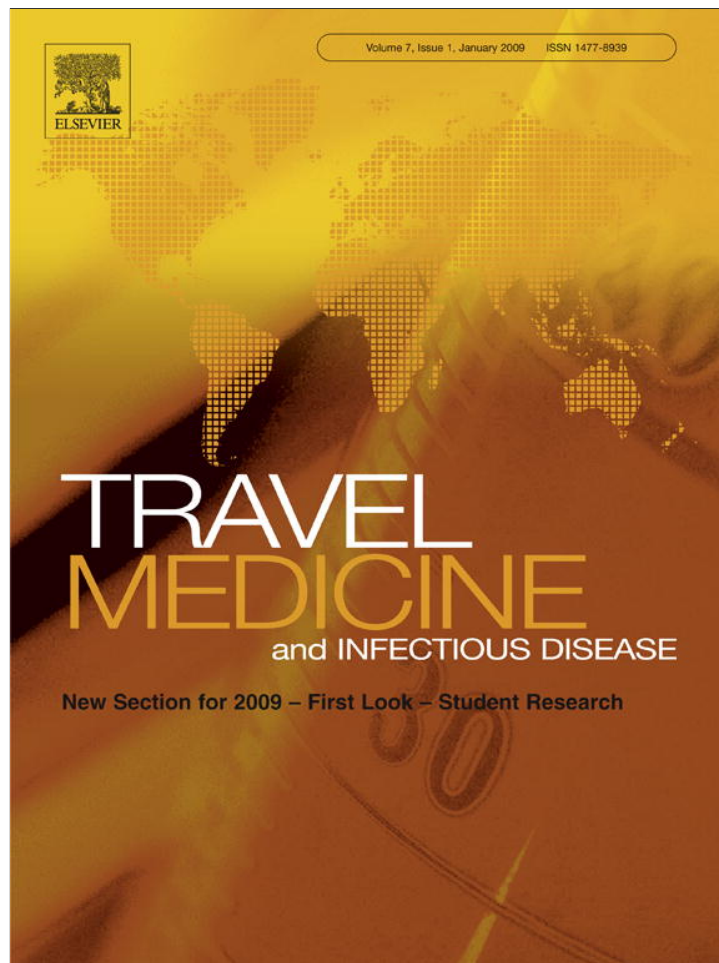


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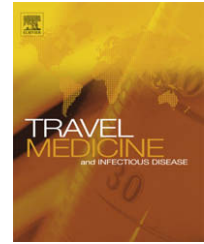


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## REVIEW

# Water disinfection in the mountains – state of the art recommendation paper of the Union Internationale des Associations d'Alpinisme Medical Commission

Thomas E.A.H. Küpper <sup>a,\*</sup>, Volker Schöffl <sup>b</sup>, Jim S. Milledge <sup>c</sup><sup>a</sup> *Institute of Occupational and Social Medicine, Aachen Technical University, Pauwelsstr. 30, D-52074 Aachen, Germany*<sup>b</sup> *Department of Trauma and Orthopaedic Surgery, Klinikum Bamberg, Germany*<sup>c</sup> *University College London, Great Britain, UK*Received 6 July 2008; received in revised form 6 November 2008; accepted 17 November 2008  
Available online 12 December 2008**KEYWORDS**Mountaineering;  
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**Summary** This paper provides the official recommendation of the Union Internationale des Associations d'Alpinisme (UIAA) Medical Commission to manage the problem of safe drinking water. The recommendation was accepted and authorized for publication by the Medical Commission during their annual meeting at Treplice, Tzechia, 2008. Safe water is essential for mountaineers worldwide in order to balance challenges associated with high altitude dehydration. The paper summarizes the advantages and disadvantages of several procedures used to procure safe drinking water in the mountains or at high altitude. Limitations or critical details, which may cause failure of the methods are mentioned systematically. We differentiate between "conventional" methods, which should be preferred because they produce safe water and "improvisation". The latter does not produce safe water but may be used if conventional methods are not available for any reason. They decrease the concentration of pathogenic microorganisms and by this they reduce the risk of enteral infection.

