THE INTERNATIONAL MOUNTAINEERING AND CLIMBING FEDERATION
UNION INTERNATIONALE DES ASSOCIATIONS D'ALPINISME

Office: Monbijoustrasse 61
CH-3000 Bern 23• SWITZERLAND
Tel.: +41 (0)31 3701828
e-mail: office@uiaa.org

RECOMMENDATION

OF THE

UIAA MEDICAL COMMISSION

VOL: 6

Water Disinfection in the Mountains

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

C. Albanus, L. Timmermann, V. Schoeffl, D. Hillebrandt, J. Milledge, Th. Küpper

3rd Revised Edition

April 2021

Content

1 Introduction

Travellers' diarrhoea is one of the most common and important health problems affecting travellers. The syndrome occurs in up to 70% (in some regions up to 90% [1]) of people travelling to less developed regions of the world, resulting in a significant interruption of the victim's activities, with nearly 40% of travellers changing their itinerary [1], [2], [3], [4]. Although contaminated food may be a more important risk factor for travellers' diarrhoea than water [1], the availability of safe water and knowledge of how to obtain it is essential for mountaineers worldwide. They have to balance (high altitude) dehydration, to improve performance, and to minimise risks such as frostbite and altitude illness. In most cases obtaining and purifying water will be the mountaineer's personal responsibility when safe community based water resources are not available. Mountaineers also have a responsibility to protect any locally employed staff and to protect the local environment from their own inevitable waste water, urine, faeces, and general rubbish. This UIAA MedCom recommendation updates the advices given in the earlier version [5], [6] according to current scientific data. It summarises advantages and disadvantages of 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 minimising environmental damage. It is backed by a simple educational video: https://www.youtube.com/watch?v=OX06NpPIMxQ

Natural surface water may be contaminated with organic or inorganic material from land and vegetation and also with industrial chemical pollutants [7]. It should also be noted that the accidental ingestion of small volumes of water during recreational water-based activities may cause disease when microorganisms with a small infectious dose are present (e.g. Cryptosporidium, Giardia, Shigella, enteric viruses, or even more dangerous germs like Naegleria fowleri) [8], [9]. Both, industrial pollutants and water-based recreational activities are beyond the scope of this recommendation but do merit attention by the traveller.

Mountaineers should be aware that most enteric organisms, including Shigella species and Salmonella typhi, hepatitis A virus, and Cryptosporidium species can survive for weeks to months when frozen in water [10], [11].

2 Definitions

- **"Safe water"** does not mean that water needs to be absolutely sterile. Water is safe (=potable) when the concentration of pathogenic germs is too low to expect any risk to human health (infection). International standards of water testing define water as safe or potable when free of E. coli or thermotolerant coliform bacteria (0 colony forming units (CFU)/100ml), independent of the sampling point (water entering the distribution system or at any point of use) [12].
- **"Disinfection"** is the killing, inactivation, or removal of germs which can induce infectious diseases.
- **"Sterilisation"** means that all germs are eliminated.
- **"Conservation"** describes procedures which prevent microbiological recontamination of previously "safe" water.

- We define **“regular methods”** for water disinfection as methods providing water which is accepted to be safe.
- **“Improvised methods”** do not guarantee safe water. These methods should only be used if no regular method is available.

3 Pathogens in water

Pathogenic germs occurring in water include bacteria, viruses, and protozoa with different characteristics in terms of survival time or resistance against methods of disinfection. Travellers’ diarrhoea is predominantly caused by bacteria (50-80%), followed by viruses (5-25%), and protozoa (<10%) [13], [14]. Among the bacterial species, ETEC (enterotoxigenic E. coli) is the most frequent cause of travellers’ diarrhoea worldwide [15]. Bacterial spores, which are much more resistant than active bacteria, are not primarily relevant waterborne pathogens [12] and most helminth diseases are more associated with food than with drinking water, although there are exceptions. Pathogens differ in their environmental resistance. Generally viruses and protozoa (cysts) are more resistant against disinfection methods than bacteria. Survival of pathogens in water is difficult to measure and compare due to the different methodological designs of the studies. Most water hygiene projects measure the presence of Escherichia coli (E. coli) which represents a reliable indicator of fecal contamination. However, the absence of E. coli may not be interpreted as being definitively potable since certain environmental conditions can favour survival of intestinal enterococcal species more than coliform bacteria [16].

Some species can survive for long periods of time in water, especially at cold temperatures [17]. For example, Campylobacter can survive for several weeks at 4°C [18]. In nutrient-rich waters some types of bacteria are even able to replicate. Host-dependent viral and protozoan species are, however, not capable of replication in water.

There are significant regional differences in germs and therefore risk. Regardless of the type of water disinfection used all travellers going to the Himalayas should be aware of typhoid fever since Nepal is one of the regions with the highest incidence worldwide especially in the tourist areas of Kathmandu [19], [20], [21], [22], [23]. A vaccination is strictly recommended although Salmonella typhi can be easily killed by all methods mentioned below. Generally, the goal is a 3 to 5 log reduction (99.9% to 99.999%), allowing for a small residual risk of enteric infection [12], [24].

4 Principles for avoiding waterborne diseases

- Maintaining good standards of hygiene when handling any kind of water, beverage, food, or human waste is the “gold standard”!
    - Do not put any other substances in containers used for drinking water, beverages, or food! 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 beverages clean! Wash your hands before handling food, water, or beverages! Recent research indicates the advantage of additional hand disinfection [25].
  - Human waste needs to be buried at least 30 m from any water source to avoid further contamination of surface water.
- Minimise the amount of safe (treated) water needed!
  - 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 water per person per day should be expected.
- If several procedures of water treatment are available, always use the safest option!
  - Having good quality raw water to disinfect improves the safety of any procedure and preserves the equipment. Collecting rainwater may be an option to obtain good quality raw water.
  - “Improvised 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 water treatment in groups:
  - Only trained persons should decide which procedure should be used. Group illness may result from water disinfection by incompetent individuals!
  - The whole team must fully understand the procedure being used.

5 Methods of water disinfection

In the mountains, there is no method available which is absolutely risk free. Knowledge of a variety of water disinfection methods is essential. While some water sources provide relatively safe water (e.g. water directly obtained from a high volume spring), most sources need some sort of treatment before consumption, even if optically clear. If it is planned to store disinfected water for more than one day, a procedure for conservation should follow disinfection (see below).

5.1 Thermal disinfection

Principles: Although the temperature of boiling water at high altitude is lower than at sea level (boiling point reduced about 0.3°C (0.54°F) every 100 meters of altitude, Table 1), boiling kills virtually all waterborne enteropathogenic germs rapidly. In fact, most relevant species are killed within one minute at temperatures above 70°C [26]. The thermal sensitivity of Hepatitis A virus (HAV) was controversial, particularly in the German literature. Now, even though data varies it is accepted that sufficient inactivation of HAV in a watery environment is provided at temperatures >80°C in less than one minute [27], [12]. For added reassurance travellers should still be vaccinated against HAV. Bacterial spores show an even higher resistance against heat, requiring temperatures above 100°C to become inactivated. However, as mentioned above, spores do not belong to the pathogens that are particularly relevant to drinking water hygiene.

