, of sheep pens and fanks (or other animal enclosure) draining into the raw water reservoir suggests that these would be classified as 'septic tanks close to the water course' or alternatively 'dung or slurry stores' and, needless to say, this would automatically be considered as an additional risk factor, over and above that posed by grazing livestock.

In light of the concerns expressed by the OCT, the risk-assessment model is being reviewed by the SE-WQRT to recognise the fact that most catchments have at least some livestock grazing on part or all of them and that within the higher risk banding that would automatically result, proportionate risk should be assigned to more intensively farmed catchments and indeed to less intensively farmed catchments with large numbers of domestic animals. This latter position describes the situation at Loch Katrine where it is reported that the animals are extensively¹⁶ farmed (SAC 2001) but it has been observed that they do not remain randomly distributed on the catchment and tend to be concentrated on high-risk areas near streams and the lochside. The Scottish Executive model does, however, consider the size of the population served. The larger the population served the higher the risk factor. Out of more than 600 water supplies in Scotland only 9 were considered very high-risk (risk factor more than 75). Since Balmore Works was upgraded to include filtration in October 1999, Loch Katrine took its place at the top of the league table, being both the largest and carrying the highest risk of the high-risk supplies both within Scotland as a whole and within the West of Scotland where it was the only supply rated above 75 with a score of 100.4 (see Appendix 12 for a listing of the 30 highest risk supplies in the West of Scotland in decreasing order). This was confirmed by different tables provided by WOSWA, which revealed that using different criteria stipulated by WOSWA, Loch Katrine was the highest risk supply of all WOSWA sites.

¹⁶ This is meant to describe the opposite of *intensively* farmed, where the density per hectare will be higher.

It was confirmed that no specific guidance on *Cryptosporidium* had been issued to consumers, including the food industry, by the Scottish Executive or WOSWA. It was also noted that some companies in the food industry might utilise water as an ingredient without further treatment to remove, or kill, *Cryptosporidium* oocysts. This issue came to light during the outbreak when publicity in the popular press resulted in a large drinks manufacturer approaching the local council for clarification on the status and extent of the outbreak. This, in turn, had been prompted by an approach to the drinks manufacturer for information by one of their major customers, a UK wide retail chain.

6.6 Previous outbreaks of cryptosporidiosis in the GGHB area

The GGHB area experienced an outbreak of cryptosporidiosis in 1993, for which no explanation was available (weeks 17-29, when 158 cases were reported over a 12 week period), and that explain the high rates for GGHB in comparison to those for Scotland described in Table 1. It experienced another outbreak in 1998 (weeks 18-23 when 59 cases were reported), the latter assumed to be part of a much larger central Scotland outbreak (more than 300 confirmed cases) investigated in the context of Loch Lomond supply and that was eventually designated as possibly associated with drinking water by the Bouchier Committee. Other outbreaks during April 1989, April 1992 and April 1998, although multifactorial in origin were considered by the Bouchier Committee (DETR/DoH 1998) to have a probable association with Loch Lomond water as per the definitions provided in the paper by Tillet et al (1998).

In the 1993 outbreak affecting GGHB, 79% of 158 cases were living in the MTW distribution and 13% were in the ESW Balmore Treatment Works/Loch Lomond distribution, both of which were unfiltered at the time (see Table 8). In contrast, during the 1998 outbreak consisting of 59 cases, only 29% were living in the MTW distribution and 56% were living in the Balmore/Loch Lomond distribution, both of which remained unfiltered. In October 1999, the Balmore works was upgraded to include a rapid gravity filtration system specifically to reduce the risk of waterborne microbiological contamination including from *Cryptosporidium*. In this outbreak, almost 88% of cases were living in the MTW distribution and only 2.6% of cases were living in the ESW Balmore works/Loch Lomond distribution. The marked differences in the distributions of the relevant water treatment works for the cases involved in the three spring-time outbreaks (including the one under investigation in this report) provide corroborating evidence that the upgrading of the Balmore Treatment Works in October 1999 has been effective in preventing cases of cryptosporidiosis in 2000. This has been confirmed by a study conducted at the time of writing by Lanarkshire Health Board that showed a marked drop in the number of Central Scotland cases living in the area supplied by Loch Lomond after October 1999 (J. Miller, personal communication). It also suggests that the 1993 and 2000 events were mainly linked to Loch Katrine while the 1998 event appears to be disproportionately associated with the Loch Lomond supply, given that only 3.0% of GGHB residents receive water from Loch Lomond. All three outbreaks affecting GGHB started within two weeks of each other and occurred during the lambing season.

Table 8

Cases of cryptosporidiosis by treatment works (TxW) supplying the postcode of residence for the 3 spring periods characterised by outbreaks: 1993 (weeks 17-29, n=158), 1998 (weeks 18-23, n=59) and 2000 (weeks 18-24, n=90).

Water supply	Number of cases in 1993 by TxW	Percentage of all cases in 1993		Number of cases in 1998 by TxW	Percentage of all cases in 1998		Number of cases in 2000 by TxW	Percentage of all cases in 2000	
Milngavie	84	53.2	78.5	10	16.9	28.8	46	51.1	87.8
Mugdock		25.3			11.9			36.7	
Craigmaddie	40			7			33		
Balmore-LL (ESW)	20	12.7		33	55.9		2	2.2	
Burncrooks	8	5.1		0	0		0	0	
Picketlaw	2	1.3		2	3.4		4	4.4	
Daer	3	1.9		2	3.4		4	4.4	
Blairlinnans - LL	1	0.6		2	3.4		0	0	
Other (inclg private)	0	0.0		3	5.1		1	1.1	
Total	158	100.0		59	100.0		90	100.0	

6.7 Livestock at Loch Katrine

Sheep

The banks of Loch Katrine constitute the single largest sheep farm in Scotland. There are 8,000 ewes and 6,000 lambs on the banks of Loch Katrine and Loch Arklet, which supplies Loch Katrine. WOSWA owns these sheep and employs the shepherds and their manager, the latter residing at Stronachlacher. There are another 2,500 sheep and 20 cattle owned by the Woodland Trust on Glen Finglas. To all intents and purposes there is no fencing to keep animals off the lochside or off the streams that feed Loch Katrine or Arklet. During the spring of 2000, Glen Finglas was reportedly not feeding into Loch Katrine.

A visit by OCT members to Stronachlacher in the spring of 2000 revealed that the minimal fencing that does exist in places has been shown to allow sheep through on a regular basis, sheep have free access to most of the lochside and feeder streams, and that sheep dung can easily be seen in these same locations. Advice on protecting private supplies provided in the *Bouchier report* (Point 10.4.1) makes it clear that access of animals to the catchment is an important element of any sanitary survey and that *'it is much better to protect the source of the supply to prevent contamination rather than trying to treat the water afterwards'* (Point 10.4.2). Such protection as suggested in Point 10.4.2 includes fencing to keep grazing animals away. Given that there is no effective treatment on the Loch Katrine supply and that it supplies such a large population it seems reasonable to apply at least the same care to protection of this supply as would be advised for a smaller private supply.

Rams at Mugdock

Every spring around the beginning of April, about 80 rams are moved from Loch Katrine to the banks of Mugdock reservoir. This was initially considered significant given the differential oocyst monitoring results for Craigmaddie and Mugdock reservoirs. However, the suspension of monitoring at Craigmaddie during the exposure period and for most of the outbreak satisfactorily explains the difference in oocyst counts. Nevertheless, these rams were not considered a threat to the water supply at Mugdock by WOSWA because of the barriers present which reportedly prevented them from gaining access to the reservoir. Nevertheless, concern was expressed by OCT members about the propensity for sheep to defy most fencing. Subsequently, WOSWA acknowledged that rams had indeed overcome fencing barriers and reported that the practice of boarding rams around the reservoir/treatment works would be permanently discontinued.

Shepherds' allocation of sheep and cattle

At the time of the outbreak, the eight shepherds at Loch Katrine were allowed 20 sheep and 2 cattle each as determined by the terms and conditions of their contracts (WOSWA 2001). Discussion with the head shepherd revealed that in fact 3 shepherds kept 4 cattle each (2 cows and 2 calves) at Edra, Glen Gyle and Culigart, respectively, totalling 12 animals. This livestock grazed in the lochside parks, which were ultimately deemed high-risk areas by the risk-assessment exercise carried out by SAC (SAC 2001). According to the head shepherd, the foursomes at Glen Gyle and Culigart had opportunity to graze near the water's edge when the grass was good for eating. Calving in this limited collection was expected to take place in February and March of 2000 with just one cow giving birth in November 1999. Altered arrangements imposed by WOSWA in response to the outbreak precluded them from these parks. However, in addition, as a more definitive measure, the shepherds' cattle were disposed of by August 2000 and the shepherds' collection of sheep by March 2001, though the risk-assessment exercise estimated that the overall reduction in risk would be just 2.18%.

Genetic fingerprinting data from a survey of Scottish cattle show that bovines share a large number of common genotypes of *C. parvum* with those found in humans, suggesting a strong epidemiological link between the two species (J.M. Wastling, A.Tait, personal communication). Unfortunately, this livestock was not tested for oocyst prevalence and genotype before being disposed of, thus precluding any possibility of assessing their role in any putative episode of contamination.

6.8 Timing of relevant events

The epidemic and laboratory reporting curves are overlaid with the dates of relevant events, hypothesised as being linked to the outbreak (see Appendix 7b). These include:

- the maximum period of lambing at Loch Katrine (as reported by the head shepherd);
- the meteorological conditions that enable oocysts to remain viable on dry ground before they are carried into the water supply during periods of rainfall;

- a small although clear increase in turbidity followed shortly after by;
- positive counts of oocysts in the water at Mugdock reservoir with the highest of these counts two weeks before the peak of the epidemic;
- the epidemic curve by onset of illness; and finally
- the laboratory reporting curve which peaks roughly 7-10 days after the epidemic curve.

The fact that the outbreak did not carry on throughout the summer during periods of continued oocyst positivity suggests that the subsequent results were too low to cause illness and/or a community level of protective immunity was developing as a result of continued low-grade infection.

The published laboratory evidence suggests that outbreaks in humans are most closely linked in time to lambing, which tends to occur at around the same time every year in the spring, depending on the altitude, in that infection in humans tends to correlate strongly with prevalence of infection in lambs as determined by veterinary laboratories (DoE/DoH 1990). Calves tend to be born at variable times throughout the year and outbreaks in humans tend not to coincide with calving or with prevalence of infection in cattle. All three suspected waterborne cryptosporidiosis outbreaks in the West of Scotland (1993, 1998 and 2000) occurred during the lambing season and within 2 weeks of each other.

The fact that the first positive result on Craigmaddie final water during the period of interest only occurred on 31 May, despite substantial infection rates in the distribution of Craigmaddie, is in keeping with the fact that monitoring did not resume until 10 May.

6.9 Variation in efforts made by various producers of drinking water to control bankside and/or catchment contamination by grazing animals

6.9.1 East of Scotland Water Authority

Discussion with East of Scotland Water Authority (ESW) revealed that it, and at least two of its predecessor organisations, Central Regional Council (CRC) and Fife Regional Council, have operated what is effectively a policy of banning sheep and cattle grazing on ESW-owned land round the margins of reservoirs. This ban applies to the land immediately surrounding a raw water source where this is feasible (i.e. where the banks are fenced, which applies to the majority of their supplies) and has been implemented for a decade. This practice was adopted in 1990¹⁷ when the recommendations of the publication '*Operational Guidelines for the Protection of Drinking Water Supplies*' were implemented.

¹⁷ The first Badenoch Report of the Expert Working Group on '*Cryptosporidium in Water Supplies*' was also published in 1990. It specifically cited evidence in the UK that lambs, and not just calves, were a cause of cryptosporidiosis infection in humans (Casemore et al 1986; Casemore 1989^a; Casemore 1989^b) and commented on the feasibility of controlling grazing on catchments.

A case in point is the Carron Valley Reservoir. The farming community on the Denny Road near Carronbridge reported receiving a letter from Central Regional Council around 1990 specifically citing cryptosporidiosis and the need to keep their animals off the fenced land around the reservoir. Prior to this, the Council collected grazing rental fees from these same farmers. ESW inherited this policy from Central Regional Council in 1996 and there is evidence they continued to implement it as recently as the Spring of 2000 when they visited farmers whose sheep had wandered under the fence and onto ground adjacent to the Loch Carron reservoir and requested that the animals be removed immediately.

ESW acknowledge that oocysts could very well enter their raw water sources from upland streams over which they have no control, but that treatment processes in place should be sufficient to remove most *Cryptosporidium* oocysts. They also point out that as a percentage of their overall catchment, the land ESW own and over which it can exert an influence in terms of control of grazing, is relatively small.

Nevertheless, this limited acreage immediately around lochs and reservoirs can be assumed to be a far higher risk in terms of contamination than the hundreds of acres of catchment land further from the shoreline or water courses. Furthermore, it is increasingly appreciated that water treatment, specifically filtration, should be accompanied by, and is not a substitute for, catchment control, in order to reduce the burden of oocysts that filtration is expected to clear.

In summary, it became clear during the investigation that there was a clear contrast between two neighbouring water authorities with ESW banning grazing, albeit on the limited land where it could do so and WOSWA not just permitting grazing on the extensive acreage it owns at Loch Katrine, but actually owning and managing the 14,000 head of sheep and on a catchment that supplies an unfiltered supply to the largest urban conurbation in Scotland.

6.9.2 Highland Spring Bottled Water

Some private producers of bottled water make efforts to restrict grazing on their catchment areas. One example of 'best practice' relates to Highland Spring Natural Mineral Water. The company in Blackford, Perthshire has established management practices on their 2,000 acres of catchment area. This includes excluding human habitation and any agricultural practices or farmed animals within this area. Through this regime, the risk of contamination by the *Cryptosporidium* oocyst is minimised. This land is leased from Blackford Farms and the restrictions imposed to provide a protection regime for the aquifer have considerable cost implications which, of necessity, need to be incorporated into the cost of the bottled product. Groundwater is vulnerable to all kinds of pollution or contamination if controls are not in place to protect it. Once it is contaminated, remedial measures may take many years to be effective, dependent on the source characteristics and the travel time of the water into the aquifer. Natural mineral waters must be safe to drink without treatment and therefore source protection is prerequisite to satisfying legislative criteria.

Highland Spring undertakes regular monitoring of their sources and bottled water

through SPDL, as an example of an ongoing 'best practice' sampling regime. Typically this is between two and four times a year for each borehole. This protocol was established during participation in the MAFF funded research programme for developing the methodology for *Cryptosporidium* analysis. As well as covering extraction boreholes, the testing regime includes less frequent monitoring of surface streams and wild mammals within the catchment area. The risk of *Cryptosporidium* contamination to Highland Spring Natural Mineral Water has been minimised by excluding livestock from their catchment area. This has been confirmed through analyses undertaken with SPDL over the last three years which has demonstrated minimal evidence of oocysts.

Sources of water for mains supply which are to be provided without filtration should acknowledge the requirement to undertake risk-assessment for that source and provide suitable means of protection, whether the source is a groundwater or surface water.

6.10 The Removal of Sheep from Loch Katrine

These two examples of 'best practice' raise the issue of the removal of sheep from Loch Katrine in keeping with deliberate policies currently demonstrated elsewhere. Concern was expressed that complete removal of the sheep flocks from Loch Katrine might allow the expansion of natural mammalian inhabitants such as voles and deer and that these would pose a similar or worse threat to the water from *Cryptosporidium*. Many published studies have confirmed that wild mammals of all descriptions can carry *Cryptosporidium* in their gut, although usually asymptotically. However, far fewer published studies reveal a link between this carriage and infection in humans. Nevertheless, cattle, sheep, goats and red deer are amongst the few non-human mammals that develop clinical illness when young and, as a result, high oocyst counts in their faeces (*Bouchier Report*, DoH/DETR 1998; S. Wright, personal communication). A study designed to measure the presence and quantity of *Cryptosporidium* oocysts in a selection of wild mammals of mainland Britain revealed that, overall, only 12% of 184 faecal samples examined were positive (Sturdee et al 1999). This ranged from 0% for the grey squirrel, brown hare, weasel, stoat and polecat to 35% for the common shrew which also provided the highest counts ranging from 3,000-25,000 oocysts per gram of faeces. Just 2 out of 23 samples obtained from foxes were positive and again their counts remained at about 3,000 oocysts per gram. It is not clear from these studies whether the gut of these mammals contain the oocysts that they have swallowed (many of these animals are carnivores) or whether the parasite is actively reproducing in their gut. In summary, for most of the animals that tested positive at least once, the proportion of samples that was positive was low (less than 25%) and the counts about 3,000 oocysts per gram despite using concentration techniques and monoclonal antibody. This is in marked contrast to the prevalence rate observed at Loch Katrine (97% using basic techniques), the high fraction (approximately 1/3) of these positive samples that displayed high counts and the published estimate of 1 million oocysts per gram of diarrhoeal lamb faeces (Blewitt et al 1989).

Only one of 16 samples provided by fallow deer tested positive as did just 4 out of 42 samples obtained from muntjac deer while their counts remained at 3,000 oocysts

per gram. The prevalence of infection in deer generally has been found to be low and as red deer are easily managed potential increases in the number of these would not be of concern (A. Sturdee, personal communication).

Rodents have been shown to carry various species of *Cryptosporidium* including, less commonly, *C. parvum*, and may act as a reservoir of infection in the farm setting perhaps by contaminating feedstuff (Chalmers 1994; Bull et al 1998). Other research suggests that the brown rat may be a more significant source of *Cryptosporidium* oocysts. Forty six of 73 brown rat faecal samples taken from 7 British farms were positive for oocysts although there is no evidence that rats demonstrate overt signs of ill health (including diarrhoea) as a result (Webster 1996). Furthermore, they produce relatively small volumes of faeces. Another study of the output of parasite oocysts from the Warwickshire College Estate revealed that the 'enduring high prevalence' of oocysts in rat, mice and voles ranged from 17-32%. The authors surmised that these wild mammals, rather than the dams, might be responsible for infecting young calves, emphasising the role of the environment as the original source of infection (Sturdee, Bodley-Tickell and Kitchen 1996/7).

Nevertheless, several important differences exist between domestic flocks of sheep, calves, goats *etc.* and wild mammals. Firstly, domestic animals tend to produce much larger volumes of faeces than do the wild mammals inhabiting Britain. Secondly, there is the fact that only farmed animals tend to develop the diarrhoeal illness that produces oocyst counts in the order of millions or thousands of millions per gram of faeces. Thirdly, in animal husbandry there is the bringing together of animals in pens and fanks for the purposes of birthing, isolation, dipping, vaccinating, lambing, sheering, *etc.* where the risk of transmission of infection is raised exponentially. Fourthly, most if not all of the wild mammals mentioned above are reared for the first few days or weeks, when their counts might be expected to be higher, in relative seclusion (small mammals under the watchful eye of their mother in a hidden nest and larger mammals such as fawns are herded well away from sight again by their mothers) and are not free to roam (S. Wright, personal communication). Although, sheep and cows do not enjoy standing in water, they do prefer the improved grazing near water courses and seek shade and this frequently coincides with trees near water margins. Any congregation of wild mammals is, therefore, unlikely to achieve the water-side density of stocks and the large production of concentrated, focused, pulsed loads of virulent oocysts that is more likely to accompany farming of domestic sheep and cattle (S. Wright, personal communication; A. Sturdee, personal communication).

Furthermore, removal of livestock would only be followed by an expansion of wild mammals if their current presence were a hindrance in terms of occupying the ecological niches or changing the habitat required for these other species. If expansion did occur, it would probably take several years to reach its maximum (A. Sturdee, personal communication). Given that this would secure the time required until filtration was in place, removal of the sheep must remain an option for consideration.

In conclusion, there may be legitimate financial reasons for retaining sheep flocks at Loch Katrine, and perhaps the means for doing that safely, but the risk of replacement by another species of mammal is unlikely to be one of them.

6.11 Recent UK experience

The published literature reveals recent examples of large urban waterborne outbreaks that are thought to be due to the presence of sheep on the catchment area of an unfiltered supply. Professor Paul Hunter, Regional Epidemiologist at the Chester PHL led the investigation of an outbreak of more than 400 cases of cryptosporidiosis in a population of more than 600,000 in North Manchester in the spring of 1999. His study revealed a strong link between sheep grazing around the feeder streams to Thirlmere reservoir, which were heavily contaminated with *Cryptosporidium* oocysts, with the outbreak despite treated water (chlorinated but not filtered) consistently testing negative for oocysts. His team reported that between 40 and 80% of sheep dung samples tested by Chester PHL on the banks of Thirlmere reservoir were found to contain *Cryptosporidium* oocysts. During this same investigation the local veterinary laboratory failed to find *Cryptosporidium* oocysts in a single specimen of sheep faeces tested (Professor Paul Hunter, personal communication), echoing this OCT's experience of the SAC laboratory's results.

Following measures to control this source of contamination, which included introducing bubble mixers where the suspected feeder streams meet the reservoir and fencing off the feeder streams with high counts, North Manchester experienced another smaller outbreak of 80 cases the following year in the Spring of 2000. Investigation of the oocyst counts at various points along the aqueduct suggested that seepage into an apparently intact although Victorian aqueduct was at fault and would explain the short, sharp profile of the epidemic curve. There is much to be learned from CDSC Northwest from these two outbreaks given the similarity in the circumstances to the Loch Katrine problem. Lessons could also be learned by WOSWA from the water undertaker supplying North Manchester (North West Water plc) which was involved in the investigation and control of the problem.

6.12 Ratio of real:reported infection

There is no widely accepted ratio of the rate of cryptosporidiosis illness in the community versus the rate of illness reported to the health board with different scientists coming up with widely differing estimates. However, it is generally accepted that reported illness accompanied by a positive *Cryptosporidium* oocyst identification in a faecal specimen represents the tip of the clinical iceberg (MacKenzie et al 1994).

3,333:1 in adults and 333:1 in children (sporadic)

Perz et al (1998) examined the potential role of tap water in the transmission of endemic *C. parvum* infection by applying a risk-assessment approach incorporating uncertainty analysis. The population was divided into four subgroups: adults and children with and without acquired immunodeficiency syndrome. The model had two components:

exposure-infection to related low-dose exposure to infection; and infection-outcome to include the probabilities of clinical outcomes leading to case detection and reporting. An assumed baseline concentration of 1 oocyst per 1000 litres and predicted mean annual risks of infection of approximately 1 in 1,000 non-AIDS adults and 2 in 1,000 AIDS adults were applied to the 1995 New York City population. Estimates of the overall probabilities that an infection would result in a reported case predicted that three reported illnesses would occur out of every 10,000 non-outbreak (endemic), tap-water related infections in non-AIDS adults and that thirty reported illnesses would occur out of every 10,000 infections in non-AIDS paediatric sub-group. In contrast, the majority of infections occurring in the AIDS subgroup were predicted to result in reported cases. It is unknown how the ratio of real:reported illness would vary between outbreak and endemic situations.

500:1 (outbreak)

In the Milwaukee, Wisconsin outbreak of 1993 there were 739 laboratory-confirmed cases of infection. Telephone survey was used to ascertain the fact that 30% of the relevant population was suffering from a compatible illness during the weeks of the outbreak. Extrapolating this information to the rest of the population and subtracting the expected background incidence of diarrhoea the authors estimated that 403,000 cases of cryptosporidiosis outbreak-related diarrhoeal illness had occurred in reality (MacKenzie et al 1994). Thus, for every every stool positive case identified it was postulated that there were at least 500 people affected (Hunter 1997). This ratio has been criticised on methodological grounds, specifically because the background incidence applied was a gross underestimate. On the basis of evidence demonstrating that self-reported diarrhoeal illness becomes inflated when the public become aware of a local outbreak, even when they live outwith the area of contamination, the actual size of the outbreak was estimated to be just 1-10% of that claimed, *i.e.* 4,000-40,000 community cases (Hunter and Syed 2001). This would result in a ratio ranging from 5.6 to 56:1.

7:1 (sporadic)

In contrast, the Public Health Laboratory Service Infectious Illness Diseases (IID) Study (Wheeler et al 1999) estimated that for every *sporadic* case reported to the health authority 3.5 cases with illness presented to their GP and 6.8 were suffering from cryptosporidiosis-related illness in the community (Jerry Wheeler, personal communication). The large discrepancy between these and the American ratios is in part due to the fact that routine surveillance of cryptosporidiosis infection is far more complete in the U.K. than in America where routine testing and reporting of microbiologically confirmed infection is not widespread. Nevertheless, it has been argued, again on methodological grounds, that this is an under-estimate given the insensitive methods for detecting *Cryptosporidium* infection used in the IID Study (Hunter 1999) and that the true ratio probably lies between 10:1 and 20:1 (Paul Hunter, personal communication). Recent human volunteer studies in the U.S. have shown that immunity to cryptosporidiosis is relatively short lived and following re-infection people become symptomatic even though their stool remains negative for oocysts (P. Hunter, personal communication). This implies that symptomatic

infection will be even more common than suggested by positive oocyst results, further inflating the real:reported ratio.

In conclusion, it would seem reasonable to conclude that significantly more cases of infection occurred, in the order of 900 to 1,800, than the 90 that were reported.

6.13 Death in an elderly lady with leukaemia

Information provided by GCC (North) revealed that a report of soiled water at this lady's address and vandalism to the hydrant in this lady's neighbourhood turned out to be an unrelated incident occurring two years prior to her illness. Given that this lady did not leave her home for any reason before becoming ill, had not consumed any suspect foods, had not visited a farm or zoo and had no contact with another case of illness, it seemed reasonable to assume that she contracted the infection from the water supply to her place of residence. There was no other evidence to suggest that the acute episode of gastro-intestinal illness was related to a more local problem of water quality.

The DoH in England and the Scottish Executive Department of Health confirmed that the revised and more specifically targeted guideline on 'boil water' advice to the immunocompromised issued by GGHB in July 1999 had the same status in Scotland as in the rest of the UK (see appendix 6). It also enjoyed the same status as did its parent document, the *Bouchier Report* (DETR/DoH 1998).

Consequently, the haematologist at the GRI acted appropriately (in concordance with the most recent guideline issued the year before) when she decided not to advise this elderly lady, who subsequently died of cryptosporidiosis, to boil her drinking water. Furthermore, discussion with the haematologist suggests that it would have been inappropriate in light of her age and condition to impose an indefinite 'boil water' notice. The status in Scotland of this guideline had been questioned because of the concern that perhaps GGHB has acted in error by locally distributing a guideline that had only been officially disseminated in England. There was also concern expressed that perhaps this particular person should have been told to boil her water in keeping with the more general advice to this effect in the original *Bouchier report* (DoH/DETR 1998). This original guideline suggested that advice on prevention, which included boiling all drinking water, be 'aimed at immunocompromised individuals', including patients with HIV infection, hypo- or agammaglobulinaemia, hyperimmunoglobulin M syndrome, severe combined immune deficiency, **leukaemia (especially during aplastic crises)**; or as a result of therapy with immunosuppressive drugs...'. Clearly, if this original guidance had been adhered to this lady would have been considered for advice on prevention of exposure.

The details of this patient's death had been initially passed on to the appropriate person at the Department of Health who informed GGHB that the guideline would not require a review in the light of this death (M. Tomlinson, personal communication). Since then, the Scottish Executive DoH has made a formal request to GGHB for a complete summary of this patient's circumstances and death.

The OCT was concerned that less than one year after guidance had been re-issued that limited the list of target groups a death would occur in precisely one of the two general categories of patients who would, otherwise, have been advised to take preventive action. Furthermore, as there is no surveillance system (active or passive) to detect complications of cryptosporidiosis, including death, it is conceivable that such complications are significantly underestimated by health boards investigating such outbreaks, particularly if there is no public attribution to the public water supply and therefore no publicity which is usually the stimulus to contact departments of public health.

7. Conclusion

In summary, all the available evidence, including descriptive epidemiology; human microbiology and genotyping; water monitoring; and sheep microbiology suggest that the excess of reported cases of cryptosporidiosis in May and June of 2000 in the GGHB area was a waterborne outbreak. The evidence also suggests that this was most likely due to contamination of the water supplied from Loch Katrine itself and treated at Milngavie Treatment Works, either at the lochside or via the feeder streams at Loch Katrine. Given the published evidence linking large springtime outbreaks in human populations with lambing and given the large population of ewes and lambs at Loch Katrine, the most likely source of the contamination was the sheep at Loch Katrine.

8. Immediate control measures

This investigation of an outbreak of cryptosporidiosis suspected to be waterborne and in the main unfiltered supply for a large urban area was largely a retrospective exercise aimed at collecting evidence as to the exact cause so as to be able to prevent similar events in the future. At the first meeting of the OCT on 2nd June, it was agreed that a 'boil water' notice was not warranted given that the last positive result on *Genera* filtering was positive on 12 May on the Mugdock supply and that the preliminary plotting of the epidemic curve suggested the peak of the outbreak was past. The practicalities of issuing a 'boil water' notice to almost 700,000 householders, the question of when to lift the 'boil water' notice and the risk of scald injuries associated with the increased use of kettles were additional reasons to avoid issuing such a notice at that point in time.

