# Portable water purification

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Utilitiesman in the US Navy operating a Reverse Osmosis Purification System in Camp Patriot, Kuwait

**Portable water purification** devices – also known as **point-of-use** (POU) **water treatment systems** and **field water disinfection** techniques – are self-contained units that can be used by recreational enthusiasts, military personnel, survivalists, and others who must obtain drinking water from untreated sources (e.g., rivers, lakes, etc.). The objective of these personal devices is to render unchlorinated water potable (that is, safe and palatable for drinking purposes).

Many commercial portable water purification systems or chemical additives are available for hiking, camping, and other travel in remote areas. These devices are not only used for remote or rural areas, but also to treat safe municipal water for aesthetic purposes by removing chlorine, bad taste, odors, and heavy metals like lead and mercury.

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## [edit] Drinking water hazards

Turbid creek water caused by heavy rains.

Large rivers may be polluted with sewage effluent, surface runoff, or industrial pollutants from sources far upstream. However, even small streams, springs and wells may be contaminated by animal waste and pathogens. The presence of dead animals upstream is not uncommon. In most parts of the world, water may be contaminated by bacteria, protozoa or parasitic worms from human and animal waste or pathogens which use other organisms as an intermediate host. Pathogenic strains of E coli bacteria survive briefly outside the body, to infect new hosts.

*Giardia lamblia* and *Cryptosporidium* *spp.*, both of which cause diarrhea (see giardiasis and cryptosporidiosis) are common pathogens. In backcountry areas of the United States and Canada they are sometimes present in sufficient quantity that water treatment is justified for backpackers,[1] although this has created some controversy.[2][3] (See Wilderness acquired diarrhea.) In Hawaii and other tropical areas, *Leptospira* *spp.* are another possible problem.[4]

Less commonly seen in developed countries are organisms such as *Vibrio cholerae* which causes cholera and various strains of *Salmonella* which cause typhoid and para-typhoid diseases. Pathogenic viruses may also be found in water. The larvae of flukes are particularly dangerous in area frequented by sheep, deer, or cattle. If such microscopic larvae are ingested, they can form potentially life threatening cysts in the brain or liver. This risk extends to plants grown in or near water including the commonly eaten watercress.

## [edit] Techniques

31st Marine Expeditionary Unit (MEU) Service Support Group 31

## [edit] Boiling

Boiling water will kill bacteria as well as other disease-causing microorganisms like Giardia lamblia and Cryptosporidium parvum which are commonly found in rivers and lakes. At high elevations, though, the boiling point of water drops, so that extra boiling time is required. Water temperatures above 70 °C (158 °F) will kill all pathogens within 30 minutes, above 85 °C (185 °F) within a few minutes, and at boiling point (100 °C (212 °F)), most pathogens will be killed, excluding certain pathogens and their spores, which must be heated to 118 °C (244 °F)(e.g.: botulism – Clostridium botulinum). This can be achieved by using a pressure cooker, as regular boiling will not heat water past 100 °C (212 °F) at sea level. It is worth noting that not all pollutants are removed from water by boiling, even in a pressure cooker. Boiling cannot remove chemicals having boiling points at or above 100 °C (212 °F), nor heavy metal contamination, e.g., colloidal metal pollutants. Activated charcoal, however, can remove many pollutants, but can't remove pathogens. A combination of rolling boiling for one minute at standard atmospheric pressure (i.e., not in a pressure cooker) plus filtering with activated charcoal can neutralize most pathogens and pollutants.

## [edit] Filtration

Portable pump filters are commercially available with ceramic filters that filter 5,000 to 50,000 litres per cartridge, removing pathogens down to the 0.2–0.3 micrometer (μm) range. Some also utilize activated charcoal filtering. Most filters of this kind remove most bacteria and protozoa, such as *Cryptosporidium* and *Giardia lamblia,* but not viruses except for the very largest of 0.3 micrometer and larger diameters, so disinfection by chemicals or ultraviolet light is still required after filtration. It is worth noting that not all bacteria are removed by 0.2 micron (micrometer) pump filters; for example, strands of thread-like *Leptospira spp.* (which can cause leptospirosis) are thin enough to pass through a 0.2 micrometer filter. Effective chemical additives to address shortcomings in pump filters include chlorine, chlorine dioxide, iodine, and sodium hypochlorite (bleach). There have been polymer and ceramic filters on the market that incorporated iodine post-treatment in their filter elements to kill viruses and the smaller bacteria that cannot be filtered out, but most have disappeared due to the unpleasant taste imparted to the water, as well as possible adverse health effects when iodine is ingested over protracted periods.

While the filtration elements may do an excellent job of removing most bacteria and fungi contaminants from drinking water when new, the elements themselves can become colonization sites. In recent years some filters have been enhanced by bonding silver metal nanoparticles to the ceramic element and/or to the activated charcoal to suppress growth of pathogens.