Water filtration using a ceramic filter system or chemical disinfection is recommended as a standard method. Boiling water should be avoided because it is too fuel consuming and has the potential to increase deforestation.

Generally, with regard to infections by water or food, all mountaineers should be vaccinated against hepatitis A and poliomyelitis in regions where they may be at-risk.

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\* Corresponding author. Tel.: +49 (0)1520 1820256; fax: +49 (0)3222 1485489.  
E-mail address: [tkuepper@ukaachen.de](mailto:tkuepper@ukaachen.de) (T.E.A.H. Küpper).

## Introduction

Travellers' diarrhea is arguably the most common and important health problem affecting travellers.<sup>1</sup> This syndrome occurs in 20–70% of travellers to less developed regions of the world.<sup>2–4</sup> This results often in significant impairment of activities with nearly 40% of victims changing their itinerary.<sup>1,5</sup> Although contaminated food may be a more important risk factor for travellers' diarrhea, the availability of safe water and the knowledge of how to obtain it is essential for any mountaineer, trekker, or hiker. The UIAA Medical Commission recommendations given below are based on an extensive literature review which included international databases such as Medline as well as standard handbooks on travel medicine and altitude medicine. The regulations given by law are based on official publications of German authorities which are in full accordance with European Union (EU) standards.

For mountaineers a balanced hydration of the body is of special importance due to altitude dehydration, the need to humidify the inspired air (although the loss is less than estimated previously<sup>7,8</sup>), and because of the need to improve performance and to minimize the risk of thromboembolic incidents or frostbite. Although the relationship between hydration and performance is not yet completely understood, there is a general consensus in alpine medicine that an adequate hydration status is strictly recommended for mountaineers. By increasing viscosity of the blood and thereby hampered peripheral flow a fluid loss of 2% of total body weight causes a significant loss of performance (about 20%).<sup>9,10</sup> This loss of performance is comparable to an additional ascent of 1,500 m.<sup>11–14</sup>

Reduced fluid intake is correlated with incidence and degree of acute mountain sickness (survey in<sup>15,16</sup>), as well as loss of fluid. For example, there are several cases where acclimatized mountaineers developed acute mountain sickness due to diarrhea induced dehydration instead of further ascent.<sup>17,15</sup> Dehydration has an additional performance decreasing effect hot environments. If the mountaineer is climbing in a hot environment, any percent loss of body weight by dehydration causes an increase of the core temperature of 0.1–0.4 °C.<sup>18</sup> In consequence, this will result in an increased risk of heat related diseases.

In principle, all methods of water disinfection aim to reduce or eliminate pathogenic microorganisms because the risk of water borne illness depends on the number of microorganisms consumed.<sup>4,19,20</sup> Unfortunately, some organisms such as hepatitis A, shigella, giardia, and others cause illness even if consumed in small numbers.<sup>4,19,20</sup> Therefore, the safest procedure possible should be used at all times to produce drinking water. The "improvisation methods" mentioned below are directed at "survival situations" where standard procedures are not available but a risk of infection is possible. For mountaineers this situation does not transpire typically at high or extreme altitudes. Instead, it is present in valleys or on lower slopes where humans or cattle reside above. It must be mentioned that even small dosage consumed by the inadvertent drinking of water while swimming in a pool or while taking a shower with unsafe water can result in symptomatic infections by Norwalk viruses, hepatitis A, shigella, giardia,

and others.<sup>4,19,20</sup> Therefore, this recommendation assumes that the mountaineer is vaccinated against microbiological organisms introduced orally, where a vaccination is available and where there may be a risk in the target region (e.g. hepatitis A, polio, typhoid fever).

In many mountain environments, safe water is not available and the mountaineer or the organizing company is responsible for the production of safe water. Minimize the amount of safe (treated) water needed first. Check first, which procedures can be done with untreated water (e.g. cleaning equipment, cleaning hands from heavy dirt etc.). Nevertheless, there is a need for the production of 4–5 l of safe drinking water per person per day. Do not forget to disinfect any item to produce or to store your safe water first.

