



Review

Waterborne transmission of protozoan parasites: Review of worldwide outbreaks - An update 2011–2016



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ABSTRACT

This review provides a comprehensive update of worldwide waterborne parasitic protozoan outbreaks that occurred with reports published since previous reviews largely between January 2011 and December 2016. At least 381 outbreaks attributed to waterborne transmission of parasitic protozoa were documented during this time period. The nearly half (49%) of reports occurred in New Zealand, 41% of the outbreaks in North America and 9% in Europe. The most common etiological agent was *Cryptosporidium* spp., reported in 63% (239) of the outbreaks, while *Giardia* spp. was mentioned in 37% (142). No outbreaks attributed to other parasitic protozoa were reported. The distribution of reported outbreaks does not correspond to more broadly available epidemiological data or general knowledge of water and environmental conditions in the reporting countries. Noticeably, developing countries that are probably most affected by such waterborne disease outbreaks still lack reliable surveillance systems, and an international standardization of surveillance and reporting systems has yet to be established.

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1. Background

Waterborne infectious diseases remain a major source of morbidity and mortality in the world, causing more than 2.2 million deaths per year and far more cases of illness every day, including diarrhea and gastrointestinal diseases (www.who.int). Among the

worldwide waterborne outbreaks from 1991 to 2008 11% were caused by parasites (Baldursson and Karanis, 2011; Karanis et al., 2007; Yang et al., 2012), and parasitic protozoan outbreaks are one of the leading causes of 1.7 billion cases of diarrhea. They contribute to 842,000 deaths annually and remain the second leading cause of death in children under 5 years of age (www.who.int, Kotloff et al., 2013; Checkley et al., 2015; Platts-Mills et al., 2015).

Cryptosporidiosis and giardiasis are among the most common

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waterborne infectious agents causing diarrhea and the most common protozoan agents with a total of 30,000 cases reported every year in the United States alone (Yoder et al., 2012a, 2012b). The waterborne incidents are logically related to human *Cryptosporidium* prevalence estimated to be 3–5%, and *Giardia* infecting approximately 10% of the world's population (Huang and White, 2006). In the group of parasitic protozoa, several other species may be transmitted to humans through the drinking water route and cause infections: *Entamoeba histolytica*, *Toxoplasma gondii*, *Balantidium coli*, *Cyclospora cayetanensis*, *Microsporidia*, *Isospora*, *Naegleria* spp., *Sarcocystis* spp., *Balantidium coli*, *Acanthamoeba* spp. and *Blastocystis hominis* (Plutzer and Karanis, 2016). Transmission by the fecal–oral route renders most of these protozoa capable of infecting humans through various means of fecal contamination of land and rivers by feces of both human and animal origin (Plutzer and Karanis, 2016; Lanata, 2003).

Accurate estimation of waterborne disease requires compilation of global health statistics and the implementation of effective surveillance systems covering all countries. In the US, the USEPA and Centers for Disease Control and Prevention have collaborated to collect information about the causes of waterborne disease outbreaks (WBDOs) starting in 1971 e.g. USA Waterborne Disease and Outbreak Surveillance System (WBDOSS). The CDC publishes annual or biennial summaries of Outbreaks Associated with Drinking Water (Beer et al., 2015a), Outbreaks Associated with Recreational Water (Hlavsa et al., 2015), and Outbreaks Associated with Environmental and Undetermined Water Exposures (Beer et al., 2015b). In succeeding years, many countries established their own independent surveillance systems; Sweden in 1980 (Stanwell-Smith et al., 2003), Japan in 1981 with the National Epidemiological Surveillance of Infectious Diseases (NESID), England and Wales in 1983 for *Cryptosporidium* and in 1992 for outbreaks of infectious intestinal disease (Wall et al., 1996), and Australia in 1990 with the National Notifiable Diseases Surveillance System (NNDSS). Furthermore, the United Kingdom established the Health Protection Agency (HPA) in 2003, which later became part of Public Health England, an executive agency of the Department of Health, and the Public Health Agency of Canada (PHAC) was founded in 2004. The following year, the European Centre for Disease Control and Prevention (ECDC) was created as an EU-wide institution for public health (<http://ecdc.europa.eu/>), according to the example of the USA. Most of the above centers provide carefully assembled data and detailed reports on waterborne parasitic protozoan outbreaks to the public. In developing countries, however, there continues to be a critical absence of governmental systems for the documentation of protozoan infections or waterborne outbreaks (Karanis et al., 2007; Baldursson and Karanis, 2011). Although these institutional systems gather epidemiological data on disease incidence attributable to the protozoan agents that clearly can be waterborne, data collection and reporting on waterborne incidents or outbreaks are not reported routinely, e.g. Yoder et al. (2008). While waterborne gastroenteritis outbreaks of various etiologies are typically reported in the literature (as summarized here), virtually no organized system provides for identification let alone description and analysis of such events in poor and developing regions. As a result, information regarding waterborne parasitic protozoan outbreaks in developing countries is insufficient. Epidemiological information and relation to water reported from the organized systems listed above may be used to estimate the impact of waterborne protozoan transmission in areas lacking direct information.

Previously, two reviews regarding worldwide waterborne outbreaks caused by parasitic protozoa have been published, which updated the number of the worldwide outbreaks until 2011; one in 2007 in the Journal of Water and Health (Karanis et al., 2007:

Waterborne transmission of protozoan parasites: A worldwide review of outbreaks and lessons learnt) examining a time period of close to a hundred years from the beginning of the previous century, and the other in 2011, in the journal Water Research for the period of 2004–2011 (Baldursson and Karanis, 2011: Waterborne transmission of protozoan parasites: Review of worldwide outbreaks - An update 2004–2010). Therefore, the aim of the present work is to update worldwide waterborne parasitic outbreaks that occurred between 2011 and 2016. Given the clearly incomplete picture of global waterborne incidence in published reports, effort is given to project a worldwide distribution pattern.

2. Search

The collection of data was based upon available global literature sources. Literature search used the MEDLINE/PubMed and Scopus databases, as well as available electronic data from surveillance systems all over the globe, including the Centre for Disease Control and Prevention (CDC) and the European Centre of Disease Prevention and Control (ECDC). The collection of data entailing this present review of waterborne parasitic protozoan outbreaks was also based on the use of on line information from, Euro Surveillance (published by ECDC), Canada Communicable Disease Report (CCDR by PHAC), Morbidity and Mortality Weekly Report (MMWR by CDC) and Public Health England's electronic gastrointestinal outbreak surveillance system (eFOSS).

In the above electronic databases the terms “outbreak (and) *Cryptosporidium*”, “outbreak (and) cryptosporidiosis”, “outbreak (and) *Giardia*”, “outbreak (and) giardiasis”, “outbreak (and) *Cyclospora*”, “outbreak (and) *Blastocystis*”, “outbreak (and) *Entamoeba*”, “outbreak (and) *Acanthamoeba*”, “outbreak (and) Amoebiasis”, “outbreak (and) *Toxoplasma*”, “outbreak (and) microsporidia”, “outbreak (and) *Sarcocystis*”, “outbreak (and) *Naegleria*”, “outbreak (and) *Balantidium coli*”, “outbreak (and) *Isospora*” were applied and the listed articles critically reviewed.

2.1. Outbreaks reported between 2011 and 2016 and analysis of results

In the five year period between January 2011 and December 2016, 381 waterborne outbreaks of parasitic protozoan diseases were reported worldwide that appeared in the online databases. Tables 1 and 2 present a summary of the outbreaks. These tables also include a few waterborne outbreaks that occurred before 2011 but were published at a later time and therefore were not included in the aforementioned reviews of 2007 and 2011.

Waterborne outbreaks of *Cryptosporidium* spp. are documented in Table 1, whereas Table 2 consists of worldwide waterborne outbreaks caused by *Giardia* spp.. Both tables specify the parameters of place (region and country), time (month and year), as well as estimated and laboratory-confirmed cases in brackets, if denoted in the original article. For each outbreak, the suspected cause and the key reference is annotated.

Waterborne outbreaks reported worldwide as compiled in this review (Tables 1 and 2), were heavily skewed to two regions, North America and Australasia, Fig. 1. The majority of the reported outbreaks (63%, or 239 outbreaks) had *Cryptosporidium* spp. as their etiological agent, while *Giardia* spp. was the cause in 37% (142) of them (Tables 1 and 2). No other protozoa were reported as the causative agents of parasitic protozoan waterborne outbreaks between the years 2011–2016. A single outbreak due to contamination of drinking water by *Cyclospora cayetanensis* took place in Puerto Rico in 2008 but was not reported until later (Brunkard et al., 2011), and is included here as it was not reported in time for the previous reviews.

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