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Water Disinfection in the Mountains

Intended for Doctors, Interested Non-Medical Persons and Trekking or Expedition Operators

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Content

1 Introduction

Travellers’ diarrhoea is arguably the most common and important health problem affecting travellers. The syndrome occurs in 20-70% of travellers to less developed regions, resulting in significant impairment of the victim’s activities, with nearly 40% changing their itinerary. Although contaminated food may be a more important risk factor for traveller’s diarrhoea than water the availability of safe water and knowledge of how to obtain it is a must for mountaineers worldwide to balance (high altitude) dehydration, to improve performance, and to minimize risks (e.g. frostbite, altitude diseases). In most cases the responsibility for obtaining and purifying water will be the mountaineer’s responsibility, because safe community based water resources are not available. This UIAA MedCom recommendation summarizes advantages and disadvantages of the several procedures with special regard to the situation in the mountains or at high altitude; and will advise mountaineers on how to prepare safe water while minimizing the environmental damage.

2 Definitions

- **“Safe water”** does not mean, that it is absolute sterile. Water is safe (=potable), if the concentration of germs is too low for any damage to human health (infection) to be expected.
- **“Disinfection”** is the killing or inactivation of germs which can induce infectious diseases.

  - We define **"regular methods"** for water disinfection as methods which provide water which is accepted to be safe.
  - **"Improvised methods"** do not provide safe water. These should only be used if no regular method is available for any reason
- **"Sterilization"** means that all germs were eliminated.
- **"Conservation"** (=preservation) describes procedures which avoid microbiological ruin of previously "safe", but sensitive products, e.g. the re-infection of water.

3 Principles to avoid water-borne diseases

- Maintaining good standards of hygiene when handling any kind of water, beverage, food, or human waste is the "Gold Standard"!
  - Do not substitute containers designed for water, beverage, or food for any other material! Severe poisoning has been reported, e.g. when fuel was carried in beverage bottles.
  - Keep any equipment, which may be in contact with food, water or beverage, clean! Wash your hands before handling water, beverage or food!
  - Human waste needs to be buried at least 30m from any water source to avoid further contamination of surface water.

- Minimize the amount of safe (treated) water needed first!
  - Determine which procedures can be done using untreated water (e.g. cleaning equipment, cleaning hands from heavy dirt etc.)?
  - Nevertheless, preparation of 4 – 5 litres of safe drinking water per person per day should be expected.
- If several procedures of water disinfection are available, always use the safest option!
  - Having good quality raw water to disinfect improves the safety of procedures and preserves the equipment. Rainwater sampling may be an option to get good raw water.
  - The preferred "regular procedures" for disinfecting water are listed below.
  - "Improvisation methods" (see below) should be used only if regular methods cannot be performed for any reason. These methods do not provide safe water, but they reduce the concentration of germs significantly and therefore they statistically reduce the risk of waterborne diseases.
- Preconditions essential for the personnel disinfecting water:

- Only trained persons should act and decide which procedure of those available should be used. Severe problems (group infections) were reported after water disinfection by incompetent persons!
- A demonstration to all the group members should be performed by those in charge of water disinfection. This should be followed the group's supervised participation in water disinfection procedures before water disinfection at one's own risk - is performed.

4 Regular methods for water disinfection

In the mountains, there is no method available which is absolutely free of any failure. Sound knowledge of a variety of water disinfection methods is a must. While relatively safe water is available in some global regions (e.g. northern Europe, or water which was directly obtained from a high volume spring), some procedure of disinfection is necessary for most regions of the world. If it is planned to store disinfected water for more than one day, a procedure for conservation (ie storing this water) should follow disinfection (see below).