There are several methods such as reverse osmosis, granular activated charcoal, and ozonisation that produce safe water. However, they may be difficult to use while mountaineering because they often require special or heavy equipment. Therefore, these methods are not included in this recommendation. Nonetheless, it should be mentioned that in some regions such as the Annapurna Circuit and the Khumbu Valley, there are community based projects and safe water stations that provide large amounts of safe water by ozonisation. This infrastructure should be used where available.

## Definitions

**Safe water:** water is potable if the concentration of pathogenic microorganisms is too low for any damage or infection to be expected.<sup>21</sup> Safe water does not mean that the water is absolutely sterile.

**Disinfection** is the killing or inactivation of microorganisms which can induce infectious diseases.<sup>19,20,22</sup>

**Sterilization** means that all microorganisms are eliminated.

**Water conservation:** describes processes that avoid microbiological contamination of previously safe but sensitive products such as the re-infection of water.

## Regular methods of water purification

In the mountains there is no absolute method that is free of any failure. Therefore, knowledge of any water purification method is a must. While conservation may only be adequate for some 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 planning to store disinfected water for more than one day, water conservation procedures should follow disinfection to avoid re-growth of remaining microorganisms (see Section [Chemical disinfection](#)). "Regular methods" are defined as methods which provide water which is accepted to be safe. Section [Improvisation of water disinfection](#) (improvised methods) summarizes methods which should be used if no standard method is available. [Table 1](#) provides an overview of the procedures described below.

## Boiling

The temperature of boiling water at altitude is lower than at sea level. Although many microorganisms will be killed at

**Table 1** Characteristics of procedures for water disinfection.

Procedure	Safe for				Remarks
	Viruses	Bacteria	Cysts ( <i>Giardia</i> , amebic) & eggs of helminths	<i>Cryptosporidium</i>	
Boiling	+	+	+	+	Fuel consuming/ deforestation
Chemical disinfection <sup>a</sup>	+	+	(+)	+ <sup>b</sup>	May be critical if water is very cold or contains organic substances <sup>c</sup>
Ceramic filter <sup>d</sup>	(+) <sup>e</sup>	+	+	+ <sup>f</sup>	Type specific failures/ limitations may become clogged, need to clean
Chemical disinfection + ceramic filter	+	+	+	+ <sup>b,f</sup>	The only absolute safe procedure at high altitude
Sand filter	–	(+) <sup>e</sup>	(+) <sup>g</sup>	n.d.	Fine sand and low flow necessary
Charcoal filter	–	(+) <sup>e</sup>	(+) <sup>g</sup>	n.d.	Low flow necessary
Sand + charcoal filter	–	(+) <sup>e</sup>	(+) <sup>g</sup>	n.d.	Fine sand and low flow necessary
Textile filter	–	(+) <sup>e</sup>	(+) <sup>f</sup>	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).

<sup>a</sup> With (hypo-) chlorite.

<sup>b</sup> High ct constant necessary.

<sup>c</sup> Longer disinfection time or higher concentration of disinfectant necessary.

<sup>d</sup> (or other filters with pores <0.2 µm).

<sup>e</sup> Not safe, but reduces concentration of microorganisms.

<sup>f</sup> Pore size <1 µm necessary.

<sup>g</sup> "nearly safe" (up to 100% elimination of most microorganisms, but a total remove of cysts and eggs cannot be guaranteed).

lower temperatures, water should boil with bubbles.<sup>4,20</sup> This procedure kills all microorganisms and therefore produces safe water up to extreme altitudes since even at 8,900 m, water boils at about 70 °C (most enteric pathogens are destroyed at temperatures of 55–80 °C<sup>4,20</sup>). However, boiling is a time and fuel consuming procedure with 1 kg wood necessary to boil 1 l of water.<sup>4</sup> Fuel must be carried to the mountains or taken from them which in turn may contribute to deforestation.<sup>4</sup> Therefore, other procedures are preferred when liquid water is available. Boiling, however, is the easiest and safest method where fuel is available and plentiful.

