LIVESAY EXPEDITIONS & ADVENTURES

Water Disinfection for Travelers

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Risk for Travelers

Waterborne disease is a risk for international travelers who visit countries that have poor hygiene and inadequate sanitation, and for wilderness users relying on surface water in any country, including the United States. Worldwide, more than one billion people have no access to potable water and 2.4 billion do not have adequate sanitation. In developing countries, the influence of high-density population and rampant pollution, along with absent, overwhelmed, or insufficient sanitation and water treatment systems, means that surface water may be highly polluted with human waste and even urban tap water may become contaminated. Primarily humans, but also animals, are the source of microorganisms that contaminate water sources and cause intestinal infections.

The list of potential waterborne pathogens is extensive and includes bacteria, viruses, protozoa, and parasitic helminths. Most of the organisms that can cause travelers' diarrhea can be waterborne, although the majority of travelers' intestinal infections are probably transmitted by food. Microorganisms with small infectious doses can even cause illness through recreational water exposure, via inadvertent water ingestion.

Bottled water has become the convenient solution for most travelers, but in some places, it may not be superior to tap water. Moreover, the plastic bottles create a huge ecological problem, since most developing countries do not recycle plastic bottles. All international travelers, especially long-term travelers or expatriates, should become familiar with and utilize simple methods to ensure safe drinking water. Disinfection, the desired result of field water treatment, means the removal or destruction of harmful microorganisms. The goal of disinfection is to reduce the risk of gastrointestinal infection and diarrheal illness. Table 2-28 compares benefits and limitations of different methods.

Field Techniques for Water Treatment

Heat

Common intestinal pathogens are readily inactivated by heat. Microorganisms are killed in a shorter time at higher temperatures, whereas temperatures as low as 140° F (60° C) are effective with a longer contact time. Pasteurization uses this principle to kill food-borne enteric pathogens and spoiling organisms at temperatures between 140° F (60° C) and 158° F (70° C), well below the boiling point of water (212° F; 100° C).

Although attaining boiling temperature is not necessary for inactivation of common intestinal pathogens, it is the only easily recognizable endpoint without using a thermometer. Microorganisms begin to die as water is heated on a stove or fire from 150° F (65° C) to boiling. All organisms except bacterial spores, which are not usually waterborne enteric pathogens, are killed within seconds at boiling temperature. Therefore, any water brought to a boil should be adequately disinfected. CDC and the Environmental Protection Agency recommend boiling for 1 minute to allow for a margin of safety and so users are clear that the water is truly boiling. Because the boiling point decreases with increasing altitude, CDC advises boiling water for 3 minutes at altitudes greater than 6,562 feet (>2000 m).

If no other means of water treatment is available, a potential alternative to boiling is to use tap water that is too hot to touch, which is probably at a temperature between 131° F (55° C) and 140° F (60° C). This temperature may be adequate to kill pathogens if the water has been kept hot in the tank for some time. However, because one cannot know for certain that this temperature has been maintained for long enough to kill all waterborne pathogens, boiling is still advisable if possible. Travelers with access to electricity can bring a small electric heating coil or a lightweight beverage warmer to boil water.

Filtration

Filter pore size is the primary determinant of a filter's effectiveness, but microorganisms also adhere to filter media by electrochemical reactions. Microfilters with "absolute" pore sizes of 0.1–0.4 µm are usually effective for removal of cysts and bacteria but may not adequately remove viruses, which are a major concern in water with high levels of fecal contamination (Table 2-29). Environmental Protection Agency (EPA) designation of water "purifier" indicates that company-sponsored testing has substantiated claims for removing 10^4 (9,999 of 10,000) viruses although EPA does not independently test the validity of these claims.

Reverse osmosis filtration can both remove microbiologic contamination and desalinate water. The high price and slow output of small hand-pump reverse-osmosis units currently prohibit use by land-based travelers; however, they are important survival aids for ocean voyagers.

If the water supply is suspected of being heavily contaminated with biologic wastes and additional assurance is needed, then a second step with chemical treatment of the water before filtration can kill viruses. Many filters contain a charcoal stage that will remove the taste of added chlorine or iodine.

Chemical Disinfection

The most common chemical water disinfectants are chlorine and iodine (halogens). Worldwide, chemical disinfection with chlorine is the most commonly used method for improving and maintaining microbiologic quality of drinking water. Sodium hypochlorite, common household bleach, is the primary disinfectant promoted by CDC and the WHO Safe Water System for individual household use in the developing world.

Primary factors that determine the rate and proportion of microorganisms killed are the concentration of halogen (measured in mg/L or parts per million) and the length of time microorganisms are exposed to the halogen (contact time, measured in minutes). Given adequate concentrations and contact times, both chlorine and iodine have similar activity and are effective against many bacteria. Due to many uncontrolled factors in the field, extending the contact time adds a margin of safety. Cloudy water contains material that will use added disinfectant so it will require higher concentrations or contact times. However, some common waterborne parasites such as *Cryptosporidium*, are poorly inactivated by halogen disinfection, even at practical extended contact times. Therefore, chemical disinfection should be supplemented with adequate filtration to remove these disease-causing microorganisms from drinking water.

Both chlorine and iodine are available in liquid and tablet form (Table 2-30). Iodine has physiologic activity (it is used by the thyroid), so WHO recommends limiting iodine water disinfection to a few weeks of emergency use. It is not recommended in persons with unstable thyroid disease, known iodine allergy, or pregnancy (because of the potential effect on the fetal thyroid).

The taste of halogens in water can be improved by several means:

- Reduce concentration and increase contact time.

- Use a filter that contains activated carbon after contact time.
- Add a tiny pinch of ascorbic acid (vitamin C, available in powder or crystal form and an ingredient in most flavored drink mixes) after the required contact time to remove the taste of halogens. (This works by converting iodine to iodide or chlorine to chloride, which have no taste or color.)

Iodine Resins

Iodine resins transfer iodine to microorganisms that come into contact with the resin, but leave little iodine dissolved in the water. The resins have been incorporated into many different filter designs available for field use. Most contain a 1-µm cyst filter, which should effectively remove protozoan cysts (it should say 1-µm or 1 micron "absolute"). Few models are sold in the United States because of inconsistent test results, but some models are still available for international use.

Salt (Sodium Chloride) Electrolysis

Passing a current through a simple brine salt solution generates mixed oxidants, primarily chlorine, which can be used for disinfection of microbes. See the discussion on chlorine above. The process was recently designed in a pocket-sized instrument that uses salt, water and electrical current generated from camera batteries to produce a disinfectant solution that is added to water.

Chlorine Dioxide

Chlorine dioxide (ClO_2) is capable of inactivating most water-borne pathogens, including *Cryptosporidium* oocysts, at practical doses and contact times. There are several new chemical methods for generating chlorine dioxide in the field for small-quantity water treatment.

Ultraviolet (UV) Light

UV light can be used as a pathogen reduction method against microorganisms. The technology requires effective pre-filtering due to its dependence on low water turbidity (cloudiness), the correct power delivery, and correct contact times to achieve maximum pathogen reduction. UV might be an effective method in pathogen reduction in backcountry water. However, there is a lack of independent testing data available on specific systems.

Solar Irradiation and Heating

UV irradiation by sunlight in the UVA range can substantially improve the microbiologic quality of water. Recent work has confirmed the efficacy and optimal procedures of the solar disinfection (SODIS) technique. Transparent bottles (e.g., clear plastic beverage bottles), preferably lying on a dark surface, are exposed to sunlight for a minimum of 4 hours. UV and thermal inactivation are synergistic for solar disinfection of drinking water. Use of a simple reflector or solar cooker can achieve temperatures of 149° F (65° C), which will pasteurize the water after 4 hours. In emergency situations such as refugee camps and disaster areas, where strong sunshine is available, solar disinfection of drinking water can improve water quality.

Silver and Other Products

Silver ion has bactericidal effects in low doses and some attractive features, including absence of color, taste, and odor. The use of silver as a drinking water disinfectant is popular in Europe, but it is not approved for this purpose in the United States because silver concentration in water is strongly affected by adsorption onto the surface of the container and there has been limited testing on viruses and cysts.

Several other common products have known antibacterial effects in water and are marketed in commercial products for travelers, including hydrogen peroxide, citrus juice, and potassium permanganate. None have sufficient data to recommend them for water disinfection in the field.

Granular activated carbon (GAC) removes organic and inorganic chemicals (including chemical disinfectants) through adsorption onto carbon particles, thereby improving odor and taste. GAC may trap but does not kill microorganisms. GAC is a common component of field filters.

Coagulation–flocculation (CF) removes suspended particles that cause a cloudy appearance and bad taste and do not settle by gravity; this process removes many but not all microorganisms. Alum, or one of several other substances, is added to the water, stirred well, allowed to settle, then poured through a simple coffee filter or fine cloth to remove the sediment. CF is an ancient technique that is still used routinely in municipal water treatment in conjunction with other treatment methods, such as disinfection, filtration, UV radiation, and ozonation.

The Preferred Technique

The optimal technique for an individual or group depends on personal preference, size of the group, water source, and the style of travel. Boiling is most effective but may not be practical in all situations. Unfortunately, alternative treatment may require a two-step process of 1) coagulation–flocculation and/or filtration and 2) halogenation. It is best to filter first and then add the halogen. On long-distance, oceangoing boats where water must be desalinated during the voyage, only reverse-osmosis membrane filters are adequate.

When the water will be stored for a period of time, such as on a boat, motor home, or a home with rainwater collection, halogens should be used to prevent the water from becoming recontaminated. A tightly sealed container is best to decrease risk of contamination. A minimum residual of 3–4 mg/L of hypochlorite should be maintained in the stored water. For short-term home storage, narrow-mouth jars or containers with water spigots prevent contamination from repeated contact with hands or utensils.

Table 2-28. Comparison of water disinfection techniques

Technique	Advantages	Disadvantages
Heat	• Does not impart additional taste or color • Single step that inactivates all enteric pathogens • Efficacy is not compromised by contaminants or particles in the water as for halogenation and filtration	• Does not improve taste, smell or appearance of poor quality water • Fuel sources may be scarce, expensive or unavailable • Does not prevent recontamination during storage

Technique	Advantages	Disadvantages
Filtration	• Simple to operate • Requires no holding time for treatment • Large choice of commercial products • Adds no unpleasant taste and often improves taste and appearance of water • Rationally combined with halogens for removal or destruction of all pathogenic waterborne microbes	• Adds bulk and weight to baggage • Many are not reliable for removal of viruses • Channeling of water or high pressure can force microorganisms through the filter • Relatively expensive, compared to chemical treatment • Eventually clogs from suspended particulate matter and may require some maintenance or repair in the field
Halogens	• Inexpensive and widely available in liquid or tablet forms • Taste can be removed by several techniques • Flexible dosing • Equally easy to treat large and small volumes	• Corrosive and stains clothing • Imparts taste and odor to water • Flexibility requires understanding of principles • Iodine is physiologically active, with potential adverse effects • Not readily effective against *Cryptosporidium* oocysts • Efficacy decreases with low water temperature and decreasing water clarity
Chlorine Dioxide	• Low doses have no taste or color • Simple to use and available in liquid or tablet form • More potent than equivalent doses of chlorine • Effective against all waterborne pathogens	• Volatile and sensitive to sunlight: do not expose tablets to air and use generated solutions rapidly • No persistent residual, so does not prevent recontamination during storage
Ultraviolet	• Imparts no taste • Portable devices now available • Effective against all waterborne pathogens	• Requires clear water • Does not improve taste or appearance of water • Relatively expensive • Requires batteries or power source • Difficult to know if devices are delivering required UV doses

Table 2-29. Microorganism size and susceptibility to filtration

Organism	Average Size (µm)	Maximum recommended filter rating (µm Absolute)[1]
Viruses	0.03	Not specified
Enteric bacteria (*E. coli*)	0.5 × 3.0–8.0	0.2–0.4
***Cryptosporidium* oocyst**	4–6	1
***Giardia* cyst**	6.0–10.0 × 8.0–15.0	3.0–5.0

[1]NSF 53 rating on a filter certifies for cyst/oocyst removal.

Table 2-30. Iodine and chlorine formulations and doses

Iodination Techniques added to 1 liter or quart of water	Yield 4 mg/L Contact (Wait) Time 45 min at 30° C 180 min at 5° C[1]	Yield 8 mg/L Contact (Wait) Time 15 min at 30° C 60 min at 5° C[1]
Iodine tablets (tetraglycine hydroperiodide) (e.g., Potable Aqua, Globaline)	1/2 tablet	1 tablet
2% iodine solution (tincture)	0.2 mL 5 gtts[2]	0.4 mL 10 gtts[2]
Saturated solution: iodine crystals in water (e.g., Polar Pure)	13.0 mL	26.0 mL
Chlorination techniques	**Yield 5 mg/L**	**Yield 10 mg/L**
Sodium hypochlorite **Household bleach 5%**	0.1 mL 2 drops	0.2 mL 4 drops
Sodium dichloroisocyanurate (e.g., AquaClear)		1 tablet
Chlorine plus flocculating agent (e.g., Chlor-floc)		1 tablet

[1]Very cold water requires prolonged contact time with iodine or chlorine to kill *Giardia* cysts. These contact times have been extended from the usual recommendations in cold water to account for this and for the uncertainty of residual concentration.

[2]Drops per minute.

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