4.1 Boiling

- **Principles:** Although the temperature of boiling water at altitude is lower than at sea level, boiling kills all enteropathogenic germs except Hepatitis A virus and therefore it produces safe water (Hepatitis A infection at high altitude is very rare. Nevertheless travellers should be vaccinated against it). **Note:** There are significant differences of the temperature necessary to kill Hepatitis A viruses given in literature. The commission decided to be on the safe side and excluded this virus from the list of germs which can be effectively killed by simple boiling and suggest hepatitis A vaccination. The topic will be monitored.
- **Procedure:** Water should boil with bubbles in it for at least one minute.
- **Advantages:** Simple method, (nearly) no failure.
- **Disadvantages:** Time and fuel consuming procedure with 1 kg wood necessary to boil 1 litre of water. Fuel must be carried to the mountains or taken locally from them, which contributes to deforestation. Therefore other procedures are preferred in any situation where liquid water is available.
- **Additional remarks:** To optimize procedure safety, all expedition members should be vaccinated against Hepatitis A.

4.2 Chemical disinfection

- **Principles:** Chemicals destroy the germs. Sodium hypochlorite or calcium hypochlorite are the most important compounds of commercially available products for travellers. Pure iodine or iodine containing substances should not be used because of possible side effects.

- **Procedure:** A sufficient amount of disinfectant must be added to the water. Shake well for homogeneous distribution of the disinfectant. Wait for appropriate disinfectant time as given by the instructions of the disinfectant. Careful warming of the water (at about 25-30°C) shortens the time necessary for disinfection (about half the time for any +10°). **Note:** At the end of the time necessary for disinfection the product should taste a bit of chlorine. Otherwise there was not sufficient disinfectant added before. Add the same amount of disinfectant as before and wait the same time for disinfection.
- **Advantages:** Can be used immediately at any place and at any time where liquid water and disinfectant is available. No fuel available, therefore no contribution to deforestation.
- **Disadvantages:** Time consuming and a bit tricky. Several failures possible, e.g.
    - Pure chlorine (or iodine) is not a sufficient disinfectant for Giardia, Cyclospora, and Cryptosporidium (only safe with very high concentrations of chlorine) as well as for eggs and larvae of several parasites.
    - If used for cold water the disinfection time must be increased, e.g. quadrupled for water at +2-5°C. Alternatively the concentration of disinfectant could be increased. This impairs the taste of the water.
    - If used for water containing organic material (e.g. algae in water from small lakes) the amount of substance used for disinfection must be increased (doubled).
    - In contrast to common belief pure silver ions do not disinfect water sufficiently, but they conserve clean water for up to 6 months. Be careful: Too high concentrations of silver ions cause pitting corrosion in aluminium containers.
- **Additional remarks:** The taste is impaired by chemical disinfection (especially if high concentrations were used to cope with cold conditions or organic material). This can be neutralized by adding one knife point of vitamin C powder per litre, added after disinfection is completed.

Note: The Medical Commission is aware of the marketing of UV sterilization systems and will be reviewing their use when more data are available. The commission is also keeping matrix filters under review.

4.3 Filtration

- **Principles:** Germs are eliminated by several physical characteristics like their size relative to the filter's pores, or hydrophobic or electrostatic interaction between the germ's surface and the filter material. Small particles (e.g. viruses) will be partially removed due to agglomeration.
- **Procedure:** Water will pass through any material with a pore size of 0.2 μm or smaller.
- **Advantages:** Relatively simple procedure for trained persons, but the equipment must be handed with care (ceramic material may break)! Large amounts

of water (for bigger groups) can be produced easily with a filter of appropriate size where liquid water is available.

- **Disadvantages:** Ceramic filters are high-tech products with construction-dependent advantages and disadvantages. Therefore detailed knowledge about the filter type used is a "must" for any user. No filter system used as single method produces safe water, because viruses are not completely removed. Therefore combine it with chemical disinfection to combine the advantages of both methods which will compensate for the disadvantage/s of the other method. Clogging is a frequent problem. Do not increase pressure for filtering! This may press germs through the system and contaminate your water. Instead clean the ceramic's surface! This should be performed only by persons trained with the system. Do not forget to dispose the first cup of water filtered after the system was maintained to be sure that the "safe side" of the filter system is clean.
- **Additional remarks:** A simple coffee filter should eliminate eggs and larvae of several parasites. Therefore a combination of a coffee filter and chlorine, which does not inactivate these germs, but bacteria and viruses, is an extremely practical method to produce safe water in the mountains. The clearer the water to be filtered, the longer the filter can be used without brushing the ceramic surface. If no clear water is available, it is useful to let the water "rest" in a bucket to settle most of the particles before filtering. Any filter system without charcoal included will not remove dissolved substances (even with charcoal included the effect is questionable and there are no data available). Avoid water which might be polluted by industry (old mines in the mountains) or agriculture (pesticides) where the approach to the mountain passes is farmland!