### Chemical disinfection

There are at least four critical points related to chemical disinfection:

1. Pure chlorine and iodine are not efficient disinfectants. Notably, *Giardia*, *Cyclospora*, and *Cryptosporidium*<sup>20,23,24</sup> as well as eggs and larvae of several parasites can still be transmitted in chlorinated water.<sup>6</sup> Theoretically, these organisms can be killed by chlorine but only if a high concentration–time constant (Concentration × time = (ct) constant) is realized. This can be achieved by additional heating or by high chlorine

concentrations but both are not realistic in the mountains due to reasons such as fuel and time constraints. Additional problems are caused because the ct constant necessary to eliminate giardia does not depend on the germicide's concentration. Instead, it depends on the concentration of microorganisms because with a large number of organisms, more are likely to remain after a given proportion are killed.<sup>22</sup>

2. Despite some evidence that pure silver ions have disinfecting potential, pure silver ions should not be used because it is too difficult to control the residual concentration. But they conserve clean water for up to 6 months.<sup>21</sup> It should be noted that too high of concentrations cause pitting corrosion of aluminium containers.
3. If used for cold water the disinfection time (contact time) must be increased.<sup>20</sup>
4. If used for water containing organic material such as algae in water from small lakes, the amount of substance used for disinfection must be increased (doubled).<sup>20</sup>

The effect of chlorine does not only depend on the concentration of the disinfectant, but also on the contact time (ct constant). It is important to use the manufacturer's recommendations for the individual disinfectant as

standard operation procedure which has to be followed strictly. Most of these recommendations are based on a water temperature of 20–25 °C. An increase of 10 °C in the water temperature reduces the ct constant to slightly less than a half of its previous value, whereas a decrease of 10 °C increases the ct constant to just over double.<sup>25</sup> For example: If water must be disinfected at +2 to 5 °C (e.g. water from glacial creeks or melting snow), either the contact time has to be quadrupled or the concentration of the disinfectant increased.<sup>22</sup> In any case some additional time should be given to have a margin of safety. Another theoretical option would be to warm the water. This should be avoided in the mountains, however, to minimize fuel consumption. If the water smells like chlorine at the end of the disinfection, a sufficient amount of disinfectant was used. If there is no smell of chlorine at the end of disinfection, add the same amount of disinfectant as used before again and wait the same time for disinfection.

Because high concentrations of disinfectant change the taste of the water significantly, the standard procedure in the mountains is the first alternative or a combination where the disinfectant's concentration is increased to a maximum of twice the concentration of the manufacturer's recommendation. Alternatively, the taste of chlorine as well as of iodine can be neutralized by vitamin C.<sup>20</sup> The amount necessary is about one knife point of vitamin C powder per litre of water, but the exact amount is not critical. Of course it should never be added before the disinfection time has passed. The ct constant is less critical in the tropics where the water temperatures are normally higher than in non-tropical destinations where the source of water is from cold torrents, snowfields or glaciers.

Commercially available products contain sodium hypochlorite or calcium hypochlorite. They are available as tablets or as liquid. Liquid has the advantage of perfect management of chlorine concentration (see above) for any amount of water to be disinfected.

Before hypochlorite products were available, iodination was often used and still can be used for water disinfection. Iodine is less inactivated by organic material in water and it protects against protozoa and their cysts (except *Cryptosporidium*), but as mentioned for chlorine a high ct constant is necessary.<sup>22,25</sup> Iodination procedures are published with a ct constant between 25 (water temperature 25 °C) and 80 (water temperature 23 °C).<sup>22,25</sup> With most procedures designed to reach an iodine concentration of 8 mg/l the microorganisms will be destroyed after a contact time of 10 min. If water is heavily contaminated, iodine concentrations of 16 mg/l are recommended by some investigations.<sup>25</sup>

There are several procedures to iodinate water, but some cannot be recommended because they do not provide an appropriate iodine concentration or cause bad taste (e.g. iodinated filters where contact time is too short, tincture of iodine (2% iodine plus 2.4% sodium iodide in ethanol), Lugol's solution (5% iodine plus 10% potassium iodide in water), or iodine solution obtained by Kahn–Visscher procedure<sup>26</sup>). The easiest and most reliable procedure is a solution of 8 g of iodine in 100 ml of ethanol. Two drops of this solution (approximately 0.1 ml) provides a final iodine concentration of 8 mg in one litre of water. Another possibility is 4 drops of *Tincturii jodii officinalis* 2%

(dilution of iodine in ethanol 96% with a final concentration of iodine of 2%) in one litre of water.