Table 1: Boiling temperature of water at several altitudes

Altitude [m]	°C	°F
0	100.0	212
1000	96.7	206
2000	93.3	200
3000	89.9	194
4000	86.6	188
5000	83.2	182
6000	79.9	176
7000	76.5	170
8000	73.2	164

Procedure: To add a margin of safety, water should boil with bubbles in it for at least one minute. A temperature above 70°C will be maintained for long enough to ensure adequate disinfection.

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 which contributes to deforestation. Therefore, other procedures are preferred in any situation where liquid water (as opposed to ice) is available. Note that water is not conserved and recontamination is possible.

Additional remarks: To optimise procedure safety, all expedition members should be vaccinated against Hepatitis A.

5.2 Chemical disinfection

There are numerous chemical disinfection products available which are sold as tablets, liquids, or powder. The most common purification substances are based on the oxidising effects of halogens. Chlorine and iodine are the halogens used in water disinfection. According to European guidelines, iodine should not be used because of possible side effects (especially regarding undiagnosed thyroid problems), making chlorine the recommended substance in chemical field water disinfection. Another method is the production of mixed oxidant species by electrolysis of a salt solution which will not be described in detail because until now it is not very common in field use. Further techniques of chemical water disinfection include hydrogen peroxide and potassium permanganate which are not now recommended (see chapter “Inadequate methods” below). Yet another chemical method of water disinfection is ozone. In the past it had only been used on a larger scale in stationary facilities for example in the Annapurna Region providing safe water for tourists and locals. New developments are entering the market, making ozone usable in portable devices but since there are no independent data on these devices as yet the commission decided to keep them under review (see also 5.2.4).

Note: For turbid water it is recommended to use a pre-filter before chemical disinfection (for details see 5.3.2.4).

5.2.1 Chlorine (Hypochlorites)

Principles: Sodium hypochlorite, calcium hypochlorite, and NaDCC (sodium dichloroisocyanurate = sodium troclosene) belong to the most important chemical compounds available for field water disinfection. In Germany NaDCC is marketed as Micropur® forte, in the U.K. it is distributed as “Oasis Water Purification Tablets”. Certisil combina® consists of sodium hypochlorite and ChloroSil® contains calcium hypochlorite. Efficacy of these substances is based on the formation of hypochlorous acid (HOCl) in water [28]. HOCl oxidises and thereby destroys structural proteins and metabolic enzymes of the microorganism which causes cell death. All relevant drinking water bacteria and viruses are susceptible to disinfection with hypochlorites. However, there is a limited effect on protozoa and the eggs and larvae of several helminths show an increased resistance against hypochlorous acid.

Chemical oxidation neutralises some tastes and odours of water and removes colour to some extent. Oxidation of dissolved manganese and iron forms trivalent compounds that can be filtered from water [29]. If water contains larger amounts of organic material (e.g. algae), chlorine reacts with these substances to form chlorinated disinfection by-products (e.g. chloramines, trihalomethanes). This results in a strong chlorinous taste and odour of the water and can irritate mucous membranes. Furthermore, chlorine atoms which react with organic material cannot contribute to further disinfection resulting in an increased chlorine demand.

Procedure: A sufficient amount of disinfectant must be added to the water (as indicated in the product’s instruction manual). Shake well for homogeneous distribution of the disinfectant. Wait for an appropriate amount of time as given by the instructions. In cold water disinfection takes longer (about 2-4 times for every 10°C). Careful warming of the water (to about 20°C) shortens the time necessary for disinfection. Turbid water should be pre-filtered to reduce the amount of chlorine used up by organic substances and to minimise the formation of chemical by-products. **Note:** It is often recommended that at the end of the time necessary for disinfection the water should taste a bit of chlorine, otherwise more chlorine should be added. The UIAA MedCom has decided to abandon this recommendation for two reasons: 1) The threshold of chlorine taste and smell differs significantly between individuals and does therefore not constitute a reliable criterion. 2) Smell and taste of chlorine can also indicate heavy organic pollution with an increased chlorine demand instead of an adequate disinfection.

Advantages: Can be used immediately at any place and any time where liquid water and disinfectant is available. Effective against most waterborne pathogens. No fuel necessary, therefore no contribution to deforestation. No heavy equipment required. Chemicals are relatively cheap and easy to obtain in larger towns and cities.

Disadvantages:

- Chemical disinfection is a method susceptible to environmental influences (e.g. water temperature, pH, organic contamination).
- Treatment is time consuming (30 minutes to 2 hours, depending on product, water temperature, turbidity, and expected germ spectrum). In cold water disinfection time needs to be increased (e.g. quadrupled for water <5°C). Alternatively, disinfectant can be added to water in higher concentrations. However, this impairs the taste and odour of the water. Chemical disinfection is susceptible to errors concerning the correct dosage or certain organisms not being covered.
- Disinfection with hypochlorites is only safe if the pH of water is less than 7.5. Be careful in limestone regions! You may double the concentration of disinfectant, but at pH >8.5 there is virtually no disinfecting effect [28].
- Chlorine compounds have a limited effectiveness against protozoa like Giardia lamblia and Cyclospora. Higher dosages or longer contact times are required in this case. There is no effectivity against Cryptosporidium parvum at practical dosages and contact times. Also eggs and larvae of several helminths show an increased resistance against hydrochlorous acid.
- Organic contamination of water results in the formation of disinfection by-products which may lower disinfection capacity, impair taste/odour of water and (in larger quantities) constitute a health risk. Water containing heavy organic contamination should be pre-filtered or the amount of disinfectant added needs to be increased (doubled).

Additional remarks:

- The taste of water is impaired by chemical disinfection, especially if high concentrations were used to cope with cold conditions or organic material. It can be neutralised by adding one knife point of vitamin C (ascorbic acid) powder per litre or commercial neutralisation drops after disinfection is completed. The disinfection effect ceases when the chlorine is neutralised!
- Chlorine products lose their effectiveness when exposed to certain environmental influences like sunlight and air. Thus, they have limited capability of conserving the water for longer periods of time. For this purpose, some chlorine products contain silver ions which prevent recontamination. Note: There are also water treatment products that only contain silver with no chlorine component (e.g. Micropur® *classic)*. Even though silver has a weak disinfection power itself, these products are intended for conservation of water that has already been disinfected and not for initial treatment!
- Trihalomethanes (chloroform) have carcinogenic potential which is why there are defined limits for these substances in communal drinking water supplies. The risk

to health of travellers applying chemical field water disinfection remains unknown. It can, however, be reasonably assumed that pathogens in water are far more important to human health than the levels of trihalomethanes that form at common chlorine dosages during a limited exposure time when travelling [26].

- There is evidence presenting certain advantages of using NaDCC over sodium and calcium hypochlorite for water treatment at individual level, even though the mode of action is the same. NaDCC is delivered in form of tablets making handling easier and safer than liquid NaOCl which presents the risk of under- or overdosage [30]. NaDCC tablets have a shelf life of 5 years while NaOCl liquid should be used up within 6 months. Due to its chemical composition NaDCC produces less by-products and has a slight buffering capacity for higher pH values. However, there is not yet an official recommendation indicating a preference for NaDCC.

5.2.2 Chlorine dioxide

Note: Due to similar names, chlorine and chlorine dioxide (ClO_2) can easily be confused. When talking about water disinfection, the term "chlorine" usually refers to hypochlorites (including NaDCC) or chlorine gas. Chlorine dioxide is a totally different substance with distinct properties and until recently ClO_2 was not available for individual use by travellers. As a volatile and explosive gas, its scope included facilities where large amounts of water are processed such as municipal water plants or swimming pools. At the present time chlorine dioxide is available as a field product in form of a 2-component solution or tablets. It is marketed under different trade names: Katadyn Micropur MP-1, Potable Aqua Chlorine Dioxide Water Purification Tablets, Aquamira and Pristine [26].

Principles: Chlorine dioxide is formed when sodium chlorite comes in contact with acid [28]. This reaction is initialised only when the tablet comes in contact with water or when the two components of the liquid solution are mixed. Chlorine dioxide gas dissolves in water but does not react with water molecules to form hypochlorous acid [31]. It is a free radical which has a high oxidising capacity without transferring chlorine atoms to organic molecules. Thus, in contrast to the hypochlorites described above, there is virtually no formation of chlorinated disinfection by-products. Chlorine dioxide kills bacteria and viruses within 15 minutes [26]. Inactivation of protozoan cysts, especially Cryptosporidium parvum, depends on water temperature: At 20 C disinfection requires 30 minutes while cold or dirty water needs 4 hours to be purified.

Procedure: For treatment of 1 litre of water add 1 tablet. The liquid preparation involves two steps: First mix the two components to initiate reaction according to the instructions. After that, mix with water. Avoid exposure to sunlight when unpacking the tablet and during treatment time because UV light breaks down chlorine dioxide [26]. Keep water bottle closed while disinfection takes place because otherwise ClO_2 molecules can escape from solution [26]. Recommended contact times are 15 minutes against bacteria and viruses and 30 minutes to 4 hours against protozoa (depending on water temperature and degree of contamination). Reaction time can be reduced by pre-filtering and slightly warming the water where possible. Note: Warm water also causes a faster degradation of chlorine dioxide!

Advantages: Chlorine dioxide is a potent water disinfectant requiring less concentration and contact times than hypochlorites. It is effective against all relevant waterborne pathogens, even Cryptosporidium parvum. In contrast to hypochlorites, chlorine dioxide is also effective in alkaline water (pH 8-9). After disinfection, chlorine dioxide leaves less chlorine taste / odour and it even neutralises bad taste or odour in the water to some extent. No chlorinated by-products like trihalomethanes are formed.

Disadvantages: In the outdoor setting, disinfection by chlorine dioxide is a time consuming procedure (as is the case with the hypochlorites) and requires protection against light [26]. Some authors favour the solid form of chlorine dioxide because imprecise amounts of liquids and delay in mixing cannot guarantee a certain dosage of ClO_2 making disinfection unreliable [26]. Since no residuals are formed, recontamination is possible. Disinfected water should be used up quickly, the storage of water disinfected by chlorine dioxide is not recommended since the substance is relatively volatile (keep bottles closed whenever possible).

Additional remark: The breakdown products of chlorine dioxide are chlorite and chlorate which in high doses can have adverse health effects. As it is the case with trihalomethanes, however, the risk of infectious waterborne diseases during travel is of far more importance compared to the short-time exposure to chlorine dioxide in the usual dosages. This assumption is supported by results of animal experiments [32].

5.2.3 Iodine

Principles: Like chlorine, iodine belongs to the chemical group of halogens, destroying microorganisms by oxidation. Elemental diatomic iodine (I_2) and hypoiodous acid (HOI), which forms when I_2 hydrolyses in water, are the primary microbicidal agents. The efficacy of disinfection with iodine is subject to the same environmental influences as chlorine: pH, water temperature, turbidity, and type of microorganism (see description above). Given adequate dosages and contact times, the disinfecting effect of chlorine and iodine is comparable [26]. However, there are some differences: Iodine shows greater chemical stability and is less volatile than chlorine. Also, effectiveness is slightly less affected by pH. Since iodine has a lower reactivity than chlorine, there is less halogen demand through organic contamination. This makes iodine more suitable for poor-quality water. On the negative side, iodine can have adverse health effects, especially on the thyroid gland. Excess intake of iodine can cause hyper- as well as hypothyroidism and goitre. This results in a higher risk for thyreotoxicosis, a disruption of reproductive function, and impaired development in fetuses. Also, a higher incidence of thyroid cancer and thyroid autoimmune diseases have been reported [33]. Thus, iodine is not recommended as a primary disinfectant by the WHO and should only be used if there is no other suitable option [34].

For iodine-based water disinfection there are two different categories: (1) iodine tablets / solutions that can be added to water, (2) iodine resins, i.e. solid-phase iodine matrices through which water is filtered while pathogens are killed by coming into contact with the resin’s surface. With the latter procedure only small amounts of iodine are released into the water and filter systems often contain a carbon element to remove residual iodine from solution. This way, the resulting drinking water is not “contaminated” with excess iodine but there is also no residual disinfecting effect.

Procedure: In the case of tablets or solution, add to water according to the instructions and wait for the time specified in the manual. In cold water, allow for a longer reaction time. Turbid water should be pre-filtered before adding the disinfectant.

As for the resin filters, stick to product specific instructions (resins need to be primed before first use!). Keep track of the number of disinfection cycles applied because the filter cartridge has a limited lifetime and needs replacement after a certain volume of water is filtered. Turbid water results in faster clogging of the filter.

Advantages: Can be used immediately at any place and any time where liquid water and disinfectant is available. No fuel necessary. In case of tablets / solutions no heavy equipment required. Effective against most waterborne pathogens. Resin filters that are equipped with a pre-filter are effective against protozoa as well.

Disadvantages: Like chlorine, disinfection with iodine tablets / solution is dependent on water condition (pH, temperature, and turbidity). Time consuming procedure. Effectiveness against protozoa is limited, no effect on Cryptosporidium in practical dosages and contact times. In contrast to chlorine there are potential adverse health effects, especially regarding thyroid dysfunction. In case of resin filters regular exchange of filter cartridge required.

Remarks: Because of the health concerns described above, the following application restrictions are acknowledged by the WHO: Iodine is not suitable for long-term disinfection. If use for more than 1 month is intended, thyroid function should be checked beforehand. Iodine is not recommended for pregnant women, infants and young children, persons with hypersensitivity against iodine, pre-existing thyroid dysfunction or a family history of thyroid disease as well as residents of areas with severe iodine-deficiency [34].

In many developing countries (e.g. Nepal) iodine products are available for travellers and locals. Their iodine content differs and therefore they should be used strictly according to the respective specifications. The same applies for Lugol’s solution (diluted potassium iodide with iodine): It is cheap and easily available in any pharmacy, but again there are various concentrations on the market from 1% to 15% or more which requires caution when used to disinfect water. When other procedures for water disinfection are not available the use of Lugol’s solution for a limited time is acceptable. For a 2% iodine solution put 5 drops in one liter of clear water (or 1 drop of 10% solution). Disinfection time, temperature dependence, and the need for higher concentrations when organic substances (e.g. algae) are in the water are similar as described for chlorine.

Iodine can also be used in its crystalline form, which is not very common but still practiced in several regions of the world and by some travellers. A small jar containing iodine crystals is filled with water, permitting elemental iodine to go into solution until the water becomes saturated. Several millilitres of this solution can be added to the water intended for drinking, followed be an adequate incubation time [35]. It is important to notice that the crystals are not inserted directly into the drinking water, which would result in a toxic concentration. Since the solubility of iodine crystals is limited, they can be used repetitively to generate iodine solution for disinfecting hundreds of litres of water, making their use very efficient. However, the process is highly dependent on temperature, warm water of about 25°C should be used to create the stock solution (lower solubility of crystalline iodine in cold water) [26].

5.2.4 Ozone

Recently a small, lightweight handheld system came on the U.S. market which produces ozone for disinfection. However, since the system has not yet been independently validated the commission decided not to include it here but to keep it under review.

5.2.5 Inadequate chemical methods

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

Hydrogen peroxide (H_2O_2) is effective against bacteria. However, the substance is very unstable and degrades quickly so that adequate concentrations cannot be guaranteed. Viruses require higher dosages and there are limited data on its potential against protozoa [26].

5.3 Filtration

Principles: The process of filtration refers to the physical removal of germs from water (not killing them as with chemical disinfection). Germs are eliminated by several physical characteristics like their size in relation 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. Depending on the filter type, there are construction-dependent advantages and disadvantages meaning that a detailed knowledge about the filter type used is essential for any user. Read the specifications of the product carefully and be aware of the pore size!

Procedure: Water passes through the filter material, driven by either gravity or by applying pressure or suction manually or electrically. Pore size should not be larger than 0.2 µm to achieve an adequate removal of pathogens. For the removal of viruses a pore size of 0.02 µm is required. Use the filter according to the instructions. If the pressure required to press water through the filter increases, the filter unit needs to be cleaned. This should be performed by persons trained with the system to avoid damage. Clean according to the instructions in the manual (some ceramic filters need to be brushed, others with hollow fibres can be backwashed). 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.

5.3.1 Types of filters

There are many different types of filters on the market, differing in material, pore size, or the presence of an additional adsorbing (e.g. activated carbon) or antibacterial (e.g. silver) component. In the following, we describe the most widely used categories of outdoor filters. Note that there are also products in which these filter elements are combined.

- **Textile filters:** Improvised or commercially available textile elements with lager pore sizes, used to pre-filtrate water to reduce turbidity or under emergency conditions (see chapter 5.3.2.4).
- **Ceramic filters:** Up to now, microporous ceramic is the most common material of outdoor water filters, with or without an activated carbon component or silver impregnation. The filter element is a cylindrical ceramic block. Ceramic filters of good quality have a pore size of 0.2 µm and are usually operated by a hand pump, pressing the water through the filter element.
- **Activated carbon:** Retains particles and microorganisms in its pore matrix by electrostatic adhesion. Available as compressed filter block or as granulate. Often combined with mechanical filters like ceramic filters. Note that gradually the binding sites within the carbon become saturated and the cartridge has to be replaced.
- **Hollow fibre filters:** These filters are based on the functional principle of semipermeable membrane filtration, similar to dialysis. The filter element consists of a bundle of hollow fibres which results in a large filtration surface. This reduces the pressure needed to bring water through the unit. Pore size differs significantly depending on the model and ranges from 0.2 (“filter”) to 0.02 µm (“purifier”). Purifiers with 0.02 µm pores are even able to remove viruses. The driving force for water flow is usually either suction (in form of a tube used like a very large straw or integrated into a bottle), gravity (in form of a bag that hangs from an elevated point), hand pump, or squeezing a water bag or bottle with attached filter. Examples of manufacturers are the companies LifeStraw and Sawyer, which sell filters as well as purifiers, so read the specifications of the product carefully to determine the pore size!
- **Glass fibre filters:** Pleated matrix of glass fibres with pore sizes down to 0.2 µm. Often combined with ceramic or other pre-filter element to avoid fast clogging. Examples: Katadyn “Vario” (hand pump glass fibre filter combined with ceramic and activated carbon), Katadyn “Gravity Camp” and “Base Camp Pro” (water bags using gravity drip for larger quantities of water).
- **Nanocomposite filters:** This category comprises a variety of different materials and constitutes the most recent development in the field of personal water treatment equipment. The idea behind these filters is a functionalisation and enlargement of the filter surface by coating it with different kinds of nanoparticles which have distinct physico-chemical properties (adsorbing, microbicidal, or catalytic). Depending on the material it is also possible to remove toxins such as heavy metals or chemicals from water. Companies selling these products tend not to reveal the exact structure and composition of their filters. The results of laboratory tests commissioned by the manufacturers are positive, but currently there is a lack of independent data. The commission will keep these systems under review (e.g. “Water-to-Go™” or “Sawyer® select filters / purifiers”).

Advantages: Relatively simple procedure, also suitable for producing larger quantities of water for groups. Depending on the pore size removal of all relevant waterborne pathogens can be achieved, also improves optical quality of the water by reducing turbidity. No bad taste or smell as with chlorine. Some materials (adsorbing substances like activated carbon or nanocomposites) even remove bad tastes / smells and toxins / chemicals. Modern filter materials like hollow fibre filters or nanocomposite filters are lighter than classical ceramic filters. Therefore, these types of filters are more suitable for use in the mountains, where luggage capacity is limited.

Disadvantages:

- Most filters do not remove viruses except for hollow fibre filters with a pore size of 0.02 µm or nanocomposite filters. A combination of filtration with chemical disinfection gives the advantages of both methods.
- Clogging is a frequent problem. The smaller the pores the safer the water, but also the more frequent the problem of clogging. If possible use clear water. Do not increase the pressure of filtration. This can pass microbes through the system and contaminate your water. In the case of membrane filters the material may be damaged by applying too much pressure. If the pressure required to press the water through the filter increases, the surface of the filter unit needs to be cleaned or replaced (see above).
- Depending on the material, filters are breakable (especially ceramic), so handle the equipment with care. Most filters are damaged when freezing containing water remnants, resulting in microscopic cracks compromising disinfection. With some filters the need for replacement is only indicated by gradually requiring increasing filtration pressure. However, if the filter is damaged filtration pressure remains low in spite of an urgent need for replacement. Some filters (e.g. some nanocomposite filters) give no sign of being "used up", so the user has to keep track of how many litres have been treated until a defined volume has been reached.
- Water is not conserved, so recontamination of treated water is a risk. The filter itself may become contaminated or contamination can come via the mouthpiece in systems designed to increase pressure by sucking. For these reasons some filters are impregnated with silver ions.

Additional remarks: The clearer the water to be filtered, the longer the filter can be used without the need for maintenance or replacement. If no clear water is available, it is useful to let the water "rest" in a bucket for the particles to settle before filtering. A simple coffee filter reduces turbidity and should eliminate eggs and larvae of helminths. Therefore the combination of a coffee filter for the eggs and larvae and chlorine for bacteria and viruses can be a suitable method for producing safe water. Any filter system without activated carbon or other adhesive substances will not remove toxins. Avoid water which might be polluted by industry (old mines in the mountains) or agriculture (pesticides) where the approach to the mountain passes through farmland!

5.3.1.1 Additional note: Gravity filtration for larger groups

Principles: Gravity ultrafilters are designed for providing safe drinking water for households in a low income setting. Recently they have been adopted by international projects since they can filter large volumes of water over prolonged periods. Systems such as LifeStraw Family 1.0 and now LifeStraw Mission™ were controversial although proven to be useful on large scale projects. They may be of interest to trekking groups or expeditions in addition to their social and community health role in rural communities. It is probable that mountaineers and travellers will get their water from households (lodges) which use such systems. They are therefore included in this recommendation as a new, low-cost method working without a power source. The unit cost would be USD 0.005 per litre treated [36]. One filter may provide enough water for a 5-person family for three years.

Procedure: Forced by gravity the water passes in a two-step procedure through a pre- and a micro- or ultrafilter, removing dirt and microorganisms.

Advantages: An easy to operate method for water treatment providing enough water for a household (about 10 L/h) without electricity or batteries. As the filters work by gravity, no pumping is needed. As two filters are included, it can handle very turbid water. There is no need to combine this method with other chemical disinfectant because the ultrafilter is small enough to eliminate viruses.

Disadvantages: The gravity filter was not designed to be used by travellers in the mountains due to its size and weight (500-700 g). By this weight-efficacy-relation it may be used by groups or in base camps or by lodges en route. The apparatus has to be cleaned regularly to prevent biofilm formation. Recontamination is an observed problem in rural households with pets and poor hygiene. As the system is a hollow fibre technology it must not freeze when wet. For mountaineers this could cause a significant risk because such micro-breaks are not visible and it is not easy to decide if the filter is dry (and then frost resistant) or not.

Additional remarks: Only few data exist on these relatively new products. **Note:** The devices differ in the pore size of the filter membranes and not all of them are able to remove viruses. UIAA MedCom will keep such filters (and others) under review.

5.3.2 Improvised filtration methods

Mountaineers or trekkers may be confronted with situations where the disinfectants favoured are out of stock or water treatment equipment is broken. In these situations they need to improvise as well as the circumstances allow. Note: Any improvisation in the process of water disinfection should be used when regular methods are not available ("survival situation"). It must be pointed out that these methods do not guarantee safe water, but by reducing the number of pathogens they significantly decrease the risk of waterborne diseases.

5.3.2.1 Sand

Principles: This simple filter method can reduce the number of larger germs like Giardia cysts and eggs or larvae of parasites (helminths) [37]. It should be (relatively) effective against Vibrio cholerae because this germ tends to agglomerate with organic material [38]. Also other bacteria and viruses can be reduced significantly [26]. Efficacy of sand filters depends on the height of the sand column (the higher the better), the flow rate of water (the slower the better) and the grain size of the sand (the smaller the better).

Procedure: Cut a very small hole (4-5 mm in diameter) into the bottom of a container (plastic bag, bucket…) and fill it with fine sand. The water passes through the sand and exits the container through the hole.

Advantages: Simple method, can be used for larger amounts of water (e.g. for groups).

Disadvantages: Due to many variables involved, 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: A slow water flow rate improves the filtration effect. This can be achieved by a smaller bottom hole and / or finer sand. If possible, sand filters, as well as any other method described below, should be combined with chemical disinfection.

5.3.2.2 Charcoal

Principles: Combines the effects of physical removal of germs due to pore size and extraction of smaller particles through adhesive forces. Additionally, charcoal can (at least partially) remove chemical contamination as well as toxins, heavy metals, or substances which cause a bad taste or smell.

Procedure: A container (plastic bag, bucket…) can be filled with charcoal obtained from a camp fire and then crushed. The water passes through the charcoal and exits the container through a small hole at the bottom (about 4-5 mm in diameter). As is the case with the sand filter, a low flow rate (accomplished by a smaller hole) will improve the filtration effect. The charcoal should be replaced every few days.

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 of charcoal filtration cannot be given.

5.3.2.3 Optimised sand-charcoal-filter

Principles: Combination of sand and charcoal filtration.

Procedure: Several layers combine their filter effects 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. A simple method that can be used for larger amounts of water (e.g. for groups).

Disadvantages: Several components are required. As mentioned above an overall effectiveness cannot be given.

Additional remarks: The system can also be used for pre-filtering turbid water to prevent clogging of ceramic filters (see above). As mentioned for pure charcoal filtration, the system should be replaced every few days to keep the procedure as safe as possible. If some small pebbles are placed in the bottom of the container, followed by a layer of fine sand, no pieces of the charcoal will 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.

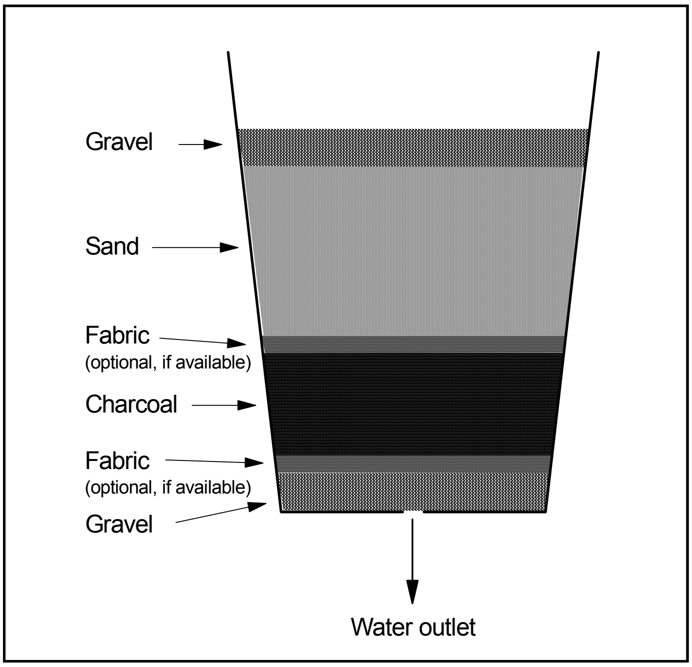

Figure 1: Optimised layering of charcoal – sand – filter

5.3.2.4 Textile filters ("Sari filter", "Millbank bag")

Principles: The procedure can reduce the number of larger pathogens like Giardia cysts and eggs or larvae of some parasites (helminths). It was proven to be (partially) effective against Vibrio cholerae, because this germ tends to agglomerate with organic material and the particles exceed the critical diameter of the textile's pores [39], [40]. The counts of other bacteria and viruses can be reduced as well [26]. Furthermore, aesthetic quality of water is improved by reducing turbidity.

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 of textile filtration cannot be given. For V. cholerae a reduction of 99% of the germs was reported [38].

Additional remarks: The tighter the textiles, the better the filtration 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. It can also be used to pre-filter the water in order to reduce turbidity before applying a ceramic filter, chemical, or UV disinfection.

5.4 Ultraviolet Light

Ultraviolet radiation leads to cell damage causing not only skin lesion in humans, but also destroying germs in drinking water. This principle has been made use of in municipal water treatment plants for almost 100 years but only recently became available for individual use while travelling. The effective component of the UV spectrum is **UV-C** (100-280nm) with maximal antimicrobial efficacy between 250 and 270 nm [41]. UV-C rays disrupt the DNA of the microorganism primarily by causing the formation of dimers between bases. As a consequence, the DNA strands cannot be copied and replicated anymore. This way the microorganism is unable to multiply and cause an infection. Also solar **UV-A** radiation can be used to disinfect water (see chapter 5.4.2 Solar disinfection). Here the mode of action is quite different in that cell damage occurs mainly indirectly via the formation of reactive oxygen species in water.

