Giardia outbreak in Bergen 2004 – what was the source of infection?

The comprehensive report on the *Giardia* outbreak in Bergen in 2004 concluded that the probable source of infection was a sewage leak that polluted the drinking water. However, several aspects of the epidemic suggest grounds for considering an alternative hypothesis about the source of infection.

The *Giardia* outbreak in Bergen in autumn 2004 was the first recognised outbreak of a parasitic infection to be caused by drinking water in Norway. The outbreak was extensive, with an estimated 2 500 persons treated for giardiasis (1). The infection was laboratory confirmed in 1 252 individuals, who have since been followed up annually (2–5). The actual number of infected individuals was probably in the order of 5 000–6 000 (6).

The disease outbreak was thoroughly examined in a comprehensive evaluation report, which was published in May 2006 (6). This reached the unanimous conclusion that the probable source of infection for the outbreak was contamination of the water source 'Svartediket' by sewage from the nearby residential area. This conclusion was based on the demonstration of a sewage leak 200–300 metres from the raw water intake from Svartediket.

Correct conclusion?

All might appear well given the consensus among the experts. However, the *Giardia* outbreak in Bergen had several unusual features. In the aftermath of the outbreak, a significant proportion of the laboratory-confirmed cases reported fatigue and irritable bowel syndrome-like symptoms, even though they had been successfully treated for giardiasis (5, 7). Upon examination five years after the outbreak, the same patients showed immunological dysfunction. The patients with chronic fatigue syndrome had reduced numbers of natural killer cells (NK cells), while those with functional gastrointestinal disease had higher levels of CD8 T cells (8). The presence of these symptoms so long after a successfully eliminated *Giardia* infection is difficult to explain (7, 9, 10). The lingering health problems after the outbreak led to over 300 compensation claims against Bergen municipality and payouts of more than 30 million Norwegian kroner in compensation (11).

The drinking water-transmitted outbreak was not solely a *Giardia* outbreak; there was a simultaneous, albeit smaller, outbreak of *Cryptosporidium*. While there were only 115 laboratory-confirmed cases of *Cryptosporidium*, this is enough to fulfil the accepted criteria for definition of an outbreak. Among those who were diagnosed with *Cryptosporidium parvum* infection, 85 % also had giardiasis (12).

Absence of hypothesis testing

The external evaluation committee (6) conducted a theoretical analysis of seven potential sources of infection and concluded that «the direct (triggering) cause of the *Giardia* epidemic was most likely a sewage leak from the nearby residential properties in the Knatten/Starefossen/Tarlebøveien area». It is worth noting the two statements that follow this conclusion: «It has not been the aim of the committee to identify precisely which home(s) the infection came from. This is out of respect for privacy and *because the answer would not have influenced the committee's conclusions*». (Emphasis mine).

«Both *Cryptosporidium* and *Giardia* are very common in Norwegian dogs»

The evaluation committee assumed that «the sewage system in the area had been in disrepair for many years prior to the incident». They write further that «the reason there has not been a similar outbreak previously is most likely because in autumn 2004, there were one or more infected persons living in the properties in question» (6). The committee made no attempt to confirm or disprove this hypothesis for the reasons given above.

«When you have eliminated the impossible, whatever remains, *however improbable*, must be the truth,» is a famous quote from Sherlock Holmes, creation of the doctor Sir Arthur Conan Doyle. The evaluation committee evidently leant towards this type of thinking, but the premise for being able to do so, is to «have eliminated the impossible.» The possibility that sheep and lamb excrement, human passers-by, or wild animals and birds could have been the source of infection for the *Giardia* epidemic was in my view ruled out fairly convincingly in the analysis. However, I believe doubts can be raised as to whether the committee was equally convincing in ruling out the involvement of dog excrement.

Dog or human as source of infection?

The evaluation committee calculated that between 38 and 152 kg of faeces per week were produced by dogs being walked along the walking trail that drains into Svartediket. This illustrates the magnitude of the possible pollution «very near the water source (a few tens of metres away) and in steep terrain that facilitates washout during periods of rainfall» (6). The committee summarises as follows: «Dog excrement probably represents the main source of *E. coli* in the raw water intake. However, dog excrement is considered to be rather improbable with respect to the source of the outbreak in autumn 2004, in relation to sewage from homes bordering the catchment area» (6). Since *E. coli* is regarded as a good indicator of faecal contamination of drinking water, this statement appears somewhat contradictory.

Both *Cryptosporidium* and *Giardia* are very common in Norwegian dogs, according to a study conducted by the Norwegian School of Veterinary Science. Some 44 % of young dogs had one or more *Cryptosporidium*-positive samples, while 21 % of dogs had one or more *Giardia*-positive samples (13). Neither *Cryptosporidium*- nor *Giardia* infection is common in humans in Norway, and co-infection with both parasites is probably extremely rare.

The sewage system in the area in question was rehabilitated shortly after the outbreak. Nevertheless, in September 2005, the year after the epidemic, concentrations of thermostable coliform bacteria/*E. coli* in the raw water intake reached their highest levels for 10 years after an episode of extremely heavy rainfall (6). The addition of sewage to the raw water intake cannot therefore have been responsible for the high levels of faecal indicator bacteria.

Heavy downpours

On 19 August 2004, there was 29.6 mm of rainfall, followed by a further 24.8 mm the next day and 17.4 mm the day after that. Over the preceding 24 days, there had been only 9.6 mm of rainfall spread over six separate days (6). Routine testing of the water supply showed high levels of faecal indicator bacteria and *E. coli* in raw water samples collected in late August (1). The epidemic curve for the *Giardia* outbreak indicates that most cases must have been infected between late August and early

October (1). Since *Giardia* cysts can survive in water for 1–2 months, infection must have occurred over a limited period in late August/early September (1).

It is reasonable to assume that the sewage leak led to a relatively constant inflow of human excrement into Svartediket, whereas contamination with dog excrement would mainly have occurred in connection with heavy downpours, which would have washed accumulated excrement from the area along the walking trail into Svartediket. According to the committee's own calculations, between 130 and 521 kg dog excrement would have been deposited along the walking trail over the 24 days preceding the heavy downpours. It would then have taken a few days for this contamination to reach the raw water intake to the water treatment plant. This is in keeping with the fact that routine testing of the water supply showed high levels of faecal indicator bacteria and *E. coli* in raw water samples collected in late August 2004.

To create an outbreak from a water treatment plant that supplies 52 000 inhabitants requires reasonably large amounts of infectious material. The washing of large quantities of *Giardia*- and *Cryptosporidium*-infected dog excrement into Svartediket from the area along the walking trail would therefore seem to be a more likely cause of the outbreak than a sewage leak.

Dam upon dam

Svartediket was formed through the phased construction of four dams of increasing size. The distance between the oldest and the newest dam is 30 metres. The top of the old dam that is closest to the newest dam lies 11 metres under the *highest* regulated water level. The evaluation committee did not state how far below the highest regulated water level the actual water level in Svartediket was on 19 August. However, this is a very important piece of information because it gives a strong indication of how quickly raw water in the water treatment plant could be supplemented by surface water. The fact that the epidemic was triggered a few days after the downpours of 19–21 August indicates that the water level in Svartediket must have been very low on 19 August.

The evaluation committee points out that in «periods of dry weather with lower water levels, proportionately more of the surface waters will reach the raw water intake» due to the old dams at respectively 11, 14 and 15 metres below the highest regulated water level (6). The committee discusses the seasonal variation in thermostable coliform bacteria/*E. coli* in the raw water intake, wherein these bacteria are almost completely absent from January to June and from November to December, on the assumption that sewage is the source of the bacteria, and is unable to reconcile the data. The most plausible explanation for the large seasonal variation in the prevalence of thermostable coliform bacteria/*E. coli* in the raw water intake is, in my view, that there is a large influx of surface water into the raw water between August and October due to the low water levels in August.

Scientific consequences

I believe that the most likely course of events in the *Giardia* outbreak in Bergen in autumn 2004 is as follows: 130–521 kg dog excrement accumulated along the walking trail at Svartediket between 26 July and 18 August 2004. During this period, light rainfall helped to ensure that the faeces did not dry out and thus retained their contents of infectious *Giardia* cysts, *Cryptosporidium* oocysts and thermostable coliform bacteria/*E. coli*. The heavy downpours of 19–21 August washed a large proportion of this excrement into Svartediket, aided by the very steep terrain along the walking trail down towards the drinking water source. Low water levels in Svartediket when the heavy downpours came, meant that the contaminated surface water quickly reached the raw water intake and thus triggered the *Giardia* outbreak.

The evaluation committee's failure to test the hypothesis that a sewage leak caused the *Giardia* outbreak has, in my view, had two consequences of a scientific nature. Firstly, it has not been acknowledged that the outbreak was probably the first drinking water-transmitted epidemic to be caused by dog excrement. Secondly, researchers who have followed up patients with chronic fatigue and irritable bowel syndrome-like symptoms after the outbreak have, naturally enough, focused on *Giardia* and to some extent *Cryptosporidium* as possible causes. This is in my view the most serious scientific consequence – that the investigation into the persistent health problems has been based exclusively on the assumption that *Giardia* and *Cryptosporidium* are the causative agents, and has been blind to the possibility that other zoonoses from dogs might in fact be responsible.

As the mathematician Paul Erdós once said: «It is not enough to be in the right place at the right time. You should also have an open mind at the right time.»

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