Safe water for travellers

Background and epidemiology: Safe drinking water is one of the most significant public health advances in the past 100 years,[1] yet over 1 billion people lack safe drinking water and 2.4 billion lack adequate sanitation.[2] Travellers are at risk of waterborne illness if they cannot ensure safe drinking water and adequate sanitation, but simple precautions minimize the risk.

Worldwide, waterborne illness from contaminated water and unsanitary conditions accounts for 1 billion cases of diarrhea and an estimated 10–25 million deaths each year, including 95% of deaths among children under the age of 5 years.[3] The most common organisms causing such illness are enterotoxigenic species of *Escherichia coli*, *Salmonella*, *Shigella*, *Giardia*, *Cryptosporidium* and hepatitis A virus.[4,5] Permanent immunity does not usually develop against most pathogens, and reinfection can occur.

The global burden of diarrhea is relevant because the local population acts as a pathogen reservoir. One or more pathogens are found in the stool of the majority of travellers from industrialized countries who become ill in developing countries, which makes "traveller's diarrhea" the most common travel-related illness.[6,7]

The risk of waterborne illness while travelling depends on the number of organisms consumed, the organism's virulence, the host's defenses and the destination. As few as 10–100 *Giardia* or *Cryptosporidium* organisms can cause infection, as compared with 1000 of *Shigella*, 10 000 of *Vibrio cholerae* and 100 000 of *Salmonella* organisms.[8] Illness can occur with exposure to, and inadvertent ingestion of, recreational water.[9] A few millilitres of water may contain sufficient pathogen to cause illness.

High-risk destinations include Africa, the Middle East, Asia and Latin America,[5] where 20%–50% of travellers are affected by waterborne illness. The incidence is high because of the lack of safe water sources and an increased prevalence of diarrheal illness in the local population. In most cases, symptoms in travellers are mild, do not interfere with regular activities and resolve within 48 hours. Only 10%–20% of patients have severe illness, and less than 1% are admitted to hospital while travelling.[5] Death is unlikely except from infection with specific organisms such as *E. coli* or *V. cholerae*, and *Cryptosporidium* with underlying illness. This is in sharp contrast to the morbidity and mortality from waterborne illness in the local population, which are significantly higher owing to a lack of safe drinking water and food, repeated pathogen exposure, chronic infection and underlying malnutrition.

Clinical management: Fluid and electrolyte replacement is the mainstay for treating traveller's diarrhea. Oral rehydration using the World Health Organization (WHO) solution (Table 1) is effective for patients of all ages, and the solution is commercially available worldwide. Loperamide, an antimotility drug, limits the number of stools and the duration of illness. Its use must be limited to 48 hours or less and must be avoided in patients under 3 years old, people with febrile symptoms and people with blood in their stool. Empiric antimicrobial therapy is indicated if travellers have 3 or more loose stools in 8 hours, because of the high risk of a bacterial cause. The oral antibiotic of choice in adults is ciprofloxacin (500 mg twice daily), and in children it is trimethoprim–sulfamethoxazole (3 and 15 mg/kg respectively twice daily).[5] Travellers should seek medical attention and stop antibiotic therapy if diarrhea persists or worsens.

Prevention: Travellers cannot reliably determine the safety of water on the basis of its look, smell or taste.[10] Tap water in most tropical or underdeveloped countries is contaminated.[11] Springs and wells may be contaminated,[11] and locally bottled water may be unsafe owing to unsanitary bottling practices or contamination of the water source itself.[12,13] Hot tap water and ice cubes are unsafe.[14,15] Water can be made safe for drinking with the use of heat, chemical treatment or filtration.

Boiling water inactivates all common waterborne pathogens. *Giardia* and other cysts, parasitic eggs and larvae, *Shigella* and *Salmonella* are killed in water at 65°C within 1 minute.[16] Viruses are killed within 1 minute in water above 70°C.[17] Boiling water for 30 seconds kills *V. cholerae*, *E. coli*[18] and *Cryptosporidium*.[19] Water brought to a boil, regardless of elevation, is considered safe, but boiling for 3 minutes adds an additional margin of safety.

Chemical treatment is the most common disinfection method. Halogens (chlorine and iodine) work by oxidizing essential cellular structures and enzymes.[20] Non-spore-forming bacteria are very susceptible to halogens, viruses have intermediate susceptibility, but protozoan cysts and spores are resistant. Chlorine dioxide is a safe halogen preparation and is effective against all waterborne pathogens, including *Cryptosporidium*.[21] A stable form of chlorine dioxide is available as a single-step method to disinfect drinking water.

Pathogens susceptible to halogens are inactivated by adequate residual halogen concentration and contact time. Concentrations of 4–5 ppm are recommended for disinfecting clear water, and

Table 1: Composition of World Health Organization oral rehydration solution

Ingredient	Amount added to 1 L of water
Sodium chloride	3.5 g (90 mEq)
Potassium chloride	1.5 g (20 mEq)
Glucose	20 g (111 mmol)
Sodium bicarbonate*	2.5 g (30 mEq)

*Recent formulations use trisodium citrate (2.9 g) to improve shelf-life.

8–10 ppm if the water is cloudy. Tables 2 and 3 outline the recommended halogen contact time at various temperatures, and the amount of iodine or chlorine solution required to achieve the desired concentrations.

Halogens have an objectionable taste and smell that is minimized with the use of flavoured drink crystals or filtration of the water after halogenation. Sodium hypochlorite, the active ingredient in bleach, may react with organic contaminants in water and produce carcinogens.[22] This potential has not been scientifically validated, and the risk of death from infectious disease from unsafe water outweighs any potential carcinogen risk. The possible toxicity from long-term iodine use is controversial; the WHO recommends that iodine be used as an emergency measure for no more than 3 weeks.[23]

With the filtration method, filters adsorb pathogens to compressed activated carbon or prevent their passage through ceramic material. Activated carbon filters adsorb organic (vegetation) and inorganic (urea, pesticides, heavy metals) matter and trap, but do not kill, microorganisms. However, these filters do not disinfect water and can become colonized with microorganisms.[24]

Table 2: Contact time with halogen for field water disinfection

Halogen concentration, ppm	Water temperature; contact time, min		
	5°C	15°C	25°C
4	180	60	45
8	60	30	15

Pathogen size determines susceptibility to filtration. Protozoan cysts are removed with a filter pore size of 1–2 μm, whereas removal of bacteria and bacterial spores requires a pore size of 0.2 μm or less. Ceramic filters remove pathogens as small as 0.2 μm. Viruses cannot be removed reliably by filtration because their average size (0.03 μm) is too small.

The optimal method to ensure safe drinking water depends on the quantity of water required, the quality of the water source and the fuel availability. In developing countries where there is human or animal activity, surface water is highly contaminated and requires disinfection with heat, chlorine dioxide, or a 2-step process (filtration plus halogenation). Charcoal filtration before disinfection removes organic and inorganic matter. Halogens should be added to stored water to prevent pathogen growth. Table 4 lists the advantages and disadvantages of each method.

In addition to water disinfection, travellers must use safe food preparation methods and practise good personal hygiene to prevent enteric illness.[25] Food should be washed with disinfected water, boiled or peeled. Proper handwashing prevents contamination of food during meal preparation.[26] Dishes and utensils should be disinfected with bleach. Human waste should be buried 20–30 cm deep, at least 30 m from any water,[27] at a location where water runoff will not contaminate nearby water sources.

Prophylactic antimicrobial agents are not generally recommended owing to potential alternation of normal bacterial flora, development of resistance, side effects and a false sense of security.[5,7] Travellers may opt for vaccination to protect against illness. In addition to an effective hepatitis A vaccine, there are now vaccines effective against cholera[28–30] and *E. coli*.[29,30]

Table 3: Amount of halogen required for disinfection of 1 litre of water

Halogen source	Halogen concentration achieved; dose required			
	4 ppm	5 ppm	8 ppm	10 ppm
Iodine tablet	½ tablet	–	1 tablet	–
2% iodine solution	0.2 mL (4 drops)	–	0.4 mL (8 drops)	–
Household bleach*	–	0.1 mL	–	0.2 mL
Chlorine tablet†	–	½ tablet	–	1 tablet
Chlorine with flocculating agent‡	½ tablet	–	1 tablet	–

*5% sodium hypochlorite.
†AquaClear™.
‡AquaCure™, AquaPure™.

Valerie F. Krym
Department of Community Health Sciences
University of Manitoba
Winnipeg, Man.
Russell D. MacDonald
Division of Emergency Medicine
Department of Medicine
University of Toronto
Toronto, Ont.

References

1. Achievements in public health, 1900-1999: control of infectious diseases. *MMWR Morbid Mortal Wkly Rep* 1999;48:621-9.
2. WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation. *Global water supply and sanitation assessment 2000 report*. Geneva: World Health Organization / New York: United Nations Children's Fund; 2000. Available: www.unicef.org/programme/wes/pubs/global/global.htm (accessed 2003 July 15).
3. Hazen T, Toranzos G. Tropical source water. In: McFeters G, editor. *Drinking water microbiology*. New York: Springer-Verlag; 1990. p. 32-53.
4. Risks from food and drink. In: *The Yellow Book: health information for international travel, 2001–2002*. Atlanta: US Centers for Disease Control and Prevention. Available: www.cdc.gov/travel/food-drink-risks.htm (accessed 2003 July 15).
5. Travelers' diarrhea. In: *The Yellow Book: health information for international travel, 2001–2002*. Atlanta: US Centers for Disease Control and Prevention. Available: www.cdc.gov/travel/diarrhea.htm (accessed 2003 July 15).
6. Black RE. Epidemiology of travelers' diarrhea and relative importance of various pathogens. *Rev Infect Dis* 1990;12(Suppl 1):S73-9.
7. Ericsson CD. Travelers' diarrhea: epidemiology, prevention, and self-treatment. *Infect Dis Clin North Am* 1998;12(2):285-303.
8. Hurst C. Estimating the risk of acquiring infectious disease from ingestion of water. In: Hurst C, editor. *Modeling disease transmission and its prevention by disinfection*. Melbourne: Cambridge University Press; 1996. p. 99-139.
9. Pruss A. Review of epidemiological studies on health effects from exposure to recreational water. *Int J Epidemiol* 1998;27:1-9.
10. Cooper R. Infectious agent risk assessment water quality project. [Sanitary Engineering and Environmental Health Research Laboratory reports 84-4 and 84-5.] Berkeley: University of California; 1984.
11. Chaudhuri M, Sattar G. Domestic drinking water treatment for developing countries. In: McFeters G, editor. *Drinking water microbiology*. New York, Springer-Verlag, 1990. p. 168-84.
12. Bharath J, Mosodeen M, Motilal S, Sandy S, Sharma S, Tessaro T, et al. Microbial quality of domestic and imported brands of bottled water in Trinidad. *Int J Food Microbiol* 2003;81(1):53-62.
13. Rivera F, Galvan M, Robles E, Leal P, Gonzalez L, Lacy AM. Bottled mineral water polluted by protozoa in Mexico. *J Protozool* 1981;28(1):54-6.
14. Dickens DL, DuPont HL, Johnson PC. Survival of bacterial enteropathogens in the ice of popular drinks. *JAMA* 1985;253:3141-3.

Table 4: Advantages and disadvantages of water disinfection methods

Variable	Heat	Filtration	Halogenation	Filtration plus halogenation	Halogenation with chlorine dioxide
Availability	Requires adequate fuel supply	Many products available commercially	Many halogen agents (chlorine and iodine) available commercially	Many products available commercially; halogen–resin filter as single-step unit increasingly available	Increasingly available
Relative cost	Fuel may be expensive	Expensive*	Inexpensive†	Filters are expensive;* halogenation is inexpensive†	Inexpensive†
Efficacy	Effective against all organisms	Does not remove viruses	*Cryptosporidium* and parasite eggs are resistant	Effective against all organisms	Effective against all organisms
Optimal conditions for use	Clear water	Clear or turbid water	Clear water; increase dose if water not clear	Clear water; increase dose if water not clear	Any type of water
Effect on taste of water	Does not alter taste	Can improve taste	Worsens taste	Filtration improves taste after halogenation	Does not alter taste
Time	Minutes to boil	Minutes to filter	Contact required for minutes to hours	Increased time	Minutes
Other considerations	Fuel is heavy, and supply may be limited	Turbid water clogs filter; charcoal filtration removes chemical and heavy metal contamination	Useful for large quantities of water and for stored water	Halogenation should be done before filtration	Single-step method for all organisms;‡ useful for large quantities of water

*Initial cost of filter can exceed $100, but filter may provide up to 10 000 L of potable water over lifetime of filter.
†Cost is less than $1 per liter of water purified.
‡If large amounts of sediment are present, filtration may be required to improve taste and appearance.