5.4.1 UV-C disinfection

The first and currently most widely spread product for point-of-use UV-C water disinfection is the SteriPEN®. Its general effectiveness has recently been validated by an independent study, which also underlined the risk of incorrect application [42].

Principles: The SteriPEN® is a handheld device emitting mainly **UV-C** radiation with a wavelength of 254 nm. Effectiveness of this method depends on characteristics of the water (e.g. turbidity, germ concentration) and handling of the device. In general, all microorganisms are susceptible to UV-C radiation. However, bacterial spores and some strains of viruses show a higher resistance against UV light than vital bacteria and protozoa [43].

Procedure: In one disinfection cycle, the SteriPEN® can treat 1 litre of clear water in 90 seconds. For the user's safety the device is equipped with a water sensor, so the UV lamp will only turn on when submerged in water. During irradiation the water has to be agitated continuously by stirring with the device or by swaying the bottle. Proper water agitation is essential for achieving a reliable disinfection [42]. After the time cycle is complete the device will switch off automatically. While the SteriPEN® is in use, dry off any water remnants in the bottle cap, neck (if possible), and around the device to prevent them from getting back into the bottle!

Advantages: Water disinfection with the SteriPEN® is an easy and fast method to achieve safe drinking water. At about 180 g, the SteriPEN® is lighter than a ceramic filter (>400 g) and disinfects water in less time than chemical treatment (90 seconds vs. 0.5-2 hours). UV light does not change the water's aspect, smell, or taste in contrast to chemical by-products.

Disadvantages: Fragility of the lamp and limited lifetime of batteries (four AA lithium batteries are necessary for 100 disinfection cycles) make an extra set of batteries and a backup method necessary. Rechargeable SteriPEN® models require an external power source after 20-50 litres. Water needs to be absolutely clear to guarantee an adequate disinfection, because particles in water scatter the UV radiation. Thus turbid water needs to be pre-filtered. Droplets in the cap and neck of the water bottle are not disinfected and pose a risk of recontamination making water storage inadvisable. Disinfection with the SteriPEN® does not remove toxins or heavy metals from the water.

Additional remarks: Common bottle materials (glass and plastic) are opaque for UV-C light, thus there is no risk to the user. However, when applying the SteriPEN® in larger containers like cooking pots, a part of the UV radiation exits the water surface. It has not yet been examined whether this constitutes a risk for the user.

5.4.2 Solar disinfection (SODIS)

Principles: Solar disinfection (known as SODIS) is recognised by the WHO and UNICEF as a possible method for treating water intended to drink. Exposure to sunlight for several hours reduces pathogenic germs in water. The mode of action is a combination of **UV-A** irradiation causing the formation of reactive oxygen species (ROS) in water and thermal disinfection [44]. Susceptibility of germs to SODIS depends on the pathogens' characteristics. While most waterborne pathogenic bacteria are inactivated within 5 to 6 hours of sun exposure (mid-latitude midday summer sunshine [45]), some viruses and protozoa are less amenable to SODIS [44]. Temperatures above 50 to 60°C are sufficient to obtain potable water within 1 hour, independently of UV radiation [26], [46]. However, since it is difficult to measure the temperature of the water correctly over hours when in the mountains it is not recommended to shorten disinfection time. Stick to 6 hours of exposure.

Procedure: A plastic (PET) or other commonly available bottle (size up to 2 litres) is filled with water and then exposed to sunlight for at least 6 hours according to the standard method. If the sky is clouded disinfection can be achieved by exposing the bottle for 2-3 days with a risk of some germs surviving [47]. A black (increase of temperature) or reflective (increase of radiation) surface underneath the bottles enhances the effect [44]. Some authors recommend shaking the bottle for 30 seconds before exposing to the sun to increase the level of dissolved oxygen, favouring the formation of ROS [44].

Advantages: If applied correctly viable pathogenic germs are reduced significantly to non-detectable levels after exposure time. Apart from PET or glass bottles, which are distributed worldwide, SODIS requires no further equipment. The use of sunlight is probably the cheapest and easiest method to disinfect large quantities of water.

Disadvantages: There is a plurality of influencing factors like temperature, water turbidity, and intensity of UV radiation on disinfection time and efficacy. People make use of SODIS without any instruction on disinfection time according to the local circumstances. This makes SODIS an uncontrolled, not reliable method. Water needs to be clear for SODIS to be effective and bottles have to be in a good condition (no scratches which scatter the UV radiation). Only where high temperatures can be achieved these preconditions are not mandatory.

Additional remarks: SODIS is mainly applied for point-of-use water disinfection where resources are limited. However, the concept of SODIS can also be transferred to the survival or back country setting [48]. To prevent recontamination, water should be consumed within 48 hours [44]. Standard plastic and glass bottles can both be used for SODIS [49]. Both materials are relatively opaque for UV-B (and UV-C which is however already filtered out by the atmosphere) but penetrable for UV-A radiation. UV rays are weakened depending on thickness and composition of the material. Usually, plastic bottles (PET) are used because they are easily obtained in many regions, lighter, and less breakable than glass bottles [44].

6 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 if there is no residual disinfectant. Therefore, a conservation method is necessary when the water is not consumed shortly after disinfection. Clean containers are a prerequisite for any plan to store safe water. **Silver ions** which inactivate some germs and block bacterial growth preserve clean water for up to 6 months [26]. Compared to silver ions, chlorination is less stable and provides conservation only for a few days, depending on water temperature as well as exposition to sunlight and air. Some disinfection products contain both, hypochlorite and silver, and therefore they fit with any water problem in the mountains, except for cysts and eggs of some parasites, which can be easily filtered (see above).

Note: In contrast to common belief pure silver ions are not sufficient to disinfect water! For initial disinfection, always use products containing a halogen component (or other disinfection method). Silver ions are recommended for conservation only! Be careful: Too high a concentration of silver ions cause pitting corrosion in aluminium containers.

7 Special recommendations for commercial mountaineering or guided groups

While mountaineers are responsible for themselves, any organisation offering mountaineering, trekking tours, or expeditions 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 organised mountaineering, trekking, or expeditions the production of safe water is in the responsibility of the trekking organisation. It should be an integral part of the organisation's safety concept, e.g. as standard operation procedure (SOP). The most important regulations the organisation must know and respect are as follows:

- Water, which is indented for human use, may not contain pathogenic 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 these 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 terms of imprisonment (e.g. in Germany for up to two years) or fined according to the laws of the respective 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, i.e. any system used during the trip.

8 Overview of the procedures

Procedure	Safe for			Remarks
	Viruses	Bacteria	Protozoan cysts & helminth eggs	
Boiling	+[1]	+	+	Fuel and time consuming, deforestation
Chemical disinfection (hypochlorites, NaDCC, chlorine dioxide)	+	+	(+)[2]	May be critical if water is very cold, has a high pH, or contains organic substances[6]
Mechanical filtration (textile, ceramic, glass fibre, hollow fibre)	(+)[3]	+	+[4]	Type specific limitations (pore size!), regular maintenance necessary
Adsorbing filtration (activated carbon, nanocomposites)	+	+	+	Binding sites become saturated over time, replacement necessary
Chemical disinfection + filtration/boiling/UV	+	+	+[2,4]	Combination of physical and chemical method can be expected to yield absolutely safe water
Improvised filtration (sand, charcoal, sari)	-	(+)[5]	(+)[5]	Fine sand and low flow improve the result, in case of textiles: prefer matted materials
UV-C disinfection	(+)[7]	+	+	No disinfection of droplets in bottle neck and cap, no conservation, clear water necessary
SODIS	(+)	(+)	(+)	Dependent on weather, water clarity, condition of bottle, and temperature

+: safe; (+): safe with some limitations; - not safe

Footnotes:

[1]: Hepatitis A virus is more resistant against heat but can also be inactivated with sufficient boiling time, vaccination against this pathogen is advisable (see text for details)

[2]: Only chlorine dioxide eliminates Cryptosporidium in practical dosages and contact times

[3]: Only filters with pore sizes of 0.02 µm (or additional adsorbing component) are effective against viruses

[4]: Pore size < 1 µm necessary

[5]: “Nearly safe” (> 99% elimination of germs possible but cannot be guaranteed)

[6]: Longer disinfection time and/or higher concentration of disinfectant necessary

[7]: Certain types of viruses (e.g. adenovirus) require very high UV-C dosages

9 References

1. Steffen, R, Epidemiology of traveler's diarrhea. Clin Infect Dis, 2005; 41 Suppl 8: S536-40.
2. Steffen, R, Hill, DR, DuPont, HL, Traveler's diarrhea: a clinical review. JAMA, 2015; 313(1): 71-80.
3. Kittitrakul, C, Lawpoolsri, S, Kusolsuk, T, Olanwijitwong, J, Tangkanakul, W, Piyaphanee, W, Traveler's Diarrhea in Foreign Travelers in Southeast Asia: A Cross-Sectional Survey Study in Bangkok, Thailand. Am J Trop Med Hyg, 2015; 93(3): 485-90.
4. Giddings, SL, Stevens, AM, Leung, DT, Traveler's Diarrhea. Med Clin North Am, 2016; 100(2): 317-30.
5. Küpper, T, Schoffl, V, Milledge, J. Consensus Statement of the UIAA Medical Commission Vol.6: Water Disinfection in the Mountains. 2008 [cited 29.3.21]; Available from: www.theuiaa.org/medical_advice.html.
6. Küpper, T, Schoffl, V, Milledge, J, Water Purification in the Mountains – State of the Art. Travel Med Infect Dis, 2009; 7(1): 7-14.
7. Hurst, C, Clark, R, Regli, S, Estimating the risk of acquiring infectious disease from ingestion of water, in Modeling disease transmission and its prevention by disinfection, Hurst, C, Editor. 1996, Cambridge University Press: Melbourne. 99–139.
8. Backer, HD, Water disinfection for international and wilderness travelers. Clin Infect Dis, 2002; 34: 355-64.
9. Heggie, T, Küpper, T, Surviving Naegleria fowleri infections: A successful case report and novel therapeutic approach. Travel Med Inf Dis (TMAID), 2017; 16(1): 49-51.
10. Dickens, DL, DuPont, HL, Johnson, PC, Survival of bacterial enteropathogens in the ice of popular drinks. JAMA, 1985; 253(21): 3141-3.
11. Thraenhart, O, Measures for disinfection and control of viral hepatitis, in Disinfection, sterilization, and preservation, Block, S, Editor. 1991, Lea & Febiger: Philadelphia.
12. WHO, Guidelines for Drinking-water Quality. 2011, World Health Organization (WHO): New York / USA.
13. Diemert, DJ, Prevention and self-treatment of traveler's diarrhea. Clin Microbiol Rev, 2006; 19(3): 583-94.
14. Rieke, B, Küpper, T, Muth, CM, eds. Moderne Reisemedizin. 2. Aufl. ed. 2013, Gentner Verlag: Stuttgart.
15. Jiang, ZD, DuPont, HL, Etiology of travellers' diarrhea. J Travel Med, 2017; 24(suppl_1): S13-S6.
16. McFeters, GA, Bissonnette, GK, Jezeski, JJ, Thomson, CA, Stuart, DG, Comparative survival of indicator bacteria and enteric pathogens in well water. Appl Microbiol, 1974; 27(5): 823-9.
17. Wang, G, Doyle, MP, Survival of enterohemorrhagic Escherichia coli O157:H7 in water. J Food Prot, 1998; 61(6): 662-7.

18. Trigui, H, Thibodeau, A, Fravalo, P, Letellier, A, S, PF, Survival in water of Campylobacter jejuni strains isolated from the slaughterhouse. Springerplus, 2015; 4: 799.

19. Basnyat, B, Maskey, AP, Zimmerman, MD, Murdoch, DR, Enteric (typhoid) fever in travelers. Clin Infect Dis, 2005; 41(10): 1467-72.

20. Colin-Jones, R, Shakya, M, Voysey, M, Theiss-Nyland, K, Smith, N, Pant, D, et al., Logistics of Implementing a Large-scale Typhoid Vaccine Trial in Kathmandu, Nepal. Clin Infect Dis, 2019; 68(Supplement_2): S138-S45.

21. Karkey, A, Aryjal, A, Basnyat, B, Baker, S, Kathmandu, Nepal: Still an enteric fever capital of the world. J Infect Developing Countries, 2008; 2(6): 461-5.

22. Basnyat, B, Tackle Nepal's typhoid problem now. Nature, 2015; 524(7565): 267.

23. Haditsch, M, [Typhoid fever in Nepal - an underestimated problem] Typhus in Nepal - ein unterschätztes Problem. Arbeitsmed Sozialmed Umweltmed, 2011; 46(6): 363-6.

24. Backer, HD, Derlet, RW, Hill, VR, Wilderness Medical Society Clinical Practice Guidelines for Water Disinfection for Wilderness, International Travel, and Austere Situations. Wilderness Environ Med, 2019; 30(4S): S100-S20.

25. Ulmer, H-V, Risse, J, Küpper, T, Practicability of Enteritis – prevention in Trekking and Mountaineering at High Altitude by Systematic Hand Disinfection. Health Promot Phys Act (HPPA), 2020; 13(4): 25-8.

26. Backer, HD, Field water disinfection, in Wilderness Medicine, Auerbach, PS, Cushing, TA, Stuart Harris, N, Editors. 2017, Elsevier: Philadelphia, PA (USA). 1985-2030.

27. Araud, E, DiCaprio, E, Ma, Y, Lou, F, Gao, Y, Kingsley, D, et al., Thermal Inactivation of Enteric Viruses and Bioaccumulation of Enteric Foodborne Viruses in Live Oysters (Crassostrea virginica). Appl Environ Microbiol, 2016; 82(7): 2086-99.

28. Roeske, W, Trinkwasserdesinfektion: Grundlagen - Verfahren - Anlagen - Geräte - Mikrobiologie - Chlorung - Ozonung - UV-Bestrahlung - Membranfiltration - Qualitätssicherung. 3rd. ed. 2016, München / Günzburg: Deutscher Industrieverlag / Roeske Verlag.