There were no other immediate or practical control measures available other than to step up clinical investigation of people suffering from persistent diarrhoea so as to maximise the number of identified cases and therefore the chance of identifying the mode of transmission of the parasite through detailed interviewing. There is no specific pharmacological treatment or cure for cryptosporidiosis infection and the letter sent to all GPs and A&E doctors aimed at increasing case detection can be used to remind clinicians with high-risk patients of the four groups of immunocompromised people that need to be selectively reminded to boil their drinking water to avoid infection. This letter is presumed to have resulted in an increase in numbers of stool specimens submitted because of a secondary peak in laboratory reporting following the letter and meant that a total of 77 cases were reported before the outbreak was officially declared over on 15th June. Controversy generated by this letter over the issue of whether it is reasonable to fully inform relevant medical practitioners was deemed misplaced given a recent publication suggesting that when a waterborne outbreak of cryptosporidiosis is suspected 'health care practitioners in the community' should be notified of 'the potential for exposure as a result of waterborne contamination' and advised of a 'procedure for reporting all cases of gastroenteritis to the responsible health authority' (Meinhardt et al 1999).

There is currently no practical contingency plan that WOSWA can implement in the event of a waterborne outbreak of cryptosporidiosis in the Loch Katrine supply in terms of diverting or substituting alternative water supplies, stepping up existing treatment processes *etc.* Due to the size of the population supplied once the outbreak was identified there was little if anything that could be done other than to study it in detail and use the intelligence gathered to prevent another outbreak. This highlights the need to reduce the risk of contamination with *Cryptosporidium* in catchments of Loch Katrine and the aqueducts to help prevent a recurrence of this event.

9. Lessons learnt

- ◆ There are several built-in delays in the system of reporting diarrhoeal illness, some of which are unavoidable, including those incurred on the part of patients, GPs, laboratory technicians, microbiologists, *etc.* By the time a health board is in a position to investigate an outbreak of cryptosporidiosis it is often over or almost over. In order to minimise further delay associated with identifying the water supply for cases of cryptosporidiosis, WOSWA has provided the health board with an electronic copy of the water supply database by individual address and postcode to enable public health officials to independently access such data on the day of laboratory reporting within health board premises.
- ◆ A sizeable proportion of cases of cryptosporidiosis were reported to SCIEH and to the source laboratory by the SPDL but were never reported by the source laboratory to the health board. Following an audit set up to investigate this problem, it was discovered that for the calendar year of 2000 this amounted to 25%. The emphasis on reporting appears to be inappropriately biased towards informing the tertiary surveillance centre rather than informing the health board that has primary responsibility for investigation and control of outbreaks. The responsibility for real time surveillance of communicable disease lies with the health board and not with SCIEH. Furthermore, it was discovered that not all hospitals routinely test faecal specimens for *Cryptosporidium* despite national PHLS guidelines advocating this practice. It is conceivable that outbreaks could occur and remain undetected if laboratories fail to test specimens for this pathogen. Finally, as there is no surveillance system to detect the complications of cryptosporidiosis infection, including death, it is conceivable that the evidence base describing which target groups merit advice to boil their drinking water is incomplete. This will have implications for the formulation of guidelines on target groups.
- ◆ In retrospect, perhaps calling an official outbreak control team would have been appropriate earlier in that the Problem Assessment format encouraged the confusion as to the role of WOSWA. A PAG is appropriate when there is an actual (or potential) waterborne hazard that might impact on human health. In this case the start point was the finding of the excess of cases of ill health and the attempt to find an explanation for them is therefore legitimately the role of an OCT and not a PAG.
- ◆ There is a need for both health and water authorities to consider that an outbreak of cryptosporidiosis in a high-risk supply area should be assumed to be waterborne in the absence of adequate alternative explanations rather than strive to attribute it to these alternative explanations.
- ◆ Very low level *Cryptosporidium* contamination of water from any but especially from known high-risk supplies should not be assumed to be of no significance and similarly any deviations in turbidity in such supplies should not be dismissed as of no significance but should be seen as possible early warnings.
- ◆ There is a need for the water authority to give full and frank disclosure of all relevant information on *Cryptosporidium* oocyst testing and turbidity, including lapses in monitoring, even if they do not consider it significant themselves.
- ◆ Further thought needs to be given to what advice to give to the public in such situations, short of issuing a blanket “boil notice”, and serious thought needs to be given to what advice the public should be given regarding known high-risk supplies that will continue to

pose a risk of allowing *Cryptosporidium* into drinking water supplies to allow the public to make an informed decision as to whether they wish to accept such a level of risk or take alternative arrangements. Reconsideration at a GGHB level of the specific target groups warranting advice to 'boil water' is required in the light of the death of an elderly patient with leukaemia.

- ◆ There was a paucity of immediate information at hand about the structure of the water supply system from Loch Katrine. There is a need to consider in more depth the whole water supply system including the aqueducts and to carry out more targeted investigation of the water supply system to exclude the possibility of problems such as that identified in the recent outbreak in Belfast where septic tank overflow and seepage were thought to be the explanation.
- ◆ Sheep and calves should be considered as a high-risk source of *Cryptosporidium* oocyst in the lambing and calving season, respectively, although the degree of risk is further influenced by the nature of the catchment area.
- ◆ Good descriptive epidemiology is essential to hypothesis generation in an outbreak situation and is every bit as important as, if not more important than, a case-control study.
- ◆ There is a need to review the laboratory protocols for investigation of *Cryptosporidium* in possible animal sources which are not symptomatic.
- ◆ The status of the water authority on the Outbreak Control Team, whose presence is an anomaly, requires to be reassessed in view of the substantial potential for conflict of interest in several areas including the course of the investigation, the content and timing of press releases, and the content and completeness of the final OCT report.

10. Recommendations

The OCT was concerned that given that a public water supply has been implicated and that the exact site of contamination remains undetermined, there is a risk of a future outbreak over the next five years until the treatment works at Milngavie is upgraded. Preventive health education regarding the risk of cryptosporidiosis from farm and zoo visits has been given to the public every year for the last four years, despite the fact that the evidence suggests that a much higher percentage of all cases combined would likely be due to water. Some members of the OCT questioned whether it was time that advice be given to the public regarding the small risk from water. Concern was expressed by other OCT members that there would be potential danger of panicking the public and a resultant loss of confidence in drinking water. They also considered that this approach would need to include the Scottish Executive as they argued that the risk to the public health was a Scotland-wide problem, particularly in the many private supplies where there is a high risk of *Cryptosporidium* contamination. However, in view of the fact that Loch Katrine is the only large public supply that remains unfiltered in Scotland it seems reasonable to address solutions to it individually rather than argue for a Scotland-wide approach that might be misplaced. A number of solutions to the Loch Katrine problem were discussed that are formulated as 18 recommendations below.

A detailed risk-assessment to be carried out by the Scottish Agricultural College was commissioned by the steering group set up by WOSWA. This important exercise involved quantifying possible points of contamination with a view to altering sheep management practices. Many proposals aimed at risk reduction emanated from this process by December 2000, as planned, and most were implemented by the spring of 2001, albeit with some unavoidable delays due to the UK-wide epidemic of Foot and Mouth Disease. The overall conclusion of this exercise suggested that the risk would be sufficiently reduced by local measures including introducing safe disposal of the waste effluent of sheep pens and fanks to obviate any need to remove the sheep.

10.1 Water Treatment

Recommendation 1 - Bring forward the proposed upgrading of the treatment works.

The OCT recommends that every effort be made to expedite the implementation of full filtration for Loch Katrine water using the most appropriate technology to effect a suitable reduction in the risk profile of that water supply.

Clearly, introducing a filtration system that will remove most oocysts is the only real solution as it would deal effectively with all oocysts regardless of their zoonotic source (human sewage; domestic animals including sheep and cattle; rodents; birds, wild deer *etc.*) and their geographic origin (seepage into the aqueducts, lochside, feeder streams *etc.*)

The OCT was informed that WOSWA has a project team in place to select the preferred bidder for this project. The contract will be via a partnership process which

will hopefully shorten the time and decrease the cost. The plan is to finish mid 2005 at a cost of £90 to £130 million. There is little to suggest that this can be brought forward. The capacity of the new works could be as high as 400 megalitres and there will be considerable environmental and public relations issues to overcome. Considerable local opposition is also anticipated since the existing reservoirs at Milngavie are a public amenity in that vicinity.

Recommendation 2 - Utilisation of spare treatment capacity at other water treatment works to supply the Greater Glasgow area.

The OCT further recommends that until a filtration facility is in operation at MTW, an appraisal should be undertaken urgently of the feasibility of using existing mains networks and existing filtration capacity at Blairlinnans and Balmore Treatment Works.

Until a filtration facility is in operation at MTW, it seems reasonable to consider the possibility of utilising spare capacity at Blairlinnans and Balmore Treatment Works to put fully treated water into the Glasgow system. It is understood that a feasibility study of diverting Loch Katrine water through the Balmore Treatment Works was already carried out by WOSWA and the existing mains distribution system is satisfactory to support such a diversion.

10.2 Livestock Management

Recommendation 3 - Detailed risk-assessment of the sheep at Loch Katrine

The OCT recommends that, if the sheep are to remain at Loch Katrine, a detailed study of *Cryptosporidium* prevalence and carriage should be initiated in parallel with risk-reduction measures as part of an overall risk-assessment.

A study of the prevalence of *Cryptosporidium* carriage and infection by flock and by age *etc* should be carried out to elucidate quantitatively and qualitatively the role of sheep carriage of *Cryptosporidium* in the causation of human infection. The concept of a detailed prevalence study was endorsed by both the SCIEH consultant in veterinary public health and a research scientist at the Moredun Research Institute (S. Wright, personal communication). It could be argued that complete removal of the sheep from Loch Katrine might be justified if the prevalence rates in late juvenile and adult sheep were unusually high (e.g. more than 15-20%) but this could only be accurately assessed by detailed survey of older animals (A. Sturdee, personal communication). The concept of such a study was also endorsed by the GGHB representative and the SCIEH environmental epidemiologist with the proviso that any scientific studies of carriage rates in sheep at Loch Katrine were carried out in parallel with, and not instead of, the implementation of risk-reduction measures. The identification of a new genotype of *Cryptosporidium* (non Type 1, non Type 2) present in sheep taken from Stronachlachar further justifies such a study.

Recommendation 4 - Alterations to the management of the sheep

The OCT recommends that WOSWA should review sheep management practice at lambing times with a view to reducing access by ewes and lambs to the lochside

and feeder streams and ultimately reducing the risk of contamination entering the raw water supply. The OCT recommends that WOSWA should review sheep management practice more generally including issues such as the disposal of sheep faeces emanating from pens and fanks.

An alternative to removing the sheep altogether is the possibility of grazing or lambing ewes during the high-risk period in April and May in an area where they are less likely to cause contamination of the loch. The two obvious possibilities include:

- moving ewes from the lochside to another area during peri-parturient period including during lambing and early suckling.
- moving ewes from lowland to highland pastures during peri-parturient period including during lambing and early suckling. The double rationale is that transmission of infection between animals is likely to be reduced when they are grazing in a more dispersed fashion at higher altitude, and subsequent contamination of the water is likely to be reduced because of the lower density on the ground of infected stools.

These adjustments to the way sheep are managed might be expected to reduce the risk of infection during spring-time. There is no way of knowing until they are tried and tested. However, whether they are feasible is another issue and it may be that the logistics and animal welfare issues involved with removing 8,000 pregnant ewes just before lambing or fencing them on to highland areas are insurmountable. Furthermore, pregnant or lactating ewes and their lambs prefer the warmer temperatures and more nutritious grass near the lowlands including at the lochside and it would be unnatural to force them on to higher ground during a vulnerable period where they may suffer higher peri-parturient or perinatal death rates, respectively.

Another adjustment to sheep management would be to prevent lambing altogether while retaining the ewes on the banks of Loch Katrine. This would eliminate the spring peak in prevalence amongst ewes which occurs during and following pregnancy, eliminate cross-infection between ewes and vulnerable lambs and reduce the environmental burden of oocysts by eliminating diarrhoeal or solid lamb dung containing high oocyst counts. This would also prevent the migration into the area of sheep from surrounding farms that may occur if all the sheep are removed given the absence of sheep fences in the area.

Clearly, any pens and fanks containing sheep faeces must be considered a high-risk if draining into, or located near to, a feeder stream or the lochside. Such high-risk sources must be functionally excluded from the water catchment by whatever means necessary.

Recommendation 5 - Erecting barriers to prevent sheep from gaining access to the lochside and feeder streams.

The OCT recommends that WOSWA should consider the possibility of reducing the risk posed by sheep by more effective control of access to the lochside and feeder streams, including that provided by permanent fencing.

If retention of the sheep flocks is seen as imperative, it would seem reasonable to consider preventing grazing ewes and lambs from gaining access to the immediate lochside area and feeder streams, at least during lambing time. This could theoretically be achieved by sheep-proof fencing. However, the need for lactating ewes to gain access to water during a dry spell may obviate this option as artificial watering arrangements would be prohibitively expensive. So too would be the fencing for an area as large as Loch Katrine with its myriad of feeder streams. Erecting such fencing just during lambing every year would not be feasible. Finally, such fencing would need regular inspection and repair as sheep have a well known propensity for defying such barriers and being followed by the rest of the flock.

Failing the adoption and demonstrated success of implementation of Recommendations 3, 4, and 5 by WOSWA, the following recommendation is made.

Recommendation 6 - Removing all domestic livestock from Loch Katrine

The OCT recommends that serious consideration be given to removing all sheep and cows from the Loch Katrine catchment area as the means of achieving the most significant probable reduction in risk of waterborne Cryptosporidium. Permanent removal would secure the greatest potential risk reduction for the future bearing in mind that any filtration process is subject to potential failure at some point as are remedial measures aimed at controlling effluent from high-risk sites such as pens and fanks. However, as an alternative, temporary removal at least should be seriously considered from areas posing the greatest potential risk of contamination until full filtration is implemented.

In 1993, a year for which a larger outbreak appears to have occurred associated with the Loch Katrine supply, there were a total of 169 cows and 108 calves owned by WOSWA at Loch Katrine, excluding 19 additional cattle owned by the shepherds. WOSWA had already taken the necessary measures to remove their own herds of cattle from Loch Katrine in September 1998 in order to reduce the risk of cryptosporidiosis. The shepherds' own limited allocations of cows and calves posed an on-going risk and the OCT supports the action already taken by WOSWA following the outbreak to have these removed. However, the principle behind the action of removing livestock should apply equally to sheep (DETR/DoH 1998) even though cattle clearly produce greater volumes of faeces than sheep. As long as sizeable collections of animals are allowed to graze in areas that are in direct contact with feeder streams and the lochside, there will remain an unquantifiable risk, particularly if their prevalence of a virulent strain of *C. parvum* were to rise.

Sheep that are negative for *Cryptosporidium* today can become positive at any point thereafter and without on-going careful monitoring it may be impossible to rule out the possibility of future outbreaks, even following detailed baseline studies of carriage rates. In the interests of public health, restricting grazing on Loch Katrine should be considered by WOSWA, particularly as they own the land around Loch Katrine and the

sheep grazing on that land. WOSWA have stated that they consider that sheep farming remains a legitimate and appropriate activity, even though they admit that the revenue raised by sheep farming was not a significant contribution to the WOSWA budget. WOSWA have expressed concern regarding the effect that withdrawing sheep grazing would have on the local community at Stronachlachar and surrounding Loch Katrine and consider this as being a significant factor in deciding whether sheep farming should be discontinued.

The fact remains, however, that the only sure way to eliminate the risk of significant lochside and feeder stream contamination from livestock is to ban sheep and cattle from grazing on the catchment. Sheep are notorious for overcoming fences. In addition, any measures to control the effluent of pens and fanks, that are inevitably heavily contaminated, have a potential to fail. Furthermore, the *C. parvum* oocyst can survive long periods in the environment and any sizeable continuing domestic animal presence will always pose the unquantifiable but real risk of another outbreak. The evidence of equal infection rates in the two reservoirs fed by Loch Katrine and the evidence from North Manchester that 400 people became ill as a result of contaminated feeder streams to Thirlmere Reservoir both suggest that large bodies of water can be directly implicated in the causation of illness.

Clearly, removing all livestock from Loch Katrine catchment will not prevent contamination of the aqueducts. Nevertheless, it would solve part of the problem and the persistence of a risk from the aqueducts is not a viable reason for failure to take action against an obvious source of contamination.

10.3 Loch Water Flow Patterns

Recommendation 7 - Investigation of localised streaming near abstraction points.

The OCT recommends that WOSWA should carry out investigation of feeder stream flows within the loch to determine if streaming is an issue which might provide opportunities for action to reduce the potential risk of concentrated contamination reaching the water take-off points.

Given the evidence from the Thirlmere outbreak in April 1999, streaming from a heavily contaminated feeder source towards the raw water take-off point may be a factor in raising the risk of *Cryptosporidium* contamination by preventing dilution in Loch Katrine itself. Dilution of such contamination could be solved by the introduction of bubble mixers or the contamination reduced by selectively restricting access by sheep to such high-risk feeder streams.

10.4 Aqueduct integrity and protection

Recommendation 8 – Investigate the integrity of the aqueducts.

The OCT recommends that WOSWA should investigate the integrity of the aqueducts and determine if there is a potential for contamination entering the supply via this route. The OCT should then assess what opportunities exist for preventing such contamination, either by repairing vulnerable sections or by advising nearby farmers on how to minimise contamination through modification of farming practice.

Although the infection rates in the two sub-distributions suggest otherwise, there remains a possibility that *Cryptosporidium* entered the water system via one or both aqueducts. Irrespective of the circumstances of this outbreak, contamination of water in the aqueduct from a range of microbiological pathogens (including *E. coli* O157, *Campylobacter*, *Cryptosporidium* etc.) whenever there is a sewage spill or farming activity above or near the path of this conduit remains a potential problem if there are any structural defects, including microscopic fractures. Given that the aqueducts are 115 and 145 years old, respectively, and that WOSWA can not control the agricultural and other industrial activity along these aqueducts it seems reasonable to suggest that the integrity of these pathways needs to be thoroughly assessed and any necessary remedial work carried out as a matter of urgency. Evidence from a recent outbreak of cryptosporidiosis in April 2000 in North Manchester (P. Hunter, personal communication) and another in September 2000 in Northern Ireland (John McKee, personal communication) suggests that aqueducts can be at risk from contamination with *Cryptosporidium*.

10.5 Rainfall Monitoring

Recommendation 9 – **Enhanced monitoring of rainfall at Loch Katrine using hourly rainfall gauges.**

The OCT recommends that hourly rainfall gauges be re-instituted at Stronachlachar to supplement or replace current daily gauges and that consideration be given to make the resulting data available within 24 hours if not within real time. In addition, efforts should be made to ensure continuation of hourly measurements at the Sloy Hydroelectricity plant at Inveruglus, Loch Lomond as part of an early warning system given that in most circumstances weather fronts (which tend to be westerly in origin), affecting Loch Katrine, will have affected the west coast of Loch Lomond first.

Although the evidence suggests that hourly rainfall has not been excessive in advance of outbreaks associated with 1993, 1998 and 2000, it seems reasonable to obtain more detailed rainfall data for Loch Katrine and on a more immediate basis given the ongoing risk from this supply until 2005/6.

10.6 Risk assessment

Recommendation 10- **Further refinement of the *Cryptosporidium* risk-assessment procedure.**

*The OCT recommends that the SE Water Quality Regulation Team should be requested to consider further refinement of the *Cryptosporidium* risk-assessment procedure to include factors such as the density of animals on the catchment area, the use of the land for lambing (or calving) and whether or not there is catchment control in terms of fencing off access to waterside and feeder streams. The risk-assessment should also take into account the vulnerability of the raw water supply to contamination not only at source but also in transmission to any treatment works, in this case the two aqueducts.*

The current risk-assessment process advocated as part of the *Cryptosporidium* Direction appears to give equal weighting to a diverse range of factors such as the presence or absence of water pollution; the presence or absence of animals on a catchment area (as opposed to the lochside density of animals that may be achieved during peak times), etc. Given the apparent association between this outbreak and the lambing/calving season, there is a case for considering further the refinement of the risk-assessment process to better reflect the risk of contamination of raw water.

10.7 Consumer Advice

Recommendation 11 – Consumer advice to major food and drinks manufacturers using Loch Katrine water.

The OCT recommends that WOSWA discuss the issue of the risk status of Loch Katrine with both its regulator (S.E. Water Quality Regulation Team) and its largest customers with a view to providing specific advice to major food and drinks manufacturers that use large quantities of Loch Katrine water. This advice would refer to the continuing risk of Cryptosporidium in order that such manufacturers may carry out adequate risk-assessments of their own procedures and determine whether or not they need to consider further local treatment options.

Recommendation 12 – Consumer advice to the public along the lines of that given regarding visits to farms and zoos.

The OCT further recommends that the Greater Glasgow Health Board, in conjunction with WOSWA, should also consider advising the public regarding the status of the Loch Katrine water in order that the public might decide for themselves what precautionary action they may choose to take.

There remains a possibility that there will be another episode of waterborne cryptosporidiosis associated with Loch Katrine until filtration is introduced. There is a case for advising both the public and the food and drink producing industry regarding the risk status of Loch Katrine water. Otherwise, both the water authority and the health board remain subject to future legal action either on behalf of a private individual or a large company should serious illness result from consuming tap water either directly, or indirectly as part of a prepared food or drink containing mains water.

10.8 Advice to the immunocompromised

Recommendation 13 – Reassessment of current guidelines targeting vulnerable groups with universal ‘boil drinking water’ advice.

The OCT recommends that the Department of Health review a full written summary of the clinical details surrounding the cryptosporidiosis-related death reported in this outbreak with a view to reviewing the most recent ‘boil water’ guidelines for the immunocompromised (issued in 1999 – See appendix 6).

Recommendation 14 – GGHB-specific guidelines on vulnerable groups and advice to boil drinking water.

The OCT further recommends that GGHB consider issuing area-specific advice to all medical practitioners within GGHB and neighbouring health board areas that receive Loch Katrine water. This area-specific advice would take into consideration that Loch Katrine water remains the largest and highest-risk public supply in Scotland and that local guidelines may need to be more inclusive than for the rest of the country, advising local practitioners to exert individual judgements about the need to consume boiled water by very young or elderly immunocompromised patients who do not satisfy the current published criteria.

Currently, there is no active or passive surveillance system to detect the complications of cryptosporidiosis infection, including death. Such cases with confirmed complications must play an important part of the evidence base when determining target groups meriting advice to boil drinking water. The death from cryptosporidiosis that occurred during this outbreak was in an elderly patient suffering from Chronic Lymphatic Leukaemia (CLL) and this occurred just one year after the guideline was revised to exclude leukaemics. The status of all leukaemias as a group of conditions meriting inclusion in the category of high-risk conditions, affecting patients who should be advised specifically to boil their water, should be referred to the Department of Health for review in the light of this case.

In addition, however, it is recommended that, given the continued risk profile of Loch Katrine, consideration be made to devising local guidelines that are more encompassing than the latest Bouchier guidelines to encourage local clinicians in this high-risk area to make individual decisions about advising susceptible patients, including leukaemics, to boil their drinking water. It seems reasonable to consider that, at the very least, people with such conditions should be allowed to make an informed decision as to whether they want to boil their drinking water. Until this outbreak, both clinicians and their patients (the public) remained unaware that the water was associated with a higher risk of this infection than any other large public supply in Scotland and were therefore not in a position to make an informed decision.

10.9 Laboratory Reporting

Recommendation 15 – Measures to increase ascertainment of cryptosporidiosis infection by the health board.

*The OCT recommends that all human stool specimens be routinely examined for the presence of *C. parvum* oocysts in keeping with current PHLS guidelines and that all cases of infection, whether sporadic or part of an outbreak should be reported to the relevant health board Department of Public Health. Where a case is confirmed by a reference laboratory it should pass the information directly to the relevant health board to minimise the risk of delay or failure in communication.*

In light of the fact that much of GGHB's population will continue to receive water from a high-risk catchment there is a need to fully assess the extent to which this is

causing cryptosporidiosis infection in the community, either on an endemic or epidemic basis. During this investigation it was discovered that the various hospital laboratories in GGHB adhered to different protocols with respect to testing stool specimens and reporting the results to the health boards. Specifically, some hospitals did not routinely test all specimens for cryptosporidiosis and some did not routinely report positive results to the health board. If the cause of an outbreak is to be accurately attributed it is essential that as complete an ascertainment and reporting of cases takes place as is possible and that this is practised consistently throughout the GGHB area.

10.10 Water Authorities and Outbreak Control Teams

Recommendation 16

The OCT recommends that in the interests of impartiality and transparency, water authorities should not be included as official members of future Outbreak Control Teams investigating possible waterborne disease outbreaks but that they should be invited to participate as members of a sub-group charged with investigating the evidence relating to the water supply. The final report of an OCT should take account of the evidence and opinions of the water authority but should not be required to have its unequivocal agreement in drawing final conclusions as to the cause of the outbreak. This measure will provide added reassurance to the public that the OCT is not subject to any potential for undue influence by any vested interest and will protect the water authorities from any assertions of exercising such influence.

It is recognised that investigation of a potentially waterborne outbreak of infection requires the active involvement and co-operation of the relevant water authority. However, the presence of water authority staff as full members of an OCT is an anomaly in that such a situation would not normally occur were an outbreak to involve a food premises/food producer. There remain important potential conflicts of interest, particularly in relation to the course of the investigation in general and decisions regarding the release of information to the public and media in particular. The status of water authority representatives as members of any OCT therefore requires further consideration. One solution would be to afford water authority representatives status as ‘in attendance’ at most OCT meetings allowing the chair of the OCT to use his discretion at calling selected meetings to be attended only by the remaining officers from the relevant council(s), health board(s), trusts, SCIEH and Scottish Executive. Alternatively, the water authority could be invited to the meetings of a subgroup of the parent OCT. However, regardless of the selected approach, it must be considered unacceptable for a water authority implicated in a waterborne outbreak to exert undue influence over either the course of the investigation or the OCT report of that investigation. Furthermore, as a key function of the OCT is to examine the clinical and personal details of people suffering from infectious gastrointestinal disease, which must not be shared with any agency (including the water authority) unless it demonstrates a clear need for that information (CF Caldicott), much of the OCT’s work requires to be discussed in the absence of the water authority.

The following two recommendations apply to research in this area:

10.11 Laboratory research

Recommendation 17 - *Cryptosporidium* fingerprinting

The OCT recommends that in future, due regard be given to the existence of this new technology and where appropriate, it be applied to outbreak investigations. However it should be noted that further research is required to enhance the resolution of the current fingerprinting technique for C. parvum. Therefore, the OCT would support the further development of this genotyping method such that in the future it can be employed outside the research laboratory and used in outbreak and other clinical investigations in Scotland. Funding of further research should be sought from a range of sources and such appeals should be assessed against competing research-funding applications.

During this investigation it was noted that the inability to link the genotype of the clinical outbreak in Glasgow with the genotype of organisms recovered from animals around Loch Katrine meant that the OCT would likely not "*obtain forensic-level proof of the cause of this outbreak and members should (therefore) not await such absolute proof before finalising a report of its conclusions*". The principal reason for this was that at the time of the outbreak the technology did not exist to enable unambiguous matches between the DNA recovered from *Cryptosporidium* from patients in Glasgow and DNA from parasites isolated from animals or environmental samples near the suspected source of the outbreak. If such a DNA fingerprinting technique were available and if adequate sampling were performed close to the time of outbreak, then the task of pinpointing (or eliminating) potential animal hosts implicated in transmission of the parasite might have been significantly easier.

Over the past 18 months the Scottish Executive, through the Chief Scientists Office, has funded a research project based at the University of Glasgow, SPDL and SCIEH aimed at the development and evaluation of molecular typing methods as a tool to investigate the epidemiology of human cryptosporidiosis. This project has progressed to the extent that proof of principle of a highly discriminatory genetic typing system has been obtained. The system has been evaluated successfully in other Scottish regions where it shows considerable promise of providing the level of discrimination between different genotypes of *C. parvum* required for the investigation of cryptosporidiosis outbreaks in Scotland.

10.12 Sociological/Economic Research

Recommendation 18 – **Detailed health economic analysis of the cost of the outbreak.**

The OCT recommends that a detailed health economic analysis of the total costs of this outbreak be estimated in order to fully assess the costs to the patient, their employer if applicable, the statutory services and the health service.