There is general consensus in the literature that there is no substantial risk for healthy people with normal thyroid function including pregnant women, if they drink water with an iodine concentration of 8 mg/l.<sup>25</sup> The principal problem is that there may be occult thyroid disease, which may be of special importance in cases of (previously unknown) pregnancy.<sup>22,20,19</sup> Therefore, any iodine intake should be strictly avoided without medical supervision and any thyroid disorder should be diagnosed before. By European law it is forbidden to use iodine for water disinfection.<sup>27</sup> This is in contrast to the United States where the use of iodine is very popular despite the fact there are approximately 15 million adult U.S. citizens with unrecognized thyroid disease<sup>28</sup> and a proportion of 2.4% of persons >60 years are affected.<sup>29</sup> If the benefits and risks of chlorination and iodination are compared, chlorination with modern hypochlorite products is preferred.

## Filtration

### Simple filters (pores > 0.5 µm)

A simple coffee filter should eliminate eggs and larvae of several parasites (helminths) and Cyclops, a small copepod which transmits dracunculosis.<sup>4</sup> Therefore, a combination of a coffee filter and chlorine is an extremely practical method to produce safe water. The smaller the pores of a filter, the safer the water and improved chance of removing small microorganisms removed. However, *Cryptosporidium* oocysts are still a problem for some filters. For example, in one study the rate of removal of *Cryptosporidium* oocysts was 99.9% while those of viruses was 99.99% and of bacteria 99.99%.<sup>30</sup> This may result from other effects such as a combination of hydrophobic and electrostatic interaction of the virus' surface with the filter material rather than size.<sup>31</sup> It is important to remember that *Cryptosporidium* does not only occur in tropical countries as most surface water in Europe and the U.S. contains it.<sup>32</sup> Coffee filters as a single method should be used as a "survival method" only.

### Sophisticated filters (pores < 0.5 µm)

Filters with pores <0.2 µm (e.g. ceramic materials) impede the passage of most bacteria, protozoa, and helminths, while those with pores <0.5 µm remove protozoa, cysts of *Entamoeba histolytica* and helminths but not bacteria. Although most viruses are smaller than 0.2 µm, the concentration of viruses will be decreased by 0.2 µm-filters because of several physical effects, especially agglomeration of microorganisms and other material. However, even the best ceramic filters designed for travelling are not completely safe for viruses. To provide this, filtration should be combined with chemical disinfection (which in contrast to filters may not remove all protozoa). Although *Cryptosporidium* cysts are much larger (2–6 µm in diameter) there are data suggesting that water must be filtered with pores of less than 1 µm to remove them completely.<sup>33</sup> If filters are used as single method, all users should be vaccinated against hepatitis A and polio in regions of where there is a polio, even if the system provides pores <0.2 µm. Although there are no data for mountaineers, it should be

noted that there is a risk for hepatitis E in some Asian countries.

Ceramic filters with pores of  $<0.2\ \mu\text{m}$  are available for small and large amounts of water which is appropriate for individuals as well as for groups. However, sometimes these filters need servicing as clogging is a frequent problem that is remedied by brushing the filtering surface. If clogged filters are used higher pressure is necessary to pump the water through it. This may cause pathogenic microorganisms being pressed through the filter resulting in filtered but still unsafe water.<sup>22</sup> 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 particulate material before filtering. This sedimentation procedure minimizes clogging. Alternatively, it is also possible to add 10–30 mg alum or calcium oxide per litre of water to clarify it by coagulation–flocculation.<sup>22</sup> Use more alum or calcium oxide if the water is very cloudy. As well, stir or shake it briskly for 1 min, then agitate gently and frequently for at least 5 min. After letting the water settle for at least 30 min, the water must be carefully decanted or poured through a cloth or paper filter.<sup>22</sup>

Depending on the construction of the filter, the systems will give 0.5–5 l/min. of clear water. In cold environments, ceramic filters which are not completely dry after use may be damaged by freezing. The manufacturer recommends maintaining the filter warm by placing it in a sleeping bag during the night.<sup>34</sup> It must be pointed out that ceramic filters are high-tech products with construction-dependent advantages and disadvantages (survey in<sup>22</sup>). Therefore, detailed knowledge about the filter type used is a "must" for any user.