29. Crittenden, JC, Trussell, RR, Hand, DW, Howe, KJ, Tchobanoglous, G, Disinfection, in Water Treatment - Principles and Design, Crittenden, JC, et al., Editors. 2012, John Wiley & Sons: Hoboken, New Jersey. 903-1032.

30. Clasen, T, Edmondson, P, Sodium dichloroisocyanurate (NaDCC) tablets as an alternative to sodium hypochlorite for the routine treatment of drinking water at the household level. Int J Hyg Environ Health, 2006; 209(2): 173-81.

31. Monaghan, S, Wall, B, Page, D, Fitzgerald, J, McGuigan, N, Kerr, H, et al., Water Treatment Manual: Disinfection. 2011, EPA Environmental Protection Agency: Wexfort / Ireland.

32. Amy, G, Bull, R, Craun, GF, Pegram, RA, Siddiqui, M, Disinfectants and disinfectant by-products. 2000, World Health Organization: New York.

33. Koutras, DA, Control of efficiency and results, and adverse effects of excess iodine administration on thyroid function. Ann Endocrinol (Paris), 1996; 57(6): 463-9.

34. WHO. Iodine as a drinking-water disinfectant. 2018 [cited 29.3.2021]; Available from: https://www.who.int/water_sanitation_health/publications/iodine-02032018.pdf?ua=1.

35. Khan, FH, Visscher, BR, Water disinfection in the wilderness - a simple, effective method of iodination. West Med J, 1975; 122(5): 450-3.

36. Chaidez, C, Ibarra-Rodriguez, JR, Valdez-Torres, JB, Soto, M, Gerba, CP, Castro-Del Campo, N, Point-of-use Unit Based on Gravity Ultrafiltration Removes Waterborne Gastrointestinal Pathogens from Untreated Water Sources in Rural Communities. Wilderness Environ Med, 2016; 27(3): 379-85.

37. Redder, A, Durr, M, Daeschlein, G, Baeder-Bederski, O, Koch, C, Muller, R, et al., Constructed wetlands - Are they safe in reducing protozoan parasites? Int J Hyg Environ Health, 2010; 213(1): 72-7.

38. Huq, A, Xu, B, Chowdhury, MA, Islam, MS, Montilla, R, Colwell, RR, A simple filtration method to remove plankton-associated Vibrio cholerae in raw water supplies in developing countries. Appl Environ Microbiol, 1996; 62(7): 2508-12.

39. Huq, A, Small, EB, West, PA, Huq, MI, Rahman, R, Colwell, RR, Ecological relationships between Vibrio cholerae and planktonic crustacean copepods. Appl Environ Microbiol, 1983; 45(1): 275-83.

40. Tamplin, ML, Gauzens, AL, Huq, A, Sack, DA, Colwell, RR, Attachment of Vibrio cholerae serogroup O1 to zooplankton and phytoplankton of Bangladesh waters. Appl Environ Microbiol, 1990; 56(6): 1977-80.

41. Gray, NF, Ultraviolet Disinfection, in Microbiology of Waterborne Diseases: Microbiological Aspects and Risks, Percival, SL, et al., Editors. 2014, Elsevier Academic Press: London. 617-30.

42. Timmermann, LF, Ritter, K, Hillebrandt, D, Küpper, T, Drinking water treatment with ultraviolet light for travelers - Evaluation of a mobile lightweight system. Travel Med Infect Dis, 2015; 13(6): 466-74.

43. Chevrefils, G, Caron, E, Wright, H, Sakamoto, G, Payment, P, Barbeau, B, et al., UV dose required to achieve incremental Log inactivation of bacteria, protozoa and viruses. IUVA News, 2006; 8(1): 38-45.

44. McGuigan, KG, Conroy, RM, Mosler, HJ, du Preez, M, Ubomba-Jaswa, E, Fernandez-Ibanez, P, Solar water disinfection (SODIS): a review from bench-top to roof-top. J Hazard Mater, 2012; 235-236: 29-46.

45. Wegelin, M, Canonica, S, Mechsner, K, Fleischmann, T, Pesaro, F, Metzler, A, Solar water disinfection: scope of the process and analysis of radiation experiments. J Water Supply: Res Technol AQUA, 1994; 43(3): 154-69.

46. Meierhofer, R, Wegelin, M, Solar water disinfection - A guide for the application of SODIS. 2002, SANDEC (Water & Sanitation in Developing

Countries) at EAWAG (Swiss Federal Institute for Environmental Science and Technology): Duebendorf/Switzerland.

47. Luzi, S, Tobler, M, Suter, F, , ea. SODIS Manual: Guidance on Solar Water Disinfection. 2016 [cited 29.3.21]; Available from: https://www.sodis.ch/methode/anwendung/ausbildungsmaterial/index_EN.

48. Tedeschi, CM, Barsi, C, Peterson, SE, Carey, KM, A pilot study of solar water disinfection in the wilderness setting. Wilderness Environ Med, 2014; 25(3): 340-5.

49. Asiimwe, JK, Quilty, B, Muyanja, CK, McGuigan, KG, Field comparison of solar water disinfection (SODIS) efficacy between glass and polyethylene terephalate (PET) plastic bottles under sub-Saharan weather conditions. J Water Health, 2013; 11(4): 729-37.

10 Members of UIAA MedCom

Agazzi, G. (Italy), Alemdar, E. (Turkey), Andjelkovic, M. (Serbia), Angelini, C. (Italy), Basnyat, B. (Nepal), Behpour, A.R. (Iran), Bouzat, P. (France), Brugger, H. (Italy), Dhillon, S. (UK), Dikic, N. (Serbia), Gurtoo, A. (India), Hefti, U. (Switzerland), Hillebrandt, D. (UK), Hilty, M. (Switzerland), Holmgren, J. (Sweden), Horakova, L. (Czech Republic), Jean, D. (France), Kamikomaki, N. (Japan), Kanazawa, H. (Japan), Koukoutsi, A.(Greece), Kuepper, T. (Germany), Masuyama, S. (Japan), Mateikaite, K. (Lithuania), McCall, J. (Canada), Meijer, H. (Netherlands), Morrison, A. (UK), Nogueira Garrigos Vinhaes, E. (Brazil), Paal, P. (Austria), Peters, P. (Luxembourg), Reis E Silva, M. (Portugal), Rodway, G. (USA), Roi, G.S. (Italy), Rosier, A. (USA), Rotman, I. (Czech Republic), Schoeffl, V. (Germany), Shahbazi, J. (Iran), Sherpa, N.N. (Nepal), Sherpa, S.Z. (Nepal), Trevena, D. (Australia), van der Spek, R. (Netherlands), van Vessem, M. (Netherlands), Von Delft, E. (South Africa), Wichardt, E.L. (Norway)

Invited guest authors:
C. Albanus and L. Timmermann, both from the Institute of Occupational & Social Medicine, RWTH Aachen Technical University, Aachen / Germany

11 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 first version 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. However, since several new data were published the commission decided to make a complete revision which is presented here. It has been accepted by written consent in lieu of a meeting April 2021.