The full costs of this cryptosporidiosis outbreak have yet to be quantified and include not just the obvious rare death but a large unknown toll of illness. Diarrhoeal illness related to cryptosporidiosis infection tends to be prolonged (unlike salmonella) and can take months to resolve in selected individuals. Most of the cases in this outbreak experienced diarrhoea for 2-3 weeks. The accompanying costs both social and financial include work and school absenteeism, GP visits, stool specimen testing and reporting, anti-diarrhoeal agents, visits by environmental health officers, hospital admission costs *etc.* There is legitimate concern that there might be a tendency to trivialise cryptosporidiosis infection because it does not cause bloody diarrhoea and renal failure the way *E coli* O157 infection can and is less likely to be fatal in previously healthy subjects.

Quantification of the full extent of the cost of an outbreak will be difficult until there is active or passive surveillance, by the health board, of complications of cryptosporidiosis infection, including death.

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12. Status of the report

This report represents a consensus of the views of the Outbreak Control Team which consisted of representatives of the various statutory agencies involved, including Greater Glasgow Health Board, Glasgow City Council, and the Scottish Centre for Infection and Environmental Health. The exception to the consensus is West of Scotland Water and their reasons for refusing to sign up to the report are described in a submission from WOSWA as follows:

WEST OF SCOTLAND WATER

Outbreak Control Team Report on Cryptosporidiosis Outbreak in 2000

West of Scotland Water does not endorse this report.

It is accepted that the most likely source of the outbreak was waterborne but there was no conclusive evidence, which linked the human cases to sheep faeces in the catchment of Loch Katrine. Information and individual views have been gathered and produced in this report which attempted to prove there was a link. In the opinion of West of Scotland Water this has resulted in an unbalanced report. The report should deal with facts, draw conclusions and make recommendations based on the evidence from the outbreak. The conclusions of the Loch Katrine *Cryptosporidium* Risk-assessment Report produced by the Scottish Agricultural College were disregarded.

West of Scotland Water does not agree with the recommendations as they stand. Concerns include recommendations, 11, 12 and 16 as they have implications for the whole Water Industry and should be referred to the Scottish Executive for further direction and input. Recommendation 16 should also be referred to the reformed Cairns Smith group.

13. Appendices

1. **Membership of the Problem Assessment Group and Outbreak Control Team.**
2. **Schedule of the meetings held.**
3. **Table of UK cryptosporidiosis outbreaks 1989-1998 (Bouchier Committee).**
4. **Maps of the supply.**
5. **Letter to GGHB first line medical staff during the outbreak.**
6. **Letter issued to all haematologists in the GGHB area in July 1999 referring to DoH guidance (also enclosed).**
- 7a. **Map showing distribution of cases in relation to water supply.**
- 7b. **Graph showing relative timing of events and overall epidemic curve.**
- 7c. **Graph showing epidemic curve by reservoir.**
8. **Cryptosporidiosis outbreak investigation proforma (Taken from the '*Bouchier Report*', DoH/DETR 1998).**
9. ***Cryptosporidium* oocyst monitoring.**
10. **Turbidity monitoring.**
11. **Press statement.**
12. **Site risk-assessment using Scottish Executive methodology.**
13. **Contributors who provided supporting evidence.**

Appendix 1

Members attending the First Problem Assessment (PAG) Group meeting

Dr Helene Irvine, CPHM (Chairman)	Greater Glasgow Health Board
Dr Colin Ramsay, Consultant Epidemiologist	Scottish Centre for Infection and Environmental Health-SCIEH
Ms Lorraine Miller, Internal Customer Team Leader	West of Scotland Water
Mr Paul Quietsch, Regulations Adviser	West of Scotland Water
Mr. John Boyd, Environmental Health Officer	Glasgow City Council

Members attending the Second Problem Assessment Group (PAG) meeting

Dr Helene Irvine CPHM (Chairman)	GGHB
Dr Colin Ramsay, Consultant Epidemiologist	SCIEH
Mr Jim Blair, Senior EHO	GCC (South)
Mr David Speirs, Senior EHO	GCC (North)
Dr Catherine Benton, Regulations and Business Manager	West of Scotland Water
Mr John Rae, Director of Planning and Financial Procurement	West of Scotland Water
Mr C Brankin, Press Liaison Officer	West of Scotland Water
Mr D Carnduff, Press Liaison Officer	West of Scotland Water

Membership of the Outbreak Control Team

Dr Helene Irvine (Chairman)	GGHB
Dr Colin Ramsay	SCIEH
Prof Bill Reilly, Consultant in Veterinary Public Health	SCIEH
Mr Jim Blair, Senior EHO	Glasgow City Council
Mr David Speirs, Senior EHO	Glasgow City Council
Ms Jennifer Nimmo, Senior EHO	E Dunbartonshire Council
Mr Jarvis McFadzean, Director of Water Supply and Treatment	West of Scotland Water
Dr Catherine Benton, Regulations and Business Manager	West of Scotland Water
Mr John Rae, Director of Planning and Financial Procurement	West of Scotland Water
Mr C Brankin, Press Liaison Officer	West of Scotland Water
Ms Elaine McKean, Press officer	GGHB
Mr Vincent McKeown, Public Health Nurse	GGHB
Miss Tracy Curtis, secretary	GGHB (taking minutes)

In attendance at OCT meetings, as a representative of the Regulator

Mr Colin McLaren, Regulation Team Officer	Scottish Executive Water Quality Regulation Team
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Appendix 2

Schedule of meetings

Title	Venue	Date
1 st Meeting of the Problem Assessment Group	GGHB, Glasgow	18 May 2000
2 nd Meeting of the Problem Assessment Group	Shieldhall Treatment Works, Glasgow	23 May 2000
1 st meeting of the Outbreak Control Team	GGHB, Glasgow	2 June 2000
2 nd meeting of the Outbreak Control Team	SCIEH, Glasgow	6 June 2000
3 rd Outbreak Control Team	GGHB, Glasgow	7 August 2000
4 th Outbreak Control Team	GGHB, Glasgow	28 August 2000
5 th Outbreak Control Team	GGHB, Glasgow	29 May 2001

Appendix 3

Table 3.1 UK outbreaks of cryptosporidiosis associated with public drinking water supplies April 1988 – April 1998

Date	Source/treatment characteristics (all water received normal chlorine based disinfection)	Oocysts detected in treated water	Approximate number of cases of cryptosporidiosis	Association with water¹	Conclusions/comments⁵
Apr 1988	Surface water with coagulation and rapid gravity filtration	Yes	27	Strong ²	Agricultural slurry contamination of water distribution
Mar 1989	Impounded reservoir supply, coagulation, rapid gravity filtration	Yes	500+	Strong ²	Contamination of source water with animal wastes, breakthrough of treatment
Mar 1989	Surface water, coagulation, rapid gravity filtration	Yes	Number of cases included in 500+ reported	Strong ²	River flows abnormally low, severe diarrhoea in cattle upstream of intake
Apr 1989	Surface water, no filtration	Yes	244	Probable ⁴	Unfiltered water, potential point source discharge from sewage treatment works and farm drains and non-point discharge from grazing animals
Dec 1989	Lowland river with bankside storage, roughing filters and slow sand filtration	No	477	Strong ⁴	Outbreak followed by-passing of filters
Dec 1990	Lowland tidally influenced river, direct abstraction, gravity filtration	No	47	Probable ²	Rapid fluctuations in source water quality at the time of the outbreak
Apr 1991	Spring, well and stream supply, crude filtration	No	5	Possible ⁴	Possible agricultural contamination of well supply, inadequate treatment
Apr 1992	Surface water, no filtration	Yes	50	Probable ⁴	Unfiltered water, potential point source discharge from sewage treatment works and farms drains and non-point discharge from grazing animals
Jul 1992	Lowland rive with direct abstraction, separation process and bankside infiltration with no filtration	No	108	Probable ³	Possible link with groundwater turbidity
Nov 1992	Upland reservoir and surface water supplying aqueduct slow sand filtration	Yes	125	Strong ²	Heavy rainfall in the catchment, high raw water turbidity, increase in treated water turbidity

Date	Source/treatment characteristics (all water received normal chlorine based disinfection)	Oocysts detected in treated water	Approximate number of cases of cryptosporidiosis	Association with water¹	Conclusions/comments⁵
Nov 1992	Groundwater, no filtration	No	47	Probable ³	Outbreak probably caused by faecal contamination from cattle housed adjacent to the well head
Apr 1993	Stream source, no filtration	Yes	3	Probable ⁴	Inadequate treatment, source open to potential animal contamination
Apr 1993	Groundwater from fissured strata, no filtration	No	40	Probable ³	Outbreak possibly caused by rapid recharge of surface water contaminated with oocysts
Apr 1993	Upland reservoir, no filtration	No	48	Probable ⁴	Possible run-off from grazing, very heavy rainfall
June 1993	Upland reservoir and surface water supplying aqueduct, slow sand filtration	No	97	Probable ³	Outbreak caused by poor operating practices and excessive head on the filters
Jun 1994	Spring fed natural impoundment, upflow filtration	No	8	Probable ⁴	Possible animal waste contamination following heavy rain
Feb 1995	Spring supply, no filtration	No	40	Strong ⁴	Heavy rain washed in waste animal material
Aug 1995	Lowland river with direct abstraction, separation process and bankside infiltration with no filtration	Yes	575	Strong ³	Plant operating above design output, evidence of turbidity peaks in the bankside infiltration water
Jan 1996	Lowland river with coagulation and filtration	Yes	126	Strong ⁴	Outbreak occurred when works was under strain with excess flow causing solids breakthrough
Mar 1996	Surface water with bankside storage, rapid gravity filtration, no coagulant	No	20	Probable ⁴	Outbreak caused by breakthrough of solids as a result of inadequate treatment during an algal bloom
Apr 1996	Lowland river with full treatment	No	80	Probable ⁴	Probable association with water but no evidence of plant operation problems
Feb 1997	Groundwater from fissured strata, no filtration	Yes	345	Probable ⁴	Outbreak caused by infiltration of surface water containing oocysts
Feb 1997	Lowland river, coagulation and filtration	No	22	Probable ⁴	Outbreak possibly associated with turbidity peak in filtered water
May 1997	Spring supply, partial filtration	No	34	Possible ⁴	Possible run-off from spring grazing

Date	Source/treatment characteristics (all water received normal chlorine based disinfection)	Oocysts detected in treated water	Approximate number of cases of cryptosporidiosis	Association with water¹	Conclusions/comments⁵
Apr 1998	Surface water, no filtration	Yes	303	Possible ⁴	Unfiltered water, potential point source discharge from sewage treatment works and farm drains and non-point discharge from grazing animals

- 1 The definitions of strong, probable and possible association with water are given in Tillet *et al* (1998)
- 2 Tillet *et al* (1998)
- 3 Furtado *et al* (1998)
- 4 Personal communication from Expert Group Secretariat
- 5 Conclusions and comments are those of the Drinking Water Inspectorate, health authorities, SCIEH, DWI NI or water utilities.

Appendix 5

Contact: Dr H Irvine
Direct Line: 0141 201 4917
Direct Fax: 0141 201 4950



18 May 2000

To All GPs and Trust Doctors in the Greater Glasgow Health Board Area

Dear Colleague,

Elevation of cryptosporidiosis cases in the catchment of Loch Katrine

Routine surveillance based on laboratory results suggests that we are experiencing a marked increase in Cryptosporidiosis infection in the GGHB area. Almost every year at this time of the year we have a seasonal increase in cryptosporidiosis as a result of the general increase in the prevalence of this parasite in the gut of domestic animals including lambs. It is suspected that the combination of warmer temperatures and increased rainfall can result in the Cryptosporidium parasite present in the droppings of lambs on the banks of Loch Katrine or further down the distribution pathway finding its way into the public drinking water supply, particularly as the Milngavie Treatment Works still lacks slow sand filtration. The cryptosporidium cyst survives chlorination although it is filtered out by slow sand filters.

Between Monday, 15 May, and Thursday 18 May, we received 24 laboratory reports of confirmed cases of cryptosporidiosis gastro-intestinal infection, which is far more than usual for this area and this time of the year and results in far greater per capita rates than for anywhere else in Scotland. All of these cases receive their water supply from the Milngavie Treatment Works which is not on stream to receive sand filtration technology until 2005/6.

In order to conclusively identify the source and elucidate the size of this outbreak we wish to draw your attention to the need to send stool specimens on people presenting with the signs and symptoms of Cryptosporidiosis. These include non-bloody diarrhoea, commonly of 2-3 weeks duration, abdominal cramping, nausea with or without vomiting, and possibly fever. There is no effective treatment. Infection can be severe and prolonged in individuals (particularly children) with serious immunocompromising conditions such as HIV infection, Severe Combined Immunodeficiency (SCID) and specific T cell deficiencies (such as CD40 ligand deficiency or Hyper IgM Syndrome). As a result, those selected patients with these serious conditions are advised to drink boiled water only as a preventive measure and this advice was reiterated in correspondence from this Department in July 1999.

We would appreciate your co-operation in trying to fully assess the extent and cause of this local, seasonal excess in rates of infection. Patients presenting with persistent diarrhoea should be asked to provide a stool specimen and a request for cryptosporidiosis cysts should be written on the request form. If positive, an environmental health officer will visit the patient to elucidate their likely source of infection.

Yours sincerely,

Dr. Helene Irvine

Consultant in Public Health Medicine

Appendix 6



Your Ref:

Our Ref: SA/MMcL

Contact: Dr. S. Ahmed

Direct Line: 0141 201 4917

Direct Fax: 0141 201 4950

9 July 1999

To All Haematologists in Greater Glasgow Health Board Area

Dear Colleague

CRYPTOSPORIDIUM IN WATER SUPPLIES

You will be well aware about the controversy that was generated following a recommendation by a working group of specialists chaired by Professor Bouchier that “immunocompromised patients should be advised to boil and cool their drinking water from whatever source”.

This has caused a lot of correspondence, debate and discussions among Microbiology, Public Health and clinical colleagues both in Glasgow and throughout the country. As a result we wrote to the Department of Health asking for further clarification as to the term “immunocompromised” and exactly which groups are at increased risk. I enclose a copy of a letter received in response which you may find useful.

I trust this will be helpful to clarify some of the earlier confusion.

Yours sincerely

Dr. S. Ahmed

Consultant in Public Health Medicine

Chairman, Area Control of Infection Committee, GGHB



Skipton House 80 London Road London SE1 6LW Telephone 0171 972 2000
Direct line 0171 972

Ms Dr Evonne Curran
Greater Glasgow Health Board,
Dalian House,
PO Box 15327,
350 St Vincent Street,
Glasgow,
G3 8YU

30th June 1999

Dear Dr Curran,

Cryptosporidium in Water Supplies

Thank you for your letter of the 26th May 1999 and in particular your review of the literature re the above.

Immunocompromised Groups

A review of the literature was carried out by the PHLS. This was examined by a working group of specialists chaired by Professor Ian Bouchier who have now defined further which groups of immunocompromised patients are at particular risk of cryptosporidiosis infection and should boil their drinking water.