Some systems use a dense material from hollow fibres for filtering. The manufacturers report pores of  $0.2\ \mu\text{m}$  in diameter. This would be enough to remove all microorganisms except viruses. However, in contrast to ceramic filters, these fibre systems cannot be cleaned easily when muddying occurs. Therefore, these systems have an advantage if clear water such as unsafe tap water has to be treated because they provide a higher flow (1–6 l/min.) and a total lifetime up to 20,000 l. Recently, special fibre filters available which should remove viruses have become available. It is important to be cautious and check the exact specifications of the type used.

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. As a consequence: avoid water which might be polluted by industry (old mines in the mountains) or agriculture (pesticides) where approach to the mountain passes farmland.

Note: There are many filter systems available on the markets worldwide which are not appropriate because the pores are too large in diameter. They impede the passage of protozoa and their cysts or worm's eggs, but not bacteria.

### Conservation of safe water

Any safe water can become contaminated again if it is handled inadequately and then stored for hours or days (depending on the temperature) with no residual

disinfectant. Therefore, conservation is useful. Silver ions which inactivate some bacteria but which have the special advantage of blocking bacterial growth, preserve clean water for up to 6 months.<sup>27</sup> In contrast to silver ions, hypochlorite preserves it only for a short period if the container is kept closed. Compared to silver ions, chlorination is less stable and its effect lasts much shorter (1–2 days, depending on temperature). Of course, clean containers are a prerequisite. Many commercially available products contain both hypochlorite and silver. Therefore, they fit with any water problem in the mountains except cysts and the eggs of parasites, which can be easily filtered (see above). The most well-known and widely used products are MultiMan ChloroSil (Peter Gelzhäuser GmbH, Puchheim, Germany), Certisil Combina (Katadyn Products Inc., Wallisellen, Switzerland), and Micropur forte (Katadyn Products Inc., Wallisellen, Switzerland).

### Improvisation of water disinfection

In some very remote mountains, trekkers may be confronted with situations where disinfectants are out of stock or ceramic filters are broken. They then need to improvise water disinfection as good as the circumstances allow. Any improvisation in the process of water disinfection should be used only in case where regular methods are not available ("survival situation"). It should be noted that these methods do not produce completely safe water. However, by decreasing the number of pathogenic microorganisms they decrease significantly the risk of waterborne diseases.<sup>19,20,22</sup>

#### Sand

A container (plastic bag, bucket or other container) with a small hole (4–5 mm in diameter) in the bottom can be filled with fine sand. This simple filter method eliminates effectively larger microorganisms such as *Giardia* cysts, or eggs or larvae of several parasites (helminths). It should also be effective against *Vibrio cholerae* (see Section [Textile filters \("Sari Filter"\)](#)). The effectiveness of this method depends mainly on two factors: the finer the sand and the smaller the flow (the smaller the hole at the bottom of the container). Because of these variables, the overall effectiveness of this survival method cannot be given. However, compared to charcoal filtration (see Section [Charcoal](#)), a pure sand filtration is less effective. If available, sand filters as well as any other method described below, should be combined with chemical disinfection. Note: Method Sections [Sand](#), [Charcoal](#), [Optimized charcoal and sand filter](#), [Textile filters \("Sari Filter"\)](#), [Solar disinfection \(SODIS\)](#) and [Citrus](#) are for "survival situations" only.

