Parasites in Norwegian drinking water as emerging pathogens

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Sammendrag
Parasittene *Cryptosporidium* og *Giardia* synes å være nye patogener i Norge, med en betydelig økning av rapporterte utbrudd siden 2004. Overføring via vann ser ut til å være spesielt viktig for disse to patogenene. Denne artikkelen beskriver de norske utbruddene knyttet til disse parasittene. Den tar opp faktorer som kan knyttes til utbruddene og betydningen av vannbåren overføringen. Parasittfunnene i norsk vann er beskrevet, og initiering og bruk av kokevarsler i forhold til funn av parasitter i drikkevann Oslo i oktober 2007. Muligheten for at også andre parasittarter kan overføres via vann er kort diskutert, med vekt på *Toxoplasma*.

Summary
The parasites *Cryptosporidium* and *Giardia* appear to be emerging pathogens in Norway, with a notable increase in reported outbreaks since 2004. Waterborne transmission appears to be of particular importance for these two pathogens. In this presentation, the Norwegian outbreaks associated with these parasites are described, factors which may be associated with their apparent emergence, and the significance of the waterborne route of transmission. Detection of these parasites in Norwegian water is described, and the issuing and rescinding of boil-water notices associated with their detection in drinking water supplies, as occurred in Oslo in October 2007. The possibility of other species of parasites which may be transmitted by the waterborne route is briefly discussed, with emphasis on *Toxoplasma*.

Introduction to emerging pathogens
'Emerging pathogens' have been described as "any new, reemerging, or drug resistant infection whose incidence in humans has increased

within the past two decades or whose incidence threatens to increase in the future." (Institute of Medicine, 1992) Such emergence need not be global, but can be on a national or local scale, and can be driven by various forces including: a) the evolution of a new pathogen or strain or pathogen; b) the import of a pathogen into a previously naïve host population; c) alteration in the host population (e.g. becoming more susceptible); d) changes in the host-pathogen interactions which enables infection to occur at a greater rate than previously; these are frequently human-derived changes, such as altered land use, but may be environmental changes such as altered weather patterns increasing flood risk and hence water contamination. Additionally, the apparent emergence of a pathogen may in fact be the recognition of a previously unrecognised or underestimated situation. With respect to waterborne pathogens, it has been noted that emerging pathogens are often zoonotic, occurring in animal populations as well as human populations, and with transfer between the different host pools (Greger, 2007).

Parasites which may be transmitted by the waterborne route

There are various parasites which may be transmitted by the waterborne route (see table 1). The importance of the waterborne route, is that whole communities may be put at risk of infection.

A range of helminths (worms),
Cryptosporidium
Giardia
Toxoplasma
Microsporidia
Cyclospora
Entamoeba
Isospora

Table 1. Parasites which may be transmitted by the waterborne route

On a global basis, the vast majority of documented waterborne outbreaks of parasitic infections are of cryptosporidiosis and giardiasis, although waterborne outbreaks with the parasites *Entamoeba histolytica, Cyclospora cayetenensis, Toxoplasma gondii, Balantidium coli,* and microsporidia have also been recorded (Karanis et al, 2007). Both cryptosporidiosis and giardiasis are primarily intestinal infections, with diarrhoea and other abdominal complaints as the predominant symptoms.

Reviewing recorded waterborne outbreaks of these infections (up to and including 2003), demonstrates that over 50 % of such outbreaks have been recorded in USA, whilst of the outbreaks recorded from Europe, over 70 % are from UK (extrapolated from data presented by Karanis et al, 2007).

Factors which contribute to the success of a parasite being transmitted by the waterborne route include the following: a) having a robust transmission stage, which can survive for considerable periods in the environment, and may also survive many conventional water treatment regimes (e.g. chlorination); b) having a small transmission stage, which may evade removal by filtration; c) having a wide-host range (zoonotic infections), thereby increasing the possibility of environmental contamination; d) infected individuals excreting large numbers of the transmission stage, thereby increasing the probability that a transmission stage will reach a susceptible host; e) having a low infectious dose, such that only very few transmission stages need to be ingested by a susceptible host in order for infection to be likely to occur.

An increase in outbreaks of parasitic infections in Norway

In general, from 1970 onwards, the occurrence of such parasitic infections in the human population of Norway was almost exclusively associated with foreign travel or with the immigrant population. These parasitic infections were considered to be sporadic and relatively rarely identified. However, since autumn 2004 three outbreaks of parasitic infection have been recorded, of which two were either definitely or potentially associated with the water-borne route of infection (table 2).

Date	Parasite	No. persons infected	Route of infection	Reference
Nov 2004	*Giardia intestinalis*	Over 1500	Primary waterborne; secondary spread.	Nygård et al, 2006; Robertson et al, 2006b
April 2005	*Cryptosporidium parvum*	5	Directly from an infected calf during a clinical veterinary procedure	Robertson et al, 2006a
March 2007	*Cryptosporidium parvum*	25	During a hotel stay; association with use of ice machine	Hajdu et al, 2007

Table 2. Outbreaks of parasitic infection recorded in Norway

Thus, these parasitic infections might be considered to be ‘emerging infections’ in Norway. Possible reasons for such emergence include:

a) changes in the parasite:
   i) the introduction of more virulent strains of these infections into Norway (increased foreign travel and larger immigrant populations importing infections from abroad which are excreted and contaminated the environment via sewage)
   ii) amplification of such ’exotic’ infections in wild or domestic animals which then further contaminate the environment

b) changes in the host:
   i) the population of Norway previously had immunity against these infections, but reduced childhood exposure has resulted in immunological naivety in the adult population
   ii) higher proportion of particularly susceptible individuals in the Norwegian population

c) changes in host/parasite interactions:
   i) aging water and sewerage infrastructure (e.g. pipelines) result in increased likelihood of contamination events
   ii) more extreme weather events (flooding, storms – result of global warming?) resulting in increased likelihood of contamination of water supplies.

Additionally, it is possible that these infections are now more likely to be diagnosed than in previous years, due to improved diagnostic techniques and greater physician and patient awareness, and thus such outbreaks are more likely recognised.

Which of these reasons has had most influence on these parasitic infections 'emerging' in Norway is not possible to determine, and it is probable that each of these possibilities plays a contributory role.

Survey of water for parasites

As it is recognised that water is relatively often contaminated with *Cryptosporidium* oocysts and *Giardia* cysts from diverse sources, and that such contamination may constitute a public health risk, methods have been developed for analysis of water for these parasites. The purpose of monitoring water for *Cryptosporidium* and/or *Giardia* can be two-fold: a) to prevent transmission of infection (or outbreak scenarios in the worst case), and b) to obtain information which can be used to assess contamination risk and thus water treatment requirements, appropriate catchment control initiatives etc. Many countries have conducted systematic surveys for these parasites, focussing upon various water types, including treated drinking water, raw water, recreational water etc. Generally it has been found that the parasites have a wide-spread occurrence, usually at low concentrations, and that sometimes there is an association with factors such as turbidity, season, degree of precipitation, and other catchment factors. A survey conducted between 1998-1999 of Norwegian raw water sources (Robertson et al, 2001), provided similar findings (Table 3) with low concentrations of parasites detected in 10 L water samples (a maximum of 4 parasites in 10 L), and significant associations with high turbidity (>2,0 NTU) and high numbers of domestic animals in the catchment.

	No. water samples	% water samples
Parasites not detected	305	75
Only Cryptosporidium oocysts detected	55	13.5
Only *Giardia* cysts detected	38	9
Both *Cryptosporidium* and *Giardia* detected	10	2.5

Table 3. Results from survey of raw water in Norway for Cryptosporidium oocysts and Giardia cysts (Robertson et al, 2001)

Detection of parasites in drinking water: issuing and rescinding boil-water notices

One difficulty of monitoring drinking water for protozoan parasites such as *Cryptosporidium* and *Giardia* is the need to make a decision on the correct course of action when parasites are detected in the supply. If high numbers of parasites are detected, particularly in association with a known contamination event such as the sewage contamination of the drinking water supply in Nokia, Finland in late November 2007, then the issue of a boil-water directive is an obvious course of action, until the situation has been rectified, and sufficient time has elapsed for the parasites to have been flushed out of the system. However, when low numbers of parasites are detected (which may, or may not be, of a species infective to humans, and which may, or may not be, viable and infective), the decision of whether or not to implement a boil-water directive may be more difficult. Also, if it is decided to issue a boil-water directive, then choosing when such a directive should be rescinded may also be difficult; it is important that these criteria are decided as soon as, or preferably before, the boil-water directive is issued (Harrison et al, 2002). Such decisions were taken following detection of low numbers of *Giardia* cysts and *Cryptosporidium* oocysts in Oslo's drinking water supply in October 2007, in association with microbiological findings indicative of a localised contamination event, and resulted in a boil-water directive lasting for 5 days (Robertson et al, submitted). In other parts of the world boil-water notices have been issued which have retrospectively been considered by some to have been unnecessary, or unnecessarily prolonged (Table 4), and there is considerable and on-going debate regarding the criteria which should be met for boil-water directives to be issued (Irvine, 2004; Robertson et al, submitted).

