

ZOONOSES ACQUIRED THROUGH DRINKING WATER

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Keywords: Drinking water, zoonoses, protozoa, bacteria, helminths, potential, emerging, risk

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Summary

Disease may be acquired from animals through drinking water either following contamination of water sources and supplies with infectious material (usually in faeces) or when infectious life cycle stages occur in intermediate hosts in an aquatic environment. Protozoa including *Cryptosporidium*, *Giardia* and *Toxoplasma gondii*, and bacteria including *Campylobacter*, Vero-cytotoxin-producing *Escherichia coli* (VTEC) and *Salmonella* are shed in the faeces of infected hosts, including farmed and/or wild animals. The aquatic environment supports the intermediate hosts of many helminths, including *Dracunculus* and schistosomes. Full water treatment of coagulation, filtration and chlorination will control many of these pathogens, although protozoan (oo)cysts are resistant to chlorination and may breach filtration plants. If chlorination is inadequate or absent, bacterial pathogens will not be controlled. Most of the world's population does not have access to good quality drinking water, particularly in the tropics where even the simple act of collecting drinking water may expose individuals to parasites in the water. In this chapter, general issues of zoonotic disease transmitted via drinking water are addressed, followed by zoonoses known to cause

human disease *via* drinking water. The organisms included are the protozoan parasites *Cryptosporidium*, *Giardia*, and *Toxoplasma gondii*, the bacteria *Campylobacter*, VTEC, *Salmonella*, leptospires, *Streptobacillus moniliformis* and *Francisella tularensis* and the helminths *Dracunculus medinensis*, schistosomes and flukes. Other zoonoses potentially acquired through drinking water including the microsporidia, *Ballantidium coli*, *Yersinia* spp., *Aeromonas* spp., Mycobacteria, *Taenia* and *Echinococcus* spp., *Gnathostoma* and prions are also addressed. Risks to consumers are multi-factorial and comprise host, parasite and environmental factors. Measures for evaluation of risk leading to the prevention and control of illness need to be improved, although advances in strategies for sampling and monitoring, and methods for detecting and characterizing isolates have increased our understanding of waterborne zoonoses.

1. Introduction

The term zoonosis was first used by Virchow in 1888 and was officially defined and widely accepted following a WHO report in 1959 as “those diseases and infections naturally transmitted between vertebrate animals and man”. Animals that are reservoir hosts may not necessarily show signs of disease but remain capable of transmitting pathogens to humans *via* drinking water. Conversely, humans may transmit disease to animals, and in the case of drinking water this is possible when human faeces or sewage have contaminated their water sources and supplies. While there are well over 200 zoonoses, the impact of zoonotic transmission on human health can be difficult to measure since some are also transmitted from person-to-person. Identifying the impact of zoonoses acquired *via* drinking water is further complicated, since the contribution of other vehicles of transmission have to be estimated. However, modern molecular biological typing techniques, applied as tracing and tracking tools, are being used to complement data from epidemiological studies and sample surveys to better identify sources of strains and routes of transmission. In addition, faecal biomarkers such as sterols and bacteriophages combined with microbial faecal indicators have been shown to be useful for differentiating human from animal sources of contamination. Zoonoses transmitted *via* drinking water have been identified in sporadic cases and in outbreaks of human illness by microbiological, environmental and epidemiological studies. Risks have also been identified in prospective epidemiological studies and sample surveys.

Diseases transmitted from animals *via* drinking water, either by the ingestion of water contaminated with pathogens or by their ingestion through contact with intermediate hosts living in water are addressed here. These are mainly the protozoan parasites *Cryptosporidium* and *Giardia*, the bacteria *Campylobacter*, Vero-cytotoxin-producing *Escherichia coli* (VTEC) and non-typhoidal salmonellae, and parasitic helminths. Waterborne disease caused by the macro parasites, including trematodes and nematodes, is mainly through consumption of, or contact with, intermediate hosts in the aquatic environment. Humans can be final, intermediate, maintenance or accidental hosts for parasitic infections. Zoonotic viruses have been rarely associated with waterborne disease. Contamination with human sewage is the usual cause of waterborne outbreaks of the calicivirus Hepatitis E Virus (HEV) but antibodies to HEV have also been identified in wild rodents and farmed pigs, sheep and cattle, suggesting an animal reservoir. HEV has been found to be pathogenic for some domestic and wild animals and contact with wild animals and environmental sources of animal wastes identified as risk

factors for human exposure. Waterborne outbreaks of human rotavirus have also occurred but animal rotaviruses are not usually zoonotic. However, the segmented rotavirus genome readily recombines and the epidemiological significance of human/bovine rotavirus recombinants identified in nature is yet to be established.

In this chapter, general issues of zoonotic disease transmitted via drinking water are addressed, followed by zoonoses known to cause human disease *via* drinking water. The organisms included are the protozoan parasites *Cryptosporidium*, *Giardia*, and *Toxoplasma gondii*, the bacteria *Campylobacter*, VTEC O157, *Salmonella*, leptospires, *Streptobacillus moniliformis* and *Francisella tularensis* and the helminths *Dracunculus medinensis*, schistosomes and flukes. Other zoonoses potentially acquired through drinking water including the microsporidia, *Ballantidium coli*, *Yersinia* spp., *Aeromonas* spp., Mycobacteria, *Taenia* and *Echinococcus* spp., *Gnathostoma* and prions are addressed at the end of the chapter.

2. General Issues of Zoonotic Disease Acquired through Drinking Water

Well-managed water treatment and supply systems provide good quality drinking water throughout the world, but 1.1 billion people do not have access to good quality drinking water. Zoonotic organisms enter the water supply through contamination of untreated ground or surface waters, through failures in treatment or post-treatment contamination during distribution and storage. In developed countries, where drinking water disinfection is in place for the majority of the population, outbreaks of waterborne illness are mainly caused by the protozoan parasites *Cryptosporidium* and *Giardia*. Good log reduction in the number of robust (oo)cysts shed in human and animal faeces into the environment is achieved by coagulation and filtration under optimal conditions. However, if treatment is inadequate, absent or the system “overloaded” by spikes in numbers of (oo)cysts, there is no treatment barrier since these life cycle stages are resistant to chlorination at levels used to treat drinking water. Chlorination is used to control most other pathogens that might occur in drinking water. Bacterial infections such as *Campylobacter* and VTEC O157 occur following contamination and where chlorination is absent or where chlorination failure has occurred. In developed countries this is commonly the case in private water supplies (i.e. those supplies not managed by a water company), which have been generally shown to be of poor microbiological quality.

Waterborne disease is important because it can affect large numbers of people since drinking water is a common exposure, and secondary transmission pathways can cause amplification of the number of cases of illness. Additionally, the effects of widespread outbreaks on the community can be wider than those solely of illness. For example, hospitals and local food manufacturing industry that normally rely on a potable water supply will be affected; there may be an impact on tourism, and a general loss of confidence in the water supply. The burden of sporadic illness attributable to waterborne zoonoses is largely unknown. However, for the majority of the world’s population access to potable water is lacking and in tropical countries the presence of pathogens and intermediate hosts of zoonotic disease in water sources and supplies is an additional burden. Most outbreaks of waterborne disease have been reported in developed countries, but even limited surveillance and epidemiological studies suggest

a more widespread problem in developing and tropical countries. Under-ascertainment of cases of waterborne disease includes low likelihood of people presenting to medical services, poor diagnostic and surveillance facilities, and epidemiological problems of identifying outbreaks of a common disease.

While waterborne pathogens may survive in the aquatic environment, they do not necessarily multiply significantly in water, and some are obligate parasites such as *Cryptosporidium* and *Giardia*. However, the presence of low numbers of target organisms can be significant since the infectious dose of many of these pathogens is low. This also presents problems for detection and monitoring. *Cryptosporidium* oocysts are also unevenly distributed in water and can survive for long periods of time, and thus conventional indicators of contamination and water quality may not apply. Recent developments in laboratory techniques have improved the recovery for testing of low numbers of organisms in water samples. These include the development of filters which permit the filtration of larger volumes of water and better elution of (oo)cysts from the filter matrix. Immunomagnetic beads (paramagnetic beads coated with organism-specific antibodies) have been specifically developed for efficient recovery of organisms, including *Cryptosporidium*, *Giardia* and VTEC O157, from the sample matrix.

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Biographical Sketch

Rachel Chalmers is a consultant clinical scientist who heads the UK's Cryptosporidium Reference Unit. She has a background in health-related microbiology, epidemiology and protozoan parasitology. Epidemiological interests include those relating to *Cryptosporidium* and other protozoan parasites, waterborne diseases and zoonoses. She has used cohort and case control studies to investigate risk factors for infection and disease, including VTEC O157 and *Cryptosporidium*, and has investigated risk factors for exposure to various zoonoses in farm workers.