5 Improvisation of water disinfection

Mountaineers or trekkers may be confronted with situations where disinfectants wanted are out of stock, or ceramic filters are broken. They then need to improvise water disinfection methods as well as the circumstances allow. **Note:** Any improvisation in the process of water disinfection should be used only in case where regular methods are not available ("survival situation"). It must be pointed out that these methods do not produce safe water, but by decreasing the number of germs they decrease significantly the risk of waterborne diseases.

5.1 Sand

- **Principles:** This simple filter method eliminates effectively larger germs like Giardia cysts, or eggs or larvae of several parasites (helminths). It should be (relatively) effective against Vibrio cholerae as well, because this germ tends to agglomerate with organic material. Other bacteria and viruses will not be eliminated.
- **Procedure:** Cut a very small hole (4-5 mm in diameter) into the bottom of a container (plasic bag, bucket…), and fill it with fine sand.

- **Advantages:** Simple any easy method, can be used for larger amounts of water (e.g. for groups).
- **Disadvantages:** Due to the several variables involved in this method, an overall effectiveness of this survival method cannot be given, but compared to charcoal filtration (see below) a pure sand filtration is less effective.
- **Additional remarks:** The finer the sand, smaller the hole, a minor water flow rate will all act to improve the filtration effect. If possible, sand filters, as well as any other method described below, should be combined with chemical disinfection.

5.2 Charcoal

- **Principles:** Refer to "Sand". Additional advantages: reduction of chemical contamination, of bacteria and (less effective) of viruses by adhesive effect of the charcoal's surface.
- **Procedure:** A container (plastic bag, bucket…) can be filled with charcoal which is obtained by a normal fire and then crushed. If the container has a small hole (about 4-5 mm in diameter) water, which was filled inside the container flows out here after being filtered by the adhesive effect of the charcoal. The smaller the hole, the minor the flow and the better the filtration effect.
- **Advantages:** Simple any easy method, can be used for larger amounts of water (e.g. for groups).
- **Disadvantages:** As mentioned for pure sand filters an overall effectiveness for charcoal filtration cannot be given.
- **Additional remarks:** If some small pebbles were placed in the bottom layer of the container first, followed by a layer of fine sand, no pieces of the charcoal would be carried into the filtered water. Some fine sand followed by a layer of pebbles on top of the charcoal will prevent the charcoal from "floating" when water is added to the container. To provide best possible safety in this method the charcoal should be replaced every four days.

5.3 Optimized sand-charcoal-filter

- **Principles:** The combination of sand and charcoal filtration
- **Procedure:** Several layers combine their filter effect and prevent the charcoal from floating. The system is shown in Figure 1.
- **Advantages:** Compared to pure sand or charcoal filtration the combination improves efficacy and safety. Simple any easy method, can be used for larger amounts of water (e.g. for groups).
- **Disadvantages:** As mentioned above an overall effectiveness cannot be given.
- **Additional remarks:** The system can also be used for pre-filtering of muddy water to prevent muddying of ceramic filters (see above). As mentioned for

pure charcoal filtration the system should be replaced every four days to keep the procedure as safe as possible.