15. Bandres JC, Mathewson JJ, DuPont HL. Heat susceptibility of bacterial enteropathogens. Implications for the prevention of travelers' diarrhea. *Arch Intern Med* 1988;148(10):2261-3.
16. Frazier W, Westhoff D. Preservation by use of high temperatures. In: *Food microbiology*. New York: McGraw-Hill; 1978. p. 89-112.
17. Sullivan R, Tierney JT, Larkin EP, Read RB Jr, Peeler JT. Thermal resistance of certain oncogenic viruses in milk. *Appl Microbiol* 1971;22:315-20.
18. Groh C, MacPherson DW, Groves DJ. Effect of heat on the sterilization of artificially contaminated water. *J Travel Med* 1996;3(1):11-3.
19. Fayer R. Effect of high temperature on infectibity of *Cryptosporidium parvum* oocysts in water. *Appl Environ Microbiol* 1994;60(8):2732-5.
20. White G. *Handbook of chlorination*. 3rd ed. New York: Van Nostrand Reinhold; 1992.
21. Peeters J, Mazas E, Masschelein W, Maturana I, DeBacker E. Effect of disinfection of drinking water with ozone or chlorine dioxide on survival of *Cryptosporidium*. *Appl Enrivon Microbiol* 1989; 55:1519-22.
22. Drinking Water Health Effects Task Force, US Environmental Protection Agency. *Health effects of drinking water treatment technologies*. Chelsea (MI): Lewis Publisher; 1989.
23. Zoeteman B. *The suitability of iodine and iodine compounds as disinfectants for small water supplies*. The Hague: WHO International Reference Centre for Community Water Supplies; 1972.
24. Longsdon G, Symons JM, Hoye RL, Arozarena MM. Alternative filtration methods for removal of *Giardia* cysts and cyst models. *J Am Water Works Assoc* 1981;73:111-8.
25. Huttly SR. The impact of inadequate sanitary conditions on health in developing countries. *World Health Stat Q* 1990;43(3):118-26.
26. Sobel J, Mahon B, Mendoza CE, Passaro D, Cano F, Baier K, et al. Reduction of fecal contamination of street-vended beverages in Guatemala by a simple system for water purification and storage, handwashing, and beverage storage. *Am J Trop Med Hyg* 1998;59(3):380-7.
27. US Army. *Sanitary control and surveillance of field water supplies*. Technical Bulletin (TB Med 577; NavMed P-5010-9, Appendix D; AFOSH Standard 48-7). Washington: Departments of the Army, Navy, and Air Force; 1999. Available: www.wood.army.mil/warrior/62G/TB%20Med%20577.pdf (accessed 2003 July 16).
28. Cohen MB, Giannella RA, Bean J, Taylor DN, Parker S, Hoeper A, et al. Randomized, controlled human challenge study of the safety, immunogenicity, and protective efficacy of a single dose of Peru-15, a live attenuated oral cholera vaccine. *Infect Immun* 2002;70(4):1965-70.
29. Savarino SJ, Hall ER, Bassily S, Wierzba TF, Youssef FG, Peruski LF Jr, et al. Introductory evaluation of an oral, killed whole cell enterotoxigenic *Escherichia coli* plus cholera toxin B subunit vaccine in Egyptian infants. *Pediatr Infect Dis J* 2002;21(4):322-30.
30. Qadri F, Wenneras C, Ahmed F, Asaduzzaman M, Saha D, Albert MJ, et al. Safety and immunogenicity of an oral, inactivated enterotoxigenic *Escherichia coli* plus cholera toxin B subunit vaccine in Bangladeshi adults and children. *Vaccine* 2000;18(24):2704-12.