#### Charcoal

A container (plastic bag, bucket or other container) can be filled with charcoal obtained by a normal fire and then crushed. If the container has a small hole (about 4–5 mm in diameter), the water will be filtered by the adhesive effect of the charcoal. If small pebbles and a layer of fine sand

were filled inside the container prior to the addition of the charcoal, no charcoal will be carried into the filtered water. Some fine sand and then a layer of pebbles on top of the charcoal inhibit the charcoal from "swimming" when water is added to the container. The system removes any larger microorganisms (*Giardia* cysts, eggs and larvae, helminths) and drastically decreases the concentration of any bacterium and although less drastically those of viruses. It should also be effective against *V. cholerae* (see Section Textile filters ("Sari Filter")). To provide the best possible system, the charcoal should be replaced every four days. As mentioned for pure sand filters, an overall effectiveness for charcoal filtration cannot be given. Charcoal can also be used to clarify water before disinfection by standard methods.

### Optimized charcoal and sand filter

The combination of Sections Sand and Charcoal improves efficacy and safety. Several layers combine their filter effect and prevent the charcoal from swimming. The system is shown in Fig. 1. The microorganisms filtered are similar to Sections Sand and Charcoal. The system can also be used for pre-filtering of muddy water to prevent muddying of ceramic filters (see above). Like pure charcoal, the system should be replaced every four days to maintain the procedure as safe as possible.

### Textile filters ("Sari Filter")

The concentration of some microorganisms, especially *V. cholerae*, can be reduced drastically, if the water is filtered through several layers of tight woven textile material.<sup>35,36</sup> Huo et al. report a 99% reduction of *V. cholerae* by this

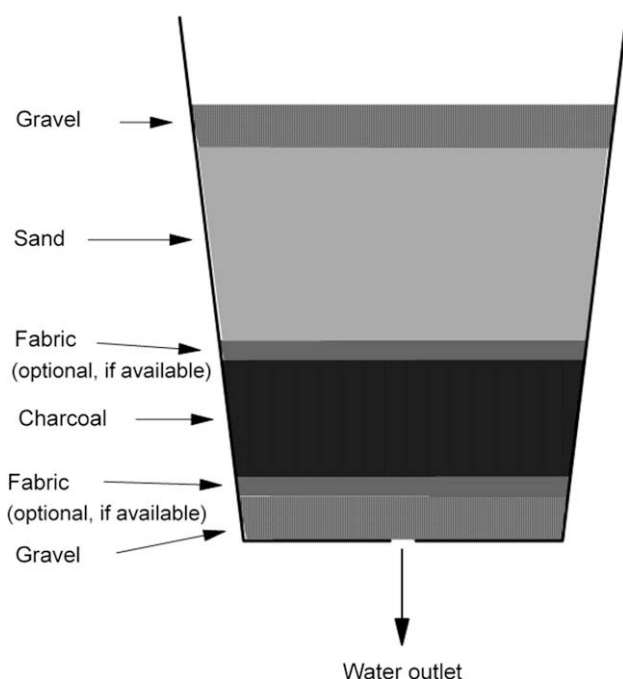


Figure 1 Optimized charcoal – sand – filter (modified from<sup>40</sup>).

simple method.<sup>36</sup> This is possible because this microorganism attaches to phyto- and zooplankton.<sup>37</sup> Therefore the agglomerates exceed the critical diameter of the textile's pores and can be filtered. The procedure effectively eliminates eggs and larvae of several parasites (helminths) as well.<sup>38</sup> The tighter the textiles are, the better the filter effect. Therefore, older textiles which are matted are more effective than new ones. However, even the best Sari filter is unable to eliminate bacteria or viruses which do not attach to something or agglomerate.

### Solar disinfection (SODIS)

Exposure of water in transparent bottles to strong sunlight for at least 4 h reduces enteric bacteria and viruses (synopsis of the literature in<sup>22</sup>). UV light and thermal inactivation (>45 °C) are strongly synergistic.<sup>22</sup> However, in colder climates or even freezing temperatures, this method is limited in the mountains. It may be used as "survival method" during approach or on the way back.

### Citrus

Citrus has been shown to reduce *V. cholerae* and may be used as "survival method" to improve water quality (survey<sup>22</sup>). A concentration of at least 2% is necessary (2 tablespoons of lime or lemon juice per litre of water) with a contact time of at least 30 min. A pH less than 3.9 is essential and therefore more juice per litre is necessary in alkaline water in regions with limestone.

### Inadequate methods

Potassium permanganate ( $\text{KMnO}_4$ ), often recommended in survival handbooks or older expedition reports, cannot be used to produce safe water or food if used in concentrations which do not change the taste of the product. Some investigators report this substance being effective at a concentration of 2 mg/l and a contact time of 45 min,<sup>25</sup> but there is a lack of data which microorganisms might be inactivated. As a consequence: avoid it and preferably use chloride.

Hydrogen peroxide is effective against bacteria. However, hydrogen peroxide is very unstable and disintegrates quickly. Therefore, adequate concentrations cannot be guaranteed. Hydrogen peroxide is not effective against viruses and its potential against protozoa is unknown. As a consequence: avoid it and prefer hypochlorite.

### Sanitation

For the safety of water and food, an appeal to the individual responsibility of every person visiting mountain environments or any other type of wilderness appears to be necessary: Take care of your and your successor's health by correct waste management! Human waste needs to be buried at least 30 m from any water source to avoid further contamination of surface water.<sup>19,20,22,39</sup> Since most group illness is spread person to person by dirty hands, hand washing with soap is essential after any deposition of any kind of waste, not only human, and before preparing food or water.<sup>22</sup>

**Table 2** Recommendations for mountaineers.

## Use or prefer:

- Boil water, if there is enough fuel and you are vaccinated against hepatitis A.
- Neither filtration nor chemical disinfection is absolute safe if used as single procedure, but the combination is safe if procedures were performed as recommended.
- Use ceramic filters where available. Take care for their maintenance (cleaning). Do not use them with forced pressure. Filtering as a single method is safe if you are vaccinated against hepatitis A and if the region is at-risk poliomyelitis.
- Use chemical disinfection as alternative to ceramic filters. Prefer hypochlorite. Take care for sufficient concentration and disinfection time. Do not forget that concentration should be doubled if water contains organic material and time must be doubled if water is very cold. Alternatively warm it to about 20 °C.
- If not used immediately (within some hours) any water produced for drinking should be preserved against contamination. Here silver ions work best.

## Be careful or avoid:

- Potassium permanganate does not provide safe water.
- Hydrogen peroxide is not stable enough to be carried in the wilderness. Therefore it does not produce safe water.
- Iodine, if any malfunction of the thyroid gland is not excluded by medical examination.
- Any improvised method, if possible. These methods are designed for the "survival case" to reduce the concentration of microorganisms.

## Trekking/expedition companies and water disinfection

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

Water which is intended for human use may not contain pathological microorganisms in concentrations that may cause an impairment of human health.<sup>21</sup> Water which is not according to the quality criteria of safe water has to be processed.<sup>21</sup> It is forbidden by law and individuals can be prosecuted if they 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 that does not fulfil the criteria can be prosecuted in term of imprisonment for up to two years or fined.<sup>21</sup> In addition, any entrepreneur or owner of a water supply installation can be prosecuted if he adds additives like hypochlorite above the concentration given by law.<sup>21,27</sup> "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.<sup>21</sup> In the case of organized mountaineering or trekking, the production of safe water is the responsibility of the trekking organization. This responsibility is strictly and given by law. It should be an integral part of the organization's safety concept and a standard operation procedure (SOP).

## Conclusions

There is no single procedure without the risk of failure. Users must be informed in detail about the procedure chosen, including important mistakes that are often made. In the case of organized travel, the operator is responsible by law to provide safe water. Boiling is not generally recommended at high altitude for several reasons although it

may be used where fuel is available and plentiful. Chemical disinfection can be recommended as "safe" method as well as filtration with ceramic filters. Independent from any method standard vaccinations, especially against hepatitis A, are recommended for any traveller. The most important recommendations for mountaineers are summarized in Table 2.

## Conflict of interest statement

No competing interests. All authors and commission members are voluntarily working and completely free in their work for the Medical Commission.

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