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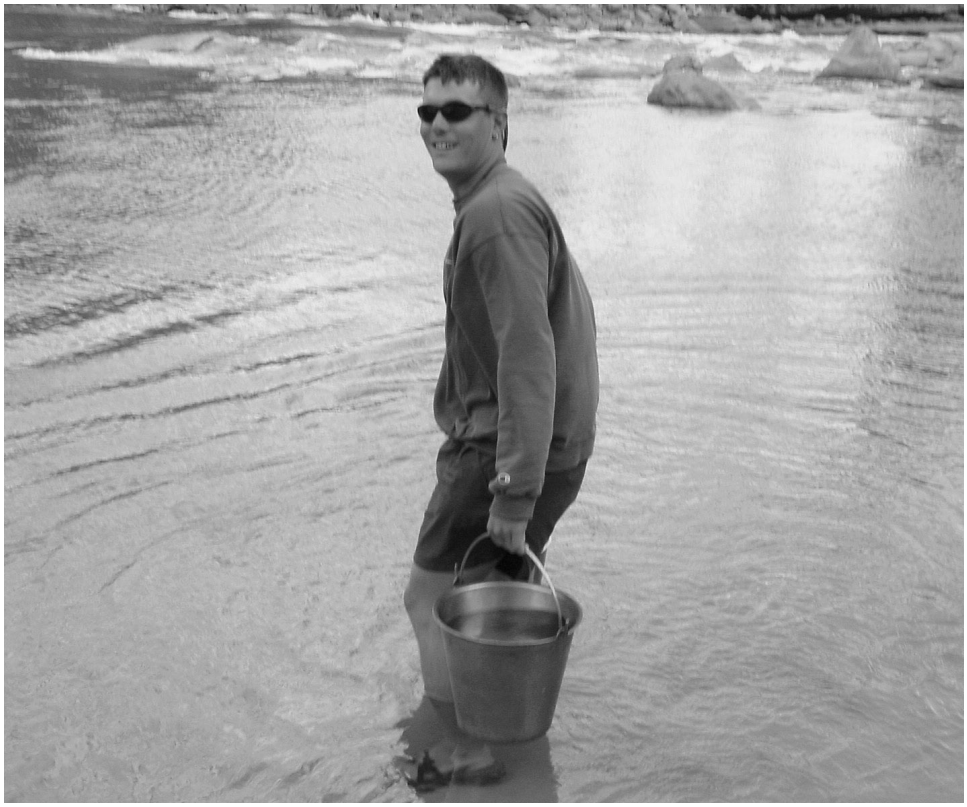
WATER PURIFICATION

WHY PURIFY WATER?

AN ADEQUATE SUPPLY of safe drinking water is essential to any backcountry experience, but it is not always possible to take along enough water to last throughout an extended trip. A person needs about 2 liters of water each day, but during a backcountry trip in hot weather, about 1 liter of water per hour may be needed to sustain a body. As a consequence, wilderness travelers often must drink water from natural sources. However, if such water is not properly treated, pathogenic microbes may be present, resulting in serious illness.

This fact is borne out each year as many people become ill, and some people die, from drinking unsafe water. People entering the backcountry risk infection if they drink untreated water from a spring, stream, river or lake, no matter how clean the water looks. Microorganisms that cause diseases are invisible to the human eye and cannot be detected.



Water borne outbreaks occur in backcountry as well as in city and rural environments. The most common reason for outbreaks is improperly treated water. Appendix B contains information on water borne outbreaks in the United States.

Water from backcountry sources is surface water. While it is true that most people who become sick from surface water do not die, water borne diseases produce painful symptoms. It will be an unforgettable experience for guests and/ or operators if they suddenly become ill with vomiting and/or diarrhea during a backcountry trip. Water borne pathogens come from many sources besides human fecal contamination. Deer, elk, sheep, beaver, muskrats and cattle may carry many of the waterborne disease causing agents. Water borne pathogens may also come from sources, such as discharges from wastewater treatment plants, septic systems, chemical toilets, or runoff after storms from ranch lands and town sites.

Without question, untreated surface water constitutes a health risk, and backcountry operators might incur liability if their clients become ill on a trip. Consequently, a backcountry operator must properly treat water for drinking, cooking, or other uses where it may be consumed. The following sections describe proper water purification methods.

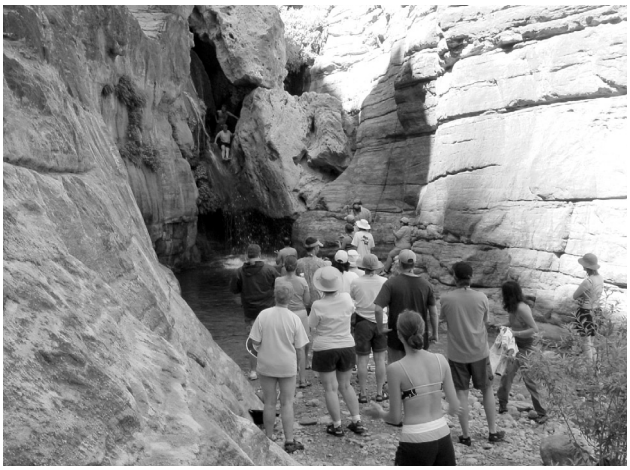
COLLECTION

Before water can be pretreated it must be collected, and care must be taken in selecting a water collection point. Microorganisms are concentrated in stagnant water, such as eddies along river or stream banks, and along lake shores where the water may be shallow and warm. These areas should not be used as collection points. It is equally important to avoid any body of water that has an algae bloom or has a strong "organic" odor as these types of areas may also contain higher concentrations of microorganisms.

The best places to collect water are from a "flowing" portion of a stream or lake, and as far away from a shoreline as possible. When collecting water it is important to be careful not to stir up sediment because microbes tend to be concentrated in sediments (11).

PRETREATMENT

It is important to pre-treat water if it is cloudy because sediment in the water will decrease the efficiency of a disinfectant. Sediment usually consists of small, suspended solids that may remain suspended without pre-treatment.



The best way to remove these suspended particles is to use a coagulant. A coagulant is an agent that, when added to water, attaches to suspended solids and forms small dense clumps called flocs so the sediment may collect at the bottom of a container.

A common coagulant used for water pretreatment is aluminum sulfate, which is also called "alum". The coagulant dosage is dependent on the sediment concentration, but usually is 5 to 90 milligrams per liter (mg/l), which is approximately 2 teaspoons of alum per 5 gallons of water[12]. After adding alum to water, the water must be allowed to settle for at least 30 minutes. A longer settling time may be required if there is excessive sediment in the water.

After the suspended solids have settled to the bottom, then the clear water must be gently poured into a clean, sanitized water container while taking care to keep the settled sediment in the bottom of the original container. If the container is bumped or the water is decanted from the container too quickly, the sediment may become re-suspended and the pretreatment process would have to be repeated.

POINT-OF-USE TREATMENT REQUIREMENTS

What is Required?

A backcountry operator is expected to provide safe water for guests. Frequently, it is necessary to utilize surface water during backcountry trips. Therefore, every effort must be taken by operators to properly treat water before it is consumed to prevent waterborne disease. If an operator allows guests to drink raw, untreated water, the result could be illness or even death especially for high risk individuals.

The federal government requires all surface water to be both filtered and disinfected to ensure removal of viruses, bacteria and parasites[13]. Boiling water is also an acceptable treatment method for backcountry operations. Currently, the federal government does not approve the use of UV disinfection. Research has not proven this method of disinfection to be effective.

Water Treatment

The primary organisms of concern in water are viruses, bacteria and parasites. All microorganisms invisible to the naked human eye. The average sizes of the microbes of concern are shown in Appendix C.

The federal government requires that these organisms be adequately removed or inactivated from potable water. Adequate removal or inactivation is shown in Appendix D.

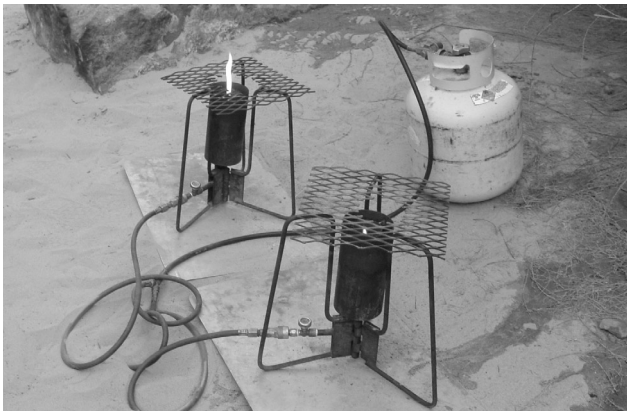
In order to achieve removal or inactivation of the microbes listed in Appendix D, the federal rule requires surface water be properly boiled, or filtered and disinfected, or provide water from an approved public drinking water system on a backcountry trip.

Water Purification by Boiling

Water boils at 212°F at sea level. However, as elevation increases both the atmospheric pressure and the boiling temperature decrease. To effectively kill pathogens in water, water must first be pre-treated, followed by boiling for at least one minute at sea level. For each thousand feet above sea level, an additional minute of boiling must be added, as shown in Table 2.

TABLE 2

Elevation in Feet	Boiling Time
Sea level	1 minute
1,000	2 minutes
2,000	3 minutes
3,000	4 minutes



Although boiling is the simplest method of water treatment, this method consumes a large amount of fuel. If there is not enough fuel to purify water for a trip, then water must be filtered and disinfected.

Water Purification by Filtration and Disinfection

Filtration

Both *Giardia* cysts and *Cryptosporidium* oocysts, which are two of the most commonly encountered parasites, are very resistant to normal concentrations of chemical disinfectants used to treat drinking water. Consequently, the most reliable method to remove these cysts and oocysts is filtration. Filtration is a process that removes contaminants by a physical process through pores. The cysts and oocysts cannot pass through the pores in the filter and are retained within the filter. During filtration, pretreated raw water is pumped from a reservoir through a porous material that separates contaminants from the water. Filters may be constructed of special media, fabric, or ceramic.

In order to achieve acceptable levels of removal of *Giardia* cysts and of *Cryptosporidium* oocysts (as shown in Appendix D) point-of-use filters must meet National Sanitation Foundation Standard (NSF) 53[13]. If a filter meets this standard, this should be indicated either on the label or in the manufacturer's specifications.

Disinfection

The disinfection process involves destroying pathogenic organisms including bacteria, viruses and fungi. Disinfection must occur after the filtration process. Filtration removes tough parasite cysts that are not destroyed by disinfectants, and disinfection destroys other smaller pathogens that may pass through a filter, such as bacteria and viruses.

The two most common disinfectants used to treat drinking water for backcountry operations are chlorine and iodine. Both of these disinfectants are members of the halogen family of chemicals. Halogen chemicals combine with hydrogen in water to form acids. These acids in turn are capable of destroying pathogenic microbes, and oxidizing organic debris (chemically removing impurities).

Chlorine

Chlorine is the most widely used disinfectant for water treatment. The most commonly available form of chlorine is household bleach, which contains approximately 5% to 6% available chlorine[16].

To disinfect water, the concentration of free available chlorine in raw water must be between 0.2 to 4.0 milligrams/liter (mg/l), or parts per million (ppm)[13]. A water test kit must be used to measure the concentration of the free available chlorine in water. After the proper concentration is reached, then the water with the free available chlorine (FAC) must be allowed to set for at least 30 minutes, which is known as the detention time or contact time. The concentration, along with the detention time, determines the germicidal efficiency of a disinfectant. This efficiency is shown in Appendix E.

If the exact concentration of the free available chlorine is not known, then the minimum holding time is 30 minutes to ensure destruction of pathogenic bacteria and viruses.

Typically, most backcountry operators will be disinfecting smaller amounts of water. The quantity is approximately 2 to 8 drops (is equal to 0.2 to 4 ppm of free available chlorine) of household bleach per gallon of water.

However, the effectiveness of free available chlorine to destroy pathogenic microorganisms is dependent on the presence of sediment and organic matter. Sediment shields microbes from the hypochlorous acid, and organic matter reacts with the hypochlorous acid to form disinfectant byproducts such as chloroform[13]. Hence, it is important to pre-treat surface water to remove as much sediment and organic material from water prior to treatment.

The temperature and pH of water also affects the effectiveness of free available chlorine. The pH is a measure of the degree of acidity or alkalinity of a solution. For chlorine to be effective, the initial pH level of the raw water must be between 6.5 and 7.6[16].

Iodine

Iodine is a halogen-compound like chlorine, and is commonly available in a liquid or tablet form at a concentration of 2%. However, unlike chlorine,

iodine is not an effective disinfectant against enteric viruses or pathogenic bacteria at pH values of 8.0 or above. Ideally, the pH of water that is to be treated must be 5.0 pH. In Table , the proper disinfection concentrations and detention time are shown[17]:

TABLE 5		
Iodine Concentration (mg/l or ppm)	Number of Drops of Iodine/gallon of water	Contact Time (minutes)
0.5 to 1.0	5 to 10	30

As with chlorine, it is important that water be pre-treated when iodine is used so that suspended solids and organic matter are largely removed prior to treatment. Otherwise, proper disinfection will not occur.

ODORS/TASTES CAUSES AND CONTROLS

Many tastes and odors that commonly occur in surface water are a result of decaying matter, such as vegetation, algae, bacteria, or wastes from industrial or municipal operations. Two commonly occurring compounds that have "earthy" odors are Geomin and 2-methylisoborneol (MIB), which are produced by certain algal growth. Unfortunately, Geomin and MIB are resistant to oxidizers like chlorine and iodine[13].

However, not all of the tastes and odors are naturally occurring. Some are linked to disinfectant byproducts. Water, when mixed with chlorine, may smell or taste moldy, earthy, stale, disinfectant-like, bitter, ammonia-like, bleach-like, or muddy[13].

There are numerous methods that may be used to control tastes and odors, however, many may not be convenient in a backcountry setting. A primary step to odor and taste control is to obtain water that is visibly clear, smells fresh, and avoid stagnant smelly water. Secondly, surface water needs to be pre-treated to remove as much sediment and organic matter as possible. Lastly, after the disinfectant is added and the settling time is completed, the batch of treated water may be "aired" by removing the lid of a water container for several minutes. This will allow some of the volatile chlorine byproducts to escape from a container before the water is consumed; however, care must be taken to prevent cross-contamination of treated water when the lid is removed.

WATER EQUIPMENT STORAGE AND CLEANING

It is equally important to make sure that water containers and attachments are properly cleaned and sanitized before, during and after use to prevent contamination. If an operator has gone to the trouble to select an appropriate water source, pre-treat, filter and disinfect the water, but he/she places it in a contaminated container, the contaminated container will negate all prior treatment.

It is essential that water containers and attachments, such as nozzles, tubes and lids are properly washed by the following process:

WASH - RINSE - SANITIZE - AIR DRY

The equipment must be washed with detergent in hot, clear water; rinsed in clear, hot water; sanitized with a chemical sanitizer approved by the Food and Drug Administration (FDA), such as chlorine and air dried. The temperature and pH of water determine the proper concentration of chlorine and contact time. The federal Food Code requires the following:

Chlorine			
Chlorine Concentration (ppm)	Contact Time (seconds)	Minimum Water Temperature	
		pH 10 or less	pH 8 or less
25	10	120°F	120°F
50	10	100°F	75°F
100	10	55°F	55°F

Quaternary Ammonia			
Quaternary Ammonia	Contact Time	Water Temperature	Water Hardness
200 ppm (or what manufacturer specifies	30 seconds	75°F	500 ppm or less

Iodine			
Iodine	Contact Time	Water Temperature	pH
12.5 to 25 ppm	30 seconds	75°F	5.0 or less

Storage

Water containers and attachments must be stored in a clean, dry place after they are washed and sanitized. Operators should avoid stacking water containers inside each other, unless they are thoroughly washed and sanitized before use. Other water equipment, like hoses and nozzles from water filters and lids from water containers, must be washed and sanitized before each use.

The nozzles and hoses from water filtration equipment may become contaminated during storage, transportation and use. Proper precautions need to be used to prevent this equipment from becoming contaminated while it is used, by preventing the hose or nozzle from coming into contact with dirt, untreated water, or other sources that may contaminate these surfaces.

The use of common sense, combined with a basic understanding of the scientific principals associated with water treatment, will result in a safer experience for everyone who experiences the backcountry.

QUIZ - WATER PURIFICATION

1. What are the safest places to collect water from surface water sources for treatment?
2. Explain why it is important to pre-treat water.
3. Name a commonly used coagulant.
4. How long must water set after a coagulant is added?
5. Why is it important to treat water prior to consumption?
6. What are the primary organisms of concern in untreated water?
7. How long would water have to be boiled to adequately disinfect at an elevation of 7,000 feet?
8. What two pathogenic organisms are removed by filtration?
9. How does free chlorine destroy bacteria and viruses?
10. Why is it critical to remove suspended solids in water prior to treatment?
11. At what pH level is iodine more effective?
12. What is the best procedure for removing turbidity?
13. What is the proper procedure to wash and sanitize water containers and attachments?
14. What is the proper concentration of chlorine to sanitize equipment if the water that is to be treated has a pH of 8.0 or less and a temperature of 55°F?

NOTES