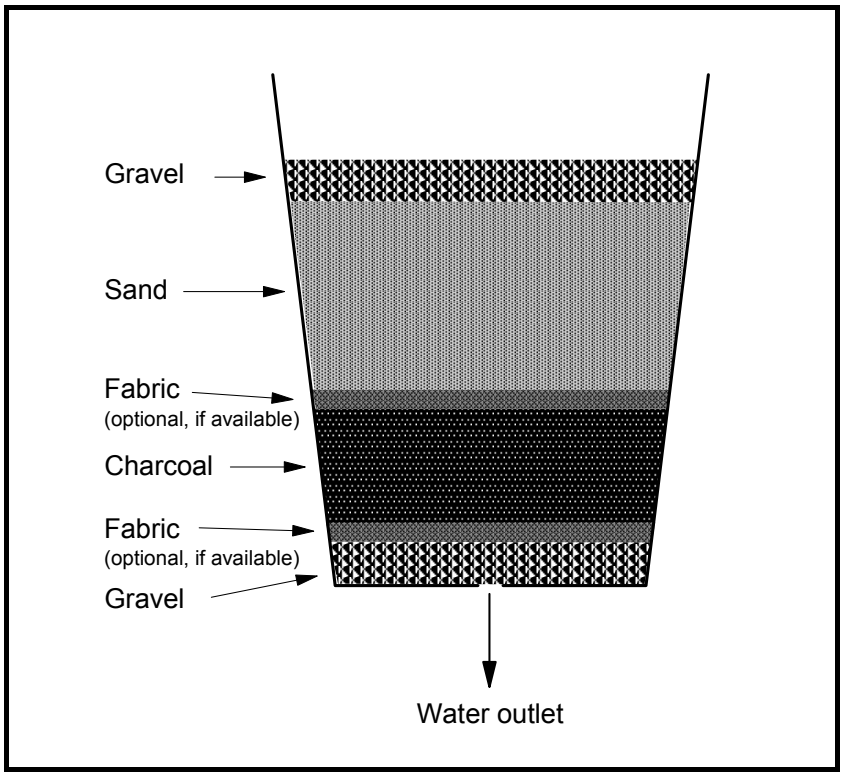

Figure 1: Optimized layering of charcoal – sand – filter

5.4 Textile filters ("Sari filter")

- **Principles:** The procedure eliminates effectively larger germs like Giardia cysts, or eggs or larvae of several parasites (helminths). It was proven to be effective against Vibrio cholerae as well, because this germ tends to agglomerate with organic material and the agglomerates exceed the critical diameter of the textile's pores.
- **Procedure:** Filter water through several layers of tightly woven textile material.
- **Advantages:** Simple method. Can be used for larger amounts of water (e.g. for groups).
- **Disadvantages:** As mentioned for pure sand filters an overall effectiveness for charcoal filtration cannot be given. For V. cholerae a reduction of 99% of the germs was reported.
- **Additional remarks:** The tighter the textiles, the better the filter effect. Therefore older textiles, which are matted, are more effective than new ones. The procedure is of special importance in community based health projects in developing countries.

6 Other Methods

6.1 Ozone

Ozone systems are too heavy and too big to be carried along while travelling or climbing. But they provide safe water for tourists and locals in several regions of the world (e.g. Annapurna Circuit).

6.2 UV light

As said above for ozone such systems which are fixed installed at several locations worldwide provide safe water fo locals and tourists. This is different for mobile systems (e.g. SteriPen). Since there are no papers available where details about handling and safety has been investigated and while there is a specific study in progress (Timmermann L. et al.) the commission decided not to give a recommendation until sufficient data are available except to use such systems with caution. Wherever regular methods (see above) are available such procedures are the methods of first choice.

7 Insufficient methods

7.1 Potassium permanganate

Potassium Permanganate ($KMnO_4$) cannot be used to produce safe water or food. If used in concentrations which do not change the taste of the product, it is insufficient so that it simply cannot be recommended anymore. An additional side effect is that it will change the colour of the tongue and teeth to brown.

7.2 Hydrogen peroxide

Hydrogen peroxide (H_2O_2) is effective against bacteria. But the substance is very unstable and disintegrates quickly. Therefore adequate concentrations cannot be guaranteed when used in the mountains. Hydrogen peroxide is not effective against viruses and its potential against protozoa is unknown.