Location	Date	Duration of boil-water notice	Parasite detected and background information	Associated illness in community	Reference
Thunder Bay, Canada	1997 months	13	2 *Giardia* cysts detected in water supply; boil water advisory in place until membrane filtration installed at treatment plant.	No	Wallis et al, 2001.
Sydney, Australia	1998	On-and-off over 3 month period	*Cryptosporidium* and *Giardia* detected at high concentrations (up to several thousand per sample). Laboratory failings mean interpretation of results is difficult.	No	McClellan, 1998.
Glasgow, Scotland	2002	5 days	*Cryptosporidium* ocysts (numbers not published) detected in reservoir. Subsequently found to be species not infective to humans.	No	Scottish Parliament Information Centre, 2002.
Carlow, Ireland	2005	Approx 6 weeks	Low numbers of *Cryptosporidium* oocysts detected in water (0.009 to 0.28 oocysts per 10L water). Species in water different to that found in patients.	26 cases of cryptosporidiosis	Outbreak Control Team Health Service Executive – South Eastern Area, 2005.

Table 4. Some controversial boil-water notices issued in conjunction with detection of Cryptosporidium oocysts and/or Giardia cysts in drinking water supplies

Other waterborne parasites which may become 'emerging pathogens' in Norway; the potential for toxoplasmosis?

It has previously been demonstrated that cryptosporidiosis and giardiasis appear to be emerging infections in Norway, with waterborne transmission being of particular significance. Considering the range of parasites which may be transmitted by the waterborne route (Table 1), it may be prudent to assess which, if any, of these may become 'emerging pathogens', with transmission via the waterborne route, in the years ahead. *Toxoplasma* may be a candidate; not only is it potentially severe infection, but it is relatively common in Norwegian sheep and deer populations. Felines are the definitive hosts of this parasite, and the oocysts which are excreted in vast numbers by infected cats, and which become infective after 4-5 days in the environment, are extremely robust, surviving freezing, drying and disinfectant treatment. Transmission to humans can occur via 3 routes; via ingestion of the excreted oocysts, via ingestion of tissue cysts from animals such as sheep or cattle which have become infected by ingestion of the oocysts; congenital infection, in which the infection is passed *in utero* from an infected mother to her foetus. Although in immunocompetent hosts the infection is usually asymptomatic, in immunocompromised hosts, or with congenital transmission, toxoplasmosis can be severe. In immunocompromised hosts, ocular toxoplasmosis may occur with chorioretinitis, or encephalitis which may be fatal. In infants who are infected *in utero*, learning and visual difficulties may emerge during childhood development, or the infants may be born with symptoms such as chorioretinitis, intracranial calcifications, and hydrocephalus.

A significant waterborne outbreak of toxoplasmosis occurred in Canada in 1995, with at least 2800 infections estimated, and maybe as many as 7700 (Karanis et al, 2007). At least 100 acute infections were recorded, 42 infections in pregnant women were noted, and 11 infants were born infected (Bowie et al, 1997). The outbreak was epidemiologically linked to an unfiltered, chloraminated water supply, and domestic, feral, or wild cats, and cougars were considered as possible sources of the contamination.

The Canadian outbreak demonstrates that waterborne toxoplasmosis is a real possibility, with potentially severe consequences. Whether such an event might occur in Norway should probably be assessed by risk assessment techniques, but relevant data include a relatively high prevalence of *Toxoplasma* antibodies in roe deer (> 33%) and moose (> 12 %) (Vikøren et al, 2004), and *Toxoplasma* antibodies being detected in slaughter lambs from over 44 % of sheep flocks tested (Skjerve et al, 1998), indicating that the risk of environmental contamination with infective *Toxoplasma* oocysts from infected felines is not insignificant.

Conclusions

Whilst cryptosporidiosis and giardiasis can apparently be categorised as 'emerging pathogens' in Norway, with emphasis on the waterborne route of infection, Norwegians are in the fortunate position of being able to learn from the experiences of other countries where these infections, and their transmission via the waterborne route, has been a problem for the last two decades. Additionally, by anticipating and taking pre-emptive measures as necessary and appropriate, the emergence of other parasites and their transmission by drinking water should be preventable.

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