The level of T cell function and the duration of any immune suppression were considered to be crucial factors in susceptibility to *Cryptosporidium*. The group concluded that the advice should be that anyone whose T cell function is compromised (this includes people with HIV infection who are immunosuppressed, children with severe combined immunodeficiency (SCID) and those with specific T cell deficiencies, such as CD40 ligand deficiency, also known as Hyper IgM Syndrome) should be advised to boil and cool their drinking water from whatever source. This includes tap or bottled water and ice cubes should also be produced from boiled and cooled water.

It was decided that there was insufficient evidence to include post-transplant patients.

'Hypogammaglobulinaemia' is felt to be an imprecise term: it means only a decrease in the gammaglobulin fraction of serum globulins. A better encompassing term is primary antibody deficiency. Within this group are well - defined (W.H.O.) disorders such as X linked agammaglobulinaemia (XLA) and common variable immunodeficiency (CVID) which do not appear to confer any increased risk of cryptosporidiosis.

I M P R O V I N G T H E H E A L T H O F T H E N A T I O N



In contrast, CD40 ligand deficiency (the preferred term for Hyper IgM syndrome) is actually a primary defect in T cell function: because of the defective interaction between CD40L on T cells and CD40 on B cells and macrophages, B cells cannot 'switch' from making IgM antibodies to making IgG and IgA antibodies. Consequently, patients have low levels of serum IgG and IgA (ie they are 'hypogammaglobulinaemic') but a normal or raised serum IgM. The defective interaction between T cells and macrophages conveys the added risk of several opportunistic infections such as cryptosporidiosis or pneumocystis carinii pneumonia (PCP). The exact diagnosis of CD40L deficiency has only become possible in the last 2-3 years through genetic analysis. Prior to this, patients with Hyper IgM syndrome, particularly those with normal rather than hyper IgM levels, would have been lumped into the unspecified diagnosis of 'hypogammaglobulinaemia'. It is suspected that this applies to those cases of 'hypogammaglobulinaemia' in your Table 2 that proved fatal and those with associated cryptosporidiosis or PCP infection.

Bottled Water

During the preparation of the Bouchier Report much time was spent discussing the safety of bottled water with regard to *Cryptosporidium*. Relevant information is given at Appendix A5 pages 125 -131. The advice given to the group was that bottled water is not free from *Cryptosporidium* oocytes and therefore it was felt to be a wise precaution to advise relevant immunocompromised patients to boil bottled water before use. While there may be no evidence that bottled water has caused cryptosporidiosis viable cells may be present in the water and potentially infective. Thus the immunocompromised groups highlighted above are advised to boil and cool bottled water before drinking.

I hope this clarification of the advice is helpful. The advice will be publicised in the next CMO's Update on the 2nd August 1999, which goes to all doctors.

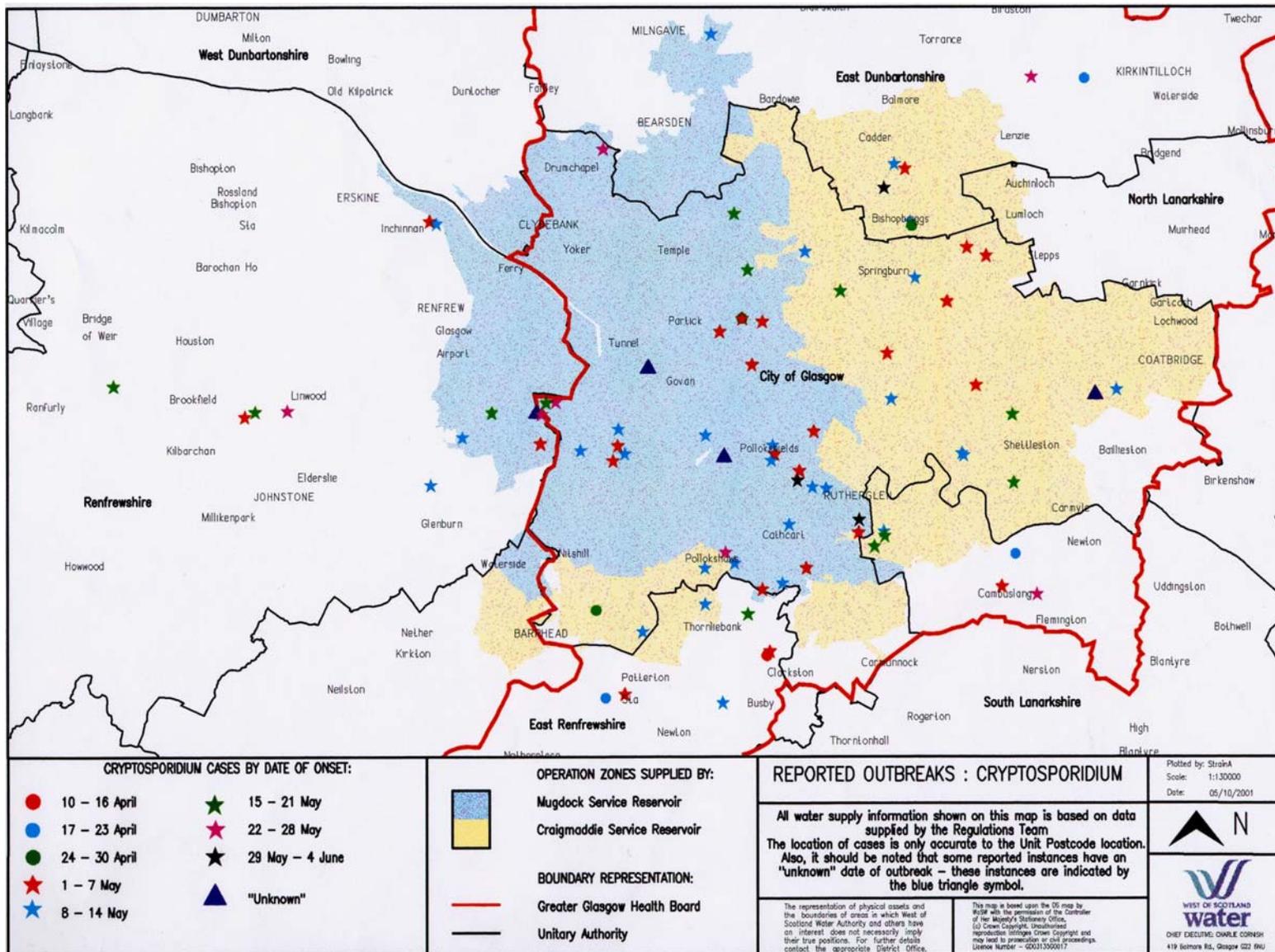
If you could organise a copy of the references cited in your paper that would be most helpful.

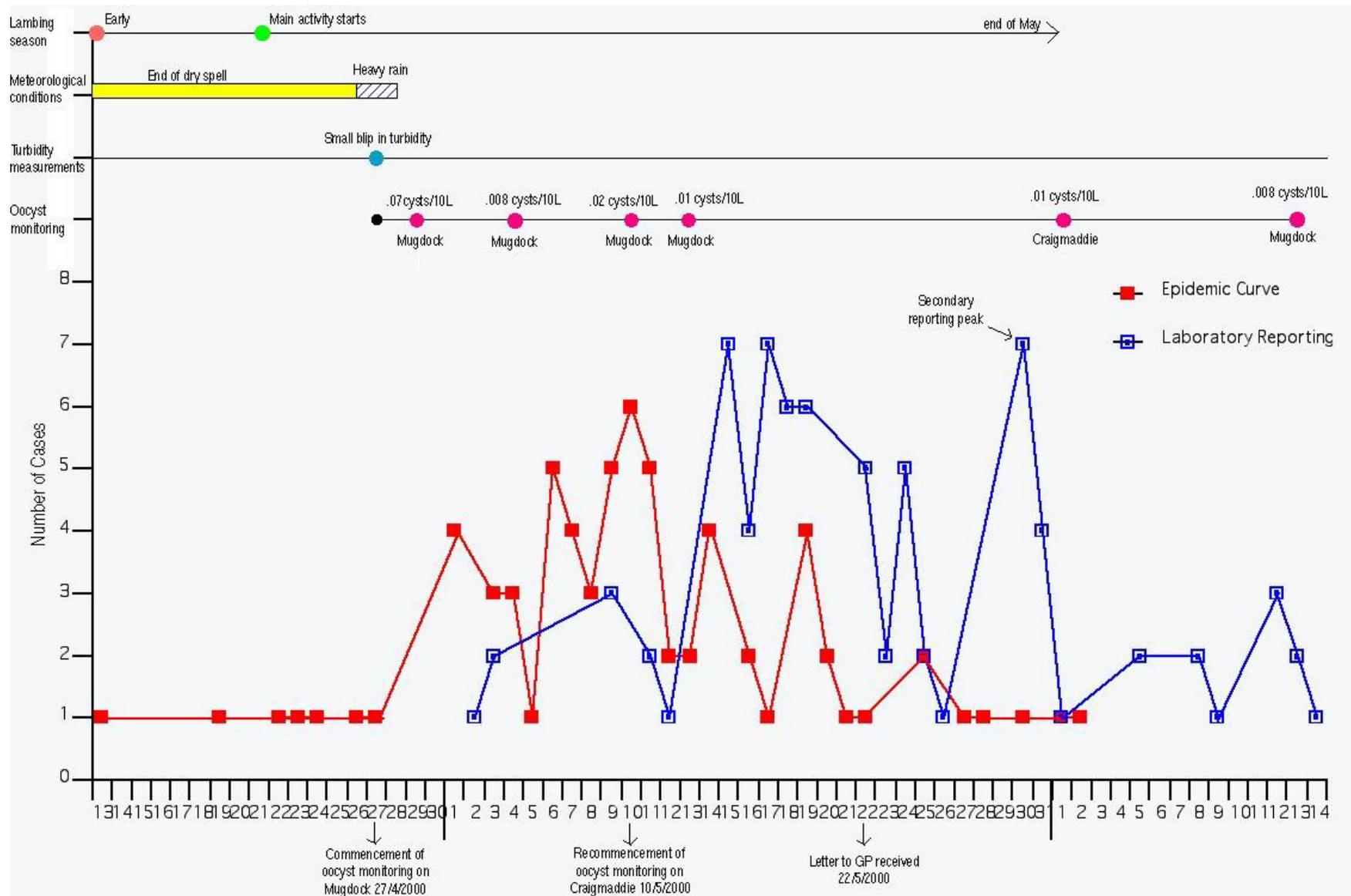
Yours sincerely,

Antonia Leigh

DP

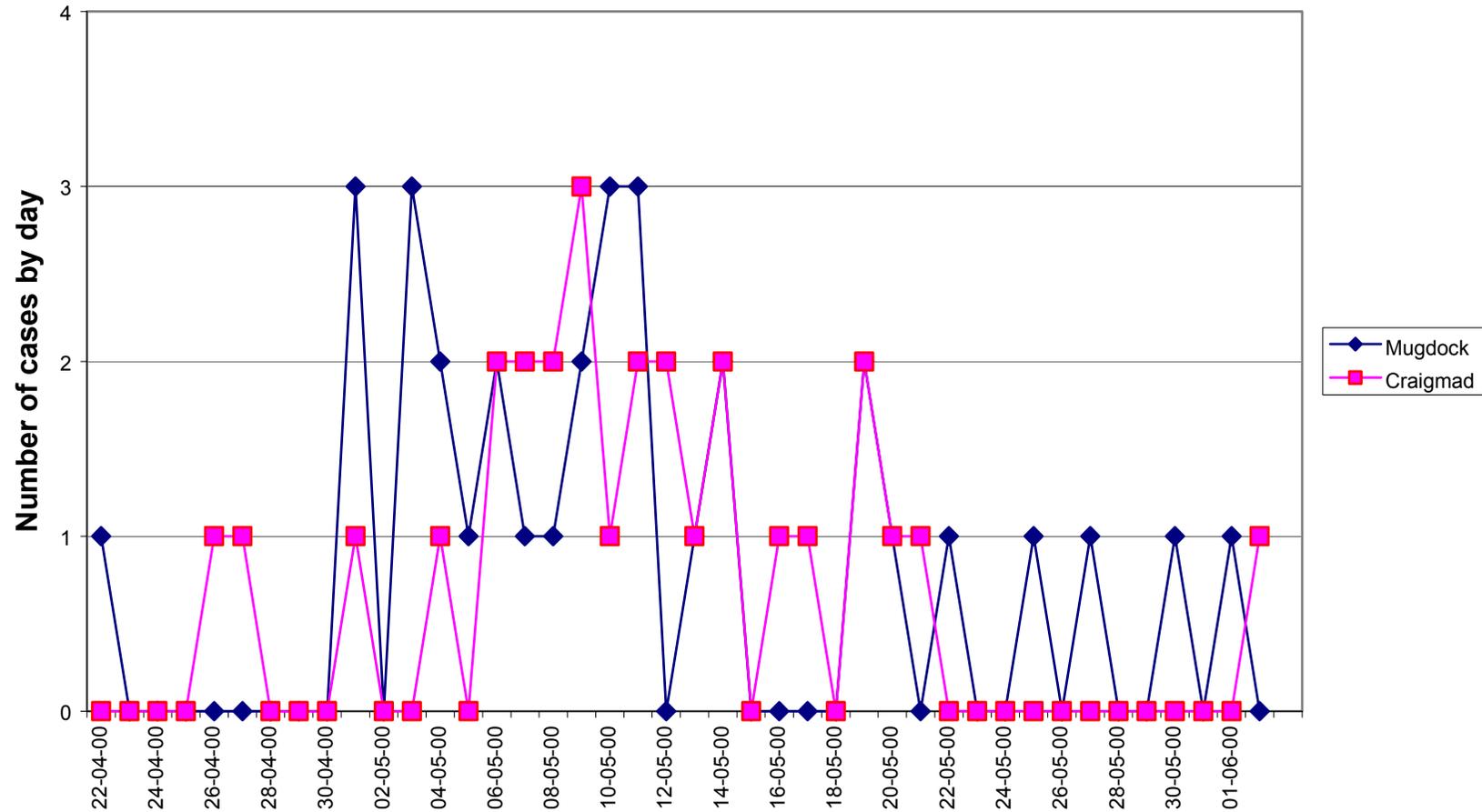
Dr Ailsa Wight
Tel: 0171 972 5357
Fax: 0171 972 5558
Email: aleigh@doh.gov.uk





Cryptosporidiosis outbreak in the distribution of Milngavie Treatment Works 2000 – Loch Katrine Water

**Appendix 7c Epidemic Curve based on onset of symptoms
by reservoir
(excluding those infected abroad)**



Appendix 8

Cryptosporidiosis outbreak investigation

Health Authority:.....Identification No

Please ring as appropriate, tick box or write in the space provided.

Case ₁/Control ₂

Interview date...../...../.....Interviewer

Interview method: Telephone ₁/Face to face ₂/Postal₃

Personal details

1 Forename.....Surname

2 Sex: **Male** ₁/**Female** ₂

3 Age: Years.....Months (if aged less than one year).....

4 Date of Birth...../...../.....

5 Address

Postcode.....Telephone

6 If case/control is an adult - occupation

7 If case control is a child, does he or she attend

School : **Yes** ₁/**No** ₂

Nursery or playgroup: **Yes** ₁/**No** ₂

Address of school or nursery.....

.....Postcode.....

Parent's occupation (Mother).....

Parent's occupation (Father).....

8 How many people live in your household

Adults (16 years and older)	Children (5-15 years)	Children (under 5 years)

9 GP name

GP address

GP telephone number

- 10 Health Authority
- 11 Local Authority
- 12 Water supply zone (from water company information)

CONTROLS ONLY (QUESTIONS 13-15)

- 13 Method of control selection: **Case nominated/GP nominated/HA Register**
Nominated for which case.....

Exclusion criteria

- 14 Have **you/your child** been ill with diarrhoea (three or more loose stools in 24 hours) at any time since (date of onset of outbreak as defined in case definition.....)

Yes ₁/No ₂

If **YES**, thank and end interview, if **NO**, continue.

- 15 In the two weeks prior to this interview have you/your child travelled outside the UK?

Yes ₁/No ₂

If **YES**, thank and end interview, if **NO**, continue.

CASES ONLY (QUESTIONS 16-23)

- 16 Have **you/your child** been ill with diarrhoea (three or more loose stools in 24 hours) since (date of onset of outbreak as defined in case definition.....)

Yes ₁/No ₂

If **NO**, thank and end interview, if **YES**, continue.

- 17 In the two weeks before the diarrhoeal illness did you/your child travel outside the UK?

Yes ₁/No ₂

If **YES**, thank and end interview, if **NO**, continue.

- 18 Did anyone in your household have diarrhoea in the two weeks before **you/your child** became ill?

Yes ₁/No ₂

If **YES** thank and end interview, if **NO** continue.

- 19 When did **you/your child's** diarrhoea start?...../...../.....

- 20 For how many days approximately were **you/your child** ill?
.....

- 21 Did **you/your child** have any of the following symptoms?

Symptom	Yes	No	Not sure
(a) Fever	1	2	3
(b) Abdominal pain	1	2	3
(c) Vomiting	1	2	3
(d) Blood in stools	1	2	3
(e) Other	1	2	3

If Other please specify (1).....
(2).....

22 Were you/was your child admitted to hospital for this illness?

Yes₁/No₂

If YES, which hospital?

Admission dates...../...../.....to...../...../.....

23 Laboratory confirmed case? Yes ₁/No ₂ Specimen date...../...../.....

Laboratory.....LabNo(1).....(2).....(3).....

CASES AND CONTROLS

Cases should be asked about their exposure in the two weeks prior to the onset of their symptoms.

Controls should be asked about exposure during the two weeks prior to the interview.

Background information

24 In the two weeks before the onset of illness (for cases)/date of interview (for controls), how many nights did you/your child spend away from home?.....

Where did you/your child visit?

Local (within 10 miles of home) ₁/Other UK ₂

Place visited	Number of nights away

Consumption of water

25 Do you/your child drink any cold tap water or drinks containing cold tap water (without boiling it first)?

Yes ₁/No ₂/Not sure ₃

If **YES** continue, if **NO**, go to question 27.

26 About how much cold (unboiled) tap water (including water used to dilute in squash or fruit juice) **do you/your child usually drink per day?** Answer as **number of glasses per day on average** (NB one glass is about 1/3 of a pint or about 200 millilitres).

(i) From the tap at home

(ii) From the tap at work/nursery/school

Address and/or post code

(iii) From the tap elsewhere

Address and/or post code

27 In the two weeks prior to illness/interview, did you drink any cold (unboiled) tap water (including water used to dilute in squash or fruit juice) in places not usually visited (public houses, parties, restaurants etc)?

Place.....Number of glasses drunk.....

Place.....Number of glasses drunk.....

28 In the two weeks before the onset of **illness (for cases)/date of interview (for controls)**, did **you/your child** have any drinks with ice added?

Yes ₁/**No** ₂/**Not sure** ₃

If **YES**: **at home** ₁/**at work or nursery or school** ₂/**elsewhere** ₃

If elsewhere, please specify

29 In the two weeks before the onset of **illness (for cases)/date of interview (for controls)**, did you/your child drink any bottled water?

Yes ₁/**No** ₂/**Not sure** ₃

carbonated ₁/**still** ₂/**both** ₃

If **YES** Brand.....

How many glasses of bottled water do you drink on average per day?.....

30 Do you use a water filter at home?

Yes ₁/**No** ₂/**Not sure** ₃

If **YES**: Type.....

31 In the two weeks before the onset of **illness (for cases)/date of interview (for controls)**, did **you/your child** drink:

Type of water	Yes	No	Not sure	Please specify where
(a) Any untreated water (private well, borehole, spring, lake, river or sea water)	1	2	3	
(b) Water from a drinks dispenser	1	2	3	

(c) Water from a drinking fountain	1	2	3	
------------------------------------	---	---	---	--

32 Type of water supply at home. **Mains** ₁/**Other** ₂/**Other** ₃

If not mains, please specify.....

33 Was there any disruption to the mains supply in the two weeks preceding **illness (for cases)/date of interview (for controls)**?

Yes ₁/**No** ₂/**Not sure** ₃

If YES, give details.....

Contact with water

34 In the two weeks before the onset of **illness (for cases)/date of interview (for controls)**, did **you/your child** visit a swimming pool?

Yes ₁/**No** ₂/**Not sure** ₃

Name of pool.....About how many times?.....

Name of pool.....About how many times?.....

Name of pool.....About how many times?.....

About how many times was the head immersed on each occasion?

None	1	1-2	2	3-7	3	>7	4	Not sure	5
------	---	-----	---	-----	---	----	---	----------	---

Did **you/your child** swallow water during a swim?

Yes ₁/**No** ₂/**Not sure** ₃

35 In the two weeks before the onset of **illness (for cases)/date of interview (for controls)**, did **you/your child** go boating/windsurfing/water/skiing/canoeing/swimming in a river or lake.

Yes ₁/**No** ₂/**Not sure** ₃

If YES, where.....About how many times?.....

How many times was the head immersed on each occasion?

None	1	1-2	2	3-7	3	>7	4	Not sure	5
------	---	-----	---	-----	---	----	---	----------	---

Did **you/your child** swallow water?

Yes ₁/**No** ₂/**Not sure** ₃

36 In the two weeks before the onset of **illness (for cases)/date of interview (for controls)**, did **you/your child** have any other contact with fresh water (eg other water sports, fishing)?

Yes ₁/No ₂/Not sure ₃

If YES, please give details

Consumption of food

37 In the two weeks before the onset of **illness (for cases)/date of interview (for controls)**, about how often did you eat the following:

Food	not at all	1-2 times	3-7 times	most days	not sure	Brand (if appropriate) and source
Lettuce	1	2	3	4	5	
Other green salad	1	2	3	4	5	
Tomatoes	1	2	3	4	5	
Coleslaw	1	2	3	4	5	
Raw vegetables	1	2	3	4	5	
Fresh Fruit	1	2	3	4	5	
Undercooked burgers	1	2	3	4	5	
Another undercooked or raw meat	1	2	3	4	5	
Raw shellfish	1	2	3	4	5	
Soft cheese, uncooked	1	2	3	4	5	
Hard cheese, uncooked	1	2	3	4	5	
Yoghurt	1	2	3	4	5	
Ice cream	1	2	3	4	5	
Cream	1	2	3	4	5	

38 Before eating do you normally wash the following foods with tap water:

Type of food	Yes	No	Not sure
(a) Lettuce	1	2	3
(b) Raw vegetables	1	2	3
(c) Fruit	1	2	3

39 In the two weeks before the onset of **illness (for cases)/date of interview (for controls)**, did **you/your child** eat or drink any unusual or new foods?

Yes ₁/No ₂/Not sure ₃

If YES: Food.....Supplier.....

40 Do **you/your child** drink unheated **pasteurised** milk (eg with cereal or as milkshake)?

Yes ₁/No ₂

If **YES**, how many glasses on average **do you/your child** drink per day?.....

Supplier

41 Do you/your child drink unheated **unpasteurised** milk (including goats and sheep milk)?

Yes ₁/No ₂

If **YES**, how many glasses on average **do you/your child** drink per day?.....

Supplier

Contact with pets/animals

NB Contact with animals refers to touching, feeding, being licked or other such close contact, and not to being in the same room or house.

42 In the two weeks before the onset of illness (for cases)/date of interview (for controls), did you/your child have contact with animals at home (pets)?

Yes ₁/No ₂

If **YES**, (a) type of pet

(b) did the pet have diarrhoea Yes ₁/No ₂

43 In the two weeks before the onset of **illness (for cases)/date of interview (for controls)**, did **you/your child** have contact with any:

(a) zoo animals Yes ₁/No ₂

If **YES**, name of zoo

(b) farm animals Yes ₁/No ₂

(prompt with farm visits, animals brought to school, visits to pet shops)

If **YES**, name of farm from where animals originated

.....

44 In the two weeks before the onset of **illness (for cases)/date of interview (for controls)**, did **you/your child** have any visits to a farm:

Yes ₁/No ₂

If **YES**, name and address of farm

Details of visit (eg contact with slurry, animal faeces)

.....

- 45 In the two weeks before the onset of **illness (for cases)/date of interview (for controls)**, did **you/your child** have contact with any other animals or birds (excluding farm and zoo animals) eg at a friend's or neighbour's house?

Yes ₁/**No** ₂

If **YES**, name and address of household

.....

.....

Additional questions relevant to individual outbreaks

Thank you for completing this questionnaire.

If you have any comments you think may be useful, please use the space below.

Questionnaire completed by:

Name.....Status.....Date.....

Appendix 9

Determinand

Between 01-Jan-2000 and 01-Jun-2000 (PP)

Mugdock 3/4 Milngavie Genera

Date/Time	Ref	SPT	Address	Crypto / 10 litre	Volume Litres		
27-Apr-00 11:45	W556117	Mugdock 3/4		0			
28-Apr-00 10:30	W555878	Mugdock 3/4		0.07	732		
29-Apr-00 10:35	W556136	Mugdock 3/4		0	896		
30-Apr-00 10:15	W556150	Mugdock 3/4		0	1246		
01-May-00 11:40	W558508	Mugdock 3/4		0	1414		
02-May-00 09:30	W558573	Mugdock 3/4		0	1286		
03-May-00 00:00	W558645	Mugdock 3/4		0.008	1300		
04-May-00 11:00	W558676	Mugdock 3/4		0	1286		
05-May-00 09:30	W558435	Mugdock 3/4		0	580		
06-May-00 09:30	W558695	Mugdock 3/4		0	1830		
07-May-00 11:00	W558709	Mugdock 3/4		0	1190		
08-May-00 00:00	W562309	Mugdock 3/4		0	1315		
09-May-00 00:00	W562403	Mugdock 3/4		0.02	620		
10-May-00 00:00	W562442	Mugdock 3/4		0			
11-May-00 00:00	W562543	Mugdock 3/4		0	1158		
12-May-00 00:00	W562618	Mugdock 3/4		0.01	845		
12-May-00 10:15	W562939	Mugdock 3/4		0	265		
14-May-00 10:15	W562938	Mugdock 3/4		0	1449		
15-May-00 10:00	W562937	Mugdock 3/4		0	819		
16-May-00 00:00	W563149	Mugdock 3/4		0	864		
17-May-00 00:00	W563250	Mugdock 3/4		0	1187		
18-May-00 00:00	W563589	Mugdock 3/4		0	845		
19-May-00 00:00	W563999	Mugdock 3/4		0	798		
20-May-00 08:30	W564014	Mugdock 3/4			0		
21-May-00 07:20	W564016	Mugdock 3/4		0			
22-May-00 09:00	W561590	Mugdock 3/4		0	1408		
23-May-00 12:30	W564683	Mugdock 3/4		0	1237		
24-May-00 00:00	W565061	Mugdock 3/4		0	1437.5		
25-May-00 08:55	W561795	Mugdock 3/4		0	1292.5		
26-May-00 07:42	W565421	Mugdock 3/4		0	1518		
27-May-00 09:45	W561857	Mugdock 3/4		0	1339		
28-May-00 10:10	W561872	Mugdock 3/4		0	1416		
29-May-00 10:30	W565488	Mugdock 3/4		0	154130-May-00 10:00	W563670 Mugdock 3/4	0 1367

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Determinand

Mugdock 3/4 Milngavie General

Between 01-Jan-2000 and 01-Jun-2000 (PP)

Date/Time	Ref	SPT	Address	Crypto / 10 litre	Volume Litres
31-May-00 00:00	W566060	Mugdock 3/4		0	1364
01-Jun-00 11:00	W563881	Mugdock 3/4		0	751
02-Jun-00 00:00	W566632	Mugdock 3/4		0	8675
Min				0	0
Max				0.07	8675
Mean				0.003	1331.5
Std Dev.				0.01195	
Samples				36	34

Determinand

Craigmaddie No5 (Genera Filt)

Between 01-Jan-2000 and 01-Jun-2000 (PP)

Date/Time	Ref	SPT	Address	Crypto / 10 litre	Volume Litres	turb FTU
07-Feb-00 11:10	W541600		Craigmaddie No5	0.0006	1664	0.43
08-Feb-00 13:45	W541825		Craigmaddie No5	0	1503	0.46
09-Feb-00 13:05	W541719		Craigmaddie No5	0	1341	0.33
10-Feb-00 10:00	W541783		Craigmaddie No5	0	1228	0.28
11-Feb-00 12:40	W541669		Craigmaddie No5	0	1506	0.29
12-Feb-00 11:15	W541844		Craigmaddie No5	0	1333	0.28
13-Feb-00 08:45	W541858		Craigmaddie No5	0	1288	0.3
14-Feb-00 14:30	W543207		Craigmaddie No5	0	1307.1	0.37
15-Feb-00 14:05	W543430		Craigmaddie No5	0	1370.4	0.37
16-Feb-00 14:59	W543317		Craigmaddie No5	0	1440.4	0.34
17-Feb-00 10:00	W543362		Craigmaddie No5	0	1106	0.31
18-Feb-00 10:00	W543269		Craigmaddie No5	0	1328	0.38
19-Feb-00 10:00	W543449		Craigmaddie No5	0	1330	< 0.2
20-Feb-00 10:00	W543463		Craigmaddie No5	0	1378	0.25
21-Feb-00 11:40	W544172		Craigmaddie No5	0	1490.3	0.27
22-Feb-00 12:10	W544388		Craigmaddie No5	0	1397	0.38
23-Feb-00 12:00	W544286		Craigmaddie No5	0	1364	0.33
24-Feb-00 12:05	W545992		Craigmaddie No5	0	1315	
25-Feb-00 10:35	W544238		Craigmaddie No5	0	1247	0.27
26-Feb-00 07:25	W544407		Craigmaddie No5	0	1187	0.41
27-Feb-00 07:25	W544421		Craigmaddie No5	0	1283	0.32
28-Feb-00 11:30	W545355		Craigmaddie No5	0	1485	0.31
29-Feb-00 12:00	W545519		Craigmaddie No5	0	760	0.33
01-Mar-00 09:00	W545464		Craigmaddie No5	0	1736	0.32
02-Mar-00 08:40	W545561		Craigmaddie No5	0	1377.3	0.47
03-Mar-00 13:30	W545416		Craigmaddie No5	0	1589.7	0.48
04-Mar-00 08:35	W545580		Craigmaddie No5	0	1066	
05-Mar-00 08:35	W545594		Craigmaddie No5	0	1313	
06-Mar-00 17:30	W546512		Craigmaddie No5	0	2361	
07-Mar-00 15:10	W546628		Craigmaddie No5	0	1202.2	
08-Mar-00 14:30	W546689		Craigmaddie No5	0	1291.2	
09-Mar-00 14:30	W546729		Craigmaddie No5	0	1321	
10-Mar-00 14:30	W546581		Craigmaddie No5	0	1322.4	
11-Mar-00 05:13	W546748		Craigmaddie No5	0	796.2	

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Determinand

Between 01-Jan-2000 and 01-Jun-2000 (PP)

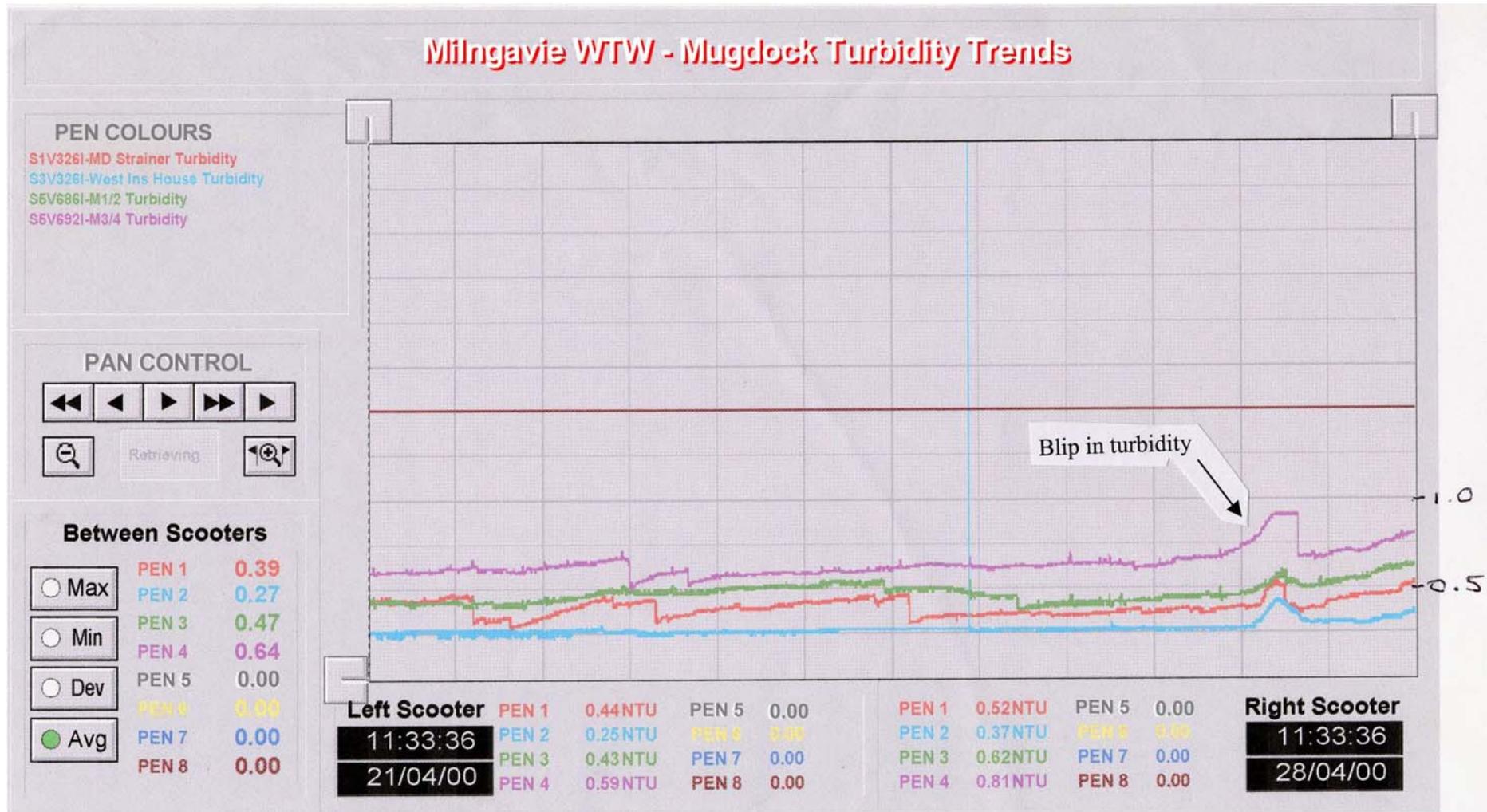
Craigmaddie No5 (Genera Filt)

Date/Time	Ref	SPT	Address	Crypto / 10 litre	Volume Litres	turb FTU
12-Mar-00 05:50	W546762		Craigmaddie No5	0	1340.4	
13-Mar-00 13:30	W548250		Craigmaddie No5	0	1672	
10-May-00 14:45	W559821		Craigmaddie No5	0	1175.5	
11-May-00 15:20	W559854		Craigmaddie No5	0	958.9	
12-May-00 13:00	W559687		Craigmaddie No5	0	846.5	
13-May-00 10:50	W559873		Craigmaddie No5	0	689	
14-May-00 07:00	W559887		Craigmaddie No5	0	926	
15-May-00 08:30	W560979		Craigmaddie No5	0	971	
16-May-00 08:30	W561234		Craigmaddie No5	0	912	
17-May-00 11:30	W561111		Craigmaddie No5	0	1286	
18-May-00 11:45	W561191		Craigmaddie No5	0	689.6	
19-May-00 10:00	W561053		Craigmaddie No5	0	798	
20-May-00 07:30	W561253		Craigmaddie No5	0	806	
21-May-00 07:30	W561267		Craigmaddie No5	0	900	
22-May-00 07:00	W561589		Craigmaddie No5	0	940	
23-May-00 11:30	W561837		Craigmaddie No5	0	1020.4	
24-May-00 10:50	W561719		Craigmaddie No5	0	870	
25-May-00 07:35	W561794		Craigmaddie No5	0	805.1	
26-May-00 05:37	W561657		Craigmaddie No5	0	824.7	
27-May-00 06:00	W561856		Craigmaddie No5	0	940	
28-May-00 06:20	W561871		Craigmaddie No5	0	898	
29-May-00 06:55	W563748		Craigmaddie No5	0	920	
30-May-00 08:30	W563669		Craigmaddie No5	0	1048	
31-May-00 08:00	W563809		Craigmaddie No5	0.01	890	
01-Jun-00 08:00	W563880		Craigmaddie No5	0	906	
Min				0	689	0.2
Max				0.01	2361	0.48
Mean				0.00018		0.3392
Std Dev.				0.00129	308.85566	0.06945
Samples				59	59	25

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Continuous turbidity monitoring results provided by WOSWA (Mugdock only)



NEWS RELEASE



June 5, 2000

INCREASE IN SEASONAL STOMACH BUG IN GLASGOW AREA

Public health officials at Greater Glasgow Health Board today reported an increase during May of the gastro-intestinal infection cryptosporidiosis. There have been 66 confirmed cases, of which 6 have required hospitalisation including an elderly immuno-compromised person who has died.

Cryptosporidiosis infection causes abdominal pain, nausea, vomiting and diarrhoea, which can be prolonged. The infection is commonly carried by animals but can be passed to humans, and between humans by hand to mouth contact. In addition the organism can also be transmitted through drinking water.

Dr Helene Irvine, Consultant in Public Health Medicine leading the investigation at GGHB said:

“We are currently investigating all known cases to identify the source of the infection. At this stage we do not know if it is one source or several. We are looking at waterborne transmission being the possible cause of this increase or some other cause such as farm visits. This infection is common around this time of year and can be picked up through visiting farms and coming into contact with the animals, particularly lambs.

“Cryptosporidiosis is an unpleasant stomach bug, but the condition is not usually life threatening however sadly one patient has died. We are urging anyone visiting farms or having contact with farm animals or sick pets, to wash their hands thoroughly after handling them and before preparing or eating food.

Although this incident is not requiring a widespread public health alert, people whose immunity levels are impaired are being reminded to boil water from all sources, before drinking it. This is because their body's defence system is reduced and they have a higher risk of contracting infection, and less ability within the body to fight it off."

The Health Board is liaising closely with the Scottish Centre for Infection and Environmental Health, West of Scotland Water Authority, the Scottish Executive and the local authorities to identify the source of infection. Ongoing daily monitoring by West of Scotland Water identified low levels of cryptosporidium present in the water supply on five occasions in late April and May – well below levels that had previously given rise to health risks in other UK water supplies.

Local GPs have been alerted to look out for this condition and to forward samples of suspected cases. Although there is no effective treatment, people with prolonged symptoms should attend their GP and take extra fluids and plenty of rest.

NOTE TO NEWS EDITORS

1. Figures in the GGHB for confirmed cases of cryptosporidium are:-

1994	98 cases
1995	71
1996	51
1997	68
1998	126
1999	105
2000	90 to date

2. Impaired immune systems may include people with HIV and AIDS infection, the hereditary condition Severe Combined Immunodeficiency and specific T cell deficiencies. Those with such a condition will have been advised directly by their GP or a Consultant.

For further information please contact Elaine McKean on 0141 201 4429

Appendix 12

Cryptosporidium Assessment using Scottish Executive Methodology for the 30 highest risk supplies amongst West of Scotland Water supplies (total of 128)

SUPPLY DISTRICT	CATCHMENT NAME	WATER TREATMENT WORKS	POPULATION	WEIGHTED SCORE
1. Glasgow North	Katrine complex	Milngavie	687,500	100.40
2. Clyde North	Carman	Carman	3,055	65.52
3. Dum & Gall	Purdomstone Res	Landshead	9500	65.23
4. Lanark South	Potetrick Burn/Peden Res	Peden	23,108	64.58
5. Dum & Gall	Ringford Area	Ringford	3900	61.77
6. Clyde South	Loch Eck	Loch Eck	13,050	57.62
7. Clyde North	Helensburgh/Blairnairn	Helensburgh	19200	53.11
8. Ayr South	Lindsey Springs	Darvel High	10,000	52.80
9. Clyde South	Loch Ascog	Loch Ascog	3,550	49.70
10. Lanark South	Loch Lyoch/ Cleuch	Lyoch	10,050	49.63
11. Dum & Gall	Loch Roan	Loch Roan	3772	48.64
12. Clyde North	Loch Sloy	Loch Sloy	2,305	47.08
13. Dum & Gall	Terregles Area	Terregles	32500	46.92
14. Dum & Gall	Cargen Area	Cargen	1760	46.74
15. Clyde North	Dalmally	Dalmally	360	46.01
16. Clyde North	Mill Loch	Gigha	150	45.26
17. Clyde South	Garb Allt	Brodick	837	44.43
18. Ayr South	Auldhouse Burn/ Crosslet Burn	Auldhouseburn	1,800	44.27
19. Ayr South	Rankinston	Rankinston	400	42.67
20. Clyde South	Benlister Burn/Cnoch Dubh	Lamlash	915	42.64
21. Clyde North	Abhainn a Mhuilinn	Craighouse	150	41.78
22. Dum & Gall	Mill Burn	Palnure	400	41.63
23. Clyde South	Lochranza Area	Lochranza	300	41.62
24. Clyde South	Cluachan Water	Shiskine	600	41.12
25. Clyde North	Allt Gruiniche	Taynuilt	700	40.97
26. Clyde South	Corrie Area	Corrie	300	39.63
27. Clyde North	Auchengaich	Belmore	4000	38.90
28. Clyde North	Tayinloan Burn	Tayinloan	150	38.30
29. Dum & Gall	Loch Middle/Cardorcan Burn	Barclye	150	38.30
30. Clyde South	Allt Ceirde/Allt Garbn	Whiting Bay	180	37.89

Appendix 13

Contributors who provided supporting evidence

Dr. Rachel M. Chalmers, Head, PHLS Cryptosporidium Reference Unit, Swansea PHL, Singleton Hospital, Swansea, England.

Professor Paul Hunter, Professor of Health Protection, Medical School, University of East Anglia, Norwich, England.

Mr. John McKee, Principal EHO, Eastern Group Environmental Health Committee, Castlereagh, Belfast, Northern Ireland.

Dr. Jim Miller, Consultant in Public Health Medicine, Department of Public Health, Lanarkshire Health Board, Hamilton, Scotland.

Dr. Anthony P. Sturdee, Bioscientist, Cryptosporidium Research Group, Centre for Environmental Research and Consultancy, School of Science and Environment, Coventry University, Priory Street, Coventry, England.

Professor Andrew Tait, Professor of Veterinary Parasitology, Welcome Centre for Molecular Parasitology, Anderson College, University of Glasgow, Glasgow, Scotland.

Dr. Maggie Tomlinson, Department of Health, London.

Dr Jonathan M. Wastling, Lecturer, Division of Infection and Immunity, Joseph Black Building, Institute of Biomedical and Life Sciences, University of Glasgow, Glasgow, Scotland.

Mr Steve E. Wright, Research Scientist, Division of Parasitology, Moredun Research Institute, International Research Centre, Pentland Science Park, Bush Loan, Penicuik, Scotland.