8 Conservation of safe water

Any stored water can become contaminated and unsafe again if it is stored for hours or days (depending on the temperature) and there is no residual disinfectant. Therefore a conservation method is useful to implement. **Silver ions**, which inactivate some bacteria, but which have the special advantage of blocking bacterial growth, preserve clean water for up to 6 months. Compared to silver ions chlorination, it is less stable and its effect lasts much shorter (1 – 2 days, depending on temperature). Of course, clean containers are a prerequisite. Many products commercially available contain both, hypochlorite and silver, and therefore they fit with any water problem in the mountains, except cysts and eggs of parasites, which can be easily filtered (see above).

9 Special recommendations for commercial mountaineering or guided groups

While mountaineers are responsible for themselves, any organization which offers mountaineering, trekking tours, or expeditions to clients, will have special responsibility for their clients. This responsibility is defined by law. The following principles are according to European law, but other countries have similar or nearly identical regulations.

In case of organized mountaineering, trekking, or expedition the production of safe water is in the responsibility of the trekking organization. This responsibility is strictly defined by law. It should be an integral part of the organization's safety concept, e.g. as standard operation procedure (SOP). The most important regulations the organization must know and respect are as follows:

- Water, which is indented for human use, may not contain pathologic germs in concentrations, which might cause an impairment of human health.
- Water, which does not meet the quality criteria for safe water, must be processed until it meets this criteria
- The law forbids, and will prosecute those individual/s who produce drinking water for other people in a way that human health may be impaired. Any entrepreneur or owner of a water supply installation, who provides water as drinking water for others, which does not fulfil the criteria, can be prosecuted in term of imprisonment for up to two years or fined according to the laws of the country. Any entrepreneur or owner of a water supply installation can be prosecuted as well, if he adds additives like chlorine above the concentration stated by law. **Note:** In contrast to U.S. regulations it is forbidden by European law to add iodine to water which shall be used for drinking!
- "Water supply installation" in the meaning of the laws is any apparatus or procedure from which drinking water will be obtained, including any point-of-use system, e.g. any system used during the trip.

10 Overview about the procedures mentioned above

Procedure	Safe for				Remarks
	viruses	bacteria	Cysts (giardia, amoebic) & eggs of helminths	Cryptosporidium	
Boiling	+[1]	+	+	+	Fuel consuming / deforestation
Chemical disinfection[6]	+	+	(+)	+[2]	May be critical if water is very cold or contains organic substances[7]
Ceramic filter	(+)[3]	+	+	+[4]	Type specific failures / limitations
Chemical disinfection + ceramic filter	+	+	+	+[2,4]	The only absolute safe procedure at high altitude
Sand filter	-	(+)[3]	(+)[5]	n.d.	Fine sand and low flow necessary
Charcoal filter	-	(+)[3]	(+)[5]	n.d.	Low flow necessary
Sand + charcoal filter	-	(+)[3]	(+)[5]	n.d.	Fine sand and low flow necessary
Textile filter	-	(+)[3]	(+)[5]	n.d.	The tighter the textiles, the better the filter effect

(+: safe; (+): safe with some limitations, see footnotes; -: not safe; n.d.: no data available)

Footnotes:

[1]: **Note:** Hepatitis A may not completely inactivated, but the procedure is safe for mountaineers vaccinated against Hepatitis A (for details see text)
[2]: high ct constant necessary
[3]: not safe, but reduces concentration of germs
[4]: pore size < 1µm necessary
[5]: "nearly safe" (up to 100% elimination of germs, but a total remove of cysts and eggs cannot be guaranteed)
[6]: with (hypo-) chloride
[7]: Longer disinfection time or higher concentration of disinfectant necessary (for details see text)

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History of this recommendation paper

As many mountaineers have deficiencies in their knowledge of this topic, or have expressed a desire to learn more, the UIAA MedCom decided to establish a special recommendation on this topic at the meeting at Snowdonia in 2006. The version presented here was approved at the UIAA MedCom Meeting at Adršpach – Zdoňov / Czech Republic in 2008.

The recommendation was updated in 2012 and approved at the annual meeting at Whistler / Canada in July 2012.