Small, hand-pumped reverse osmosis filters were originally developed for the military in the late 1980s for use as survival equipment, for example, to be included with inflatable rafts on aircraft. Civilian versions are available. Instead of using the static pressure of a water supply line to force the water through the filter, pressure is provided by a hand-operated pump, similar in function and appearance to a mechanic's grease gun. These devices can generate drinkable water from seawater.

## [edit] Activated charcoal absorption

Granular activated carbon filtering utilizes a form of activated carbon with a high surface area, and adsorbs many compounds, including many toxic compounds. Water passing through activated carbon is commonly used in concert with hand pumped filters to address organic contamination, taste, or objectionable odors. Activated carbon filters aren't usually used as the primary purification techniques of portable water purification devices, but rather as secondary means to complement another purification technique. It is most commonly implemented for pre- or post-filtering, in a separate step than ceramic filtering, in either case being implemented prior to the addition of chemical disinfectants used to control bacteria or viruses that filters cannot remove. Activated charcoal can remove chlorine from treated water, removing any residual protection remaining in the water protecting against pathogens, and should not, in general, be used without careful thought after chemical disinfection treatments in portable water purification processing. Ceramic/Carbon Core filters with a 0.5 micron or smaller pore size are excellent for removing bacteria and cysts while also removing chemicals.

## [edit] Chemical disinfection

Iodine used for water purification is commonly added to water as a solution, in crystallized form, or in tablets containing tetraglycine hydroperiodide that release 8 mg of iodine per tablet adaptation to chronic tetraglycine hydroperiodide. The iodine kills many, but not all, of the most common pathogens present in natural fresh water sources. Carrying iodine for water purification is an imperfect but lightweight solution for those in need of field purification of drinking water. Kits are available in camping stores that include an iodine pill and a second pill (vitamin C or ascorbic acid) that will remove the iodine taste from the water after it has been disinfected, such as those marketed under the Potable Aqua Plus name. The addition of vitamin C, in the form of a pill or in flavored drink powders, precipitates much of the iodine out of solution, so it should not be added until the iodine has had sufficient time to work. This time is 30 minutes in relatively clear, warm water, but is considerably longer if the water is turbid or cold. Iodine treated drinking water, treated with tablets containing tetraglycine hydroperiodide, also reduces the uptake of radioactive iodine in human subjects to only 2% of the value it would otherwise be.[5] This could be an important factor worthy of consideration for treating water in a post nuclear event survival situation. If the iodine has precipitated out of the solution, then the drinking water has less available iodine in solution. Also the amount of iodine in one tablet is not sufficient to block uptake. Tetraglycine hydroperiodide maintains its effectiveness indefinitely before the container is opened; although some manufacturers suggest not using the tablets more than three months after the container has initially been opened, the shelf life is in fact very long provided that the container is resealed immediately after each time it is opened.[6]

A potentially lower cost alternative to using iodine-based water purification tablets is the use of iodine crystals, commonly sold under the Polar Pure name.[7] A small amount of water is poured into a small glass bottle (with a capacity of approximately 1 ounce or 30 cubic centimeters), containing approximately 0.25 ounces (7 grams) of iodine crystals, and then shaken vigorously to produce a saturated solution of Iodine. At 25°C (77°F) 12.5 cubic centimeters of this solution is added to one liter of water to be disinfected. In 15 minutes the water may be consumed. At a temperature of 20°C (68°F) let the water to be consumed stand for 20 minutes. At a temperature of 3°C (37°F) let the water stand for 30 minutes or use 25 cubic centimeters of saturated solution per liter.[8] (Do not store the saturated iodine solution in a plastic bottle as the Iodine vapor will pass through the plastic and corrode steel that is in close proximity.) Note also that this method may not be adequate in killing Giaridia cysts in cold water.[9] One solution is to warm the water to be consumed to 20°C (68°F) before treatment. Take care not to consume Iodine crystals; the amount of Iodine in the saturated solution may be two to four times the lethal dose.[10] Care must be taken to prevent the small glass bottle of iodine crystals covered with water from freezing in cold climates. An advantage of using iodine crystals is that only a small amount of iodine is dissolved from the iodine crystals at each use, giving this method of treating water a capability for treating very large amounts of water, around 2,000 liters (500 gallons), with but a small bottle of crystals. Unlike tetraglycine hydroperiodide tablets, iodine crystals have essentially an unlimited shelf life as long as they are not exposed to air for long periods of time and are kept under water. (Iodine crystals will sublimate if exposed to air for long periods of time.) The large quantity of water that can be purified with iodine crystals at low cost makes this technique especially cost effective for point of use or emergency water purification methods intended for use longer than the shelf life of tetraglycine hydroperiodide.

Chlorine-based halazone tablets were formerly popularly used for portable water purification. Chlorine in water is more than three times more effective as a disinfectant against *Escherichia coli* than iodine.[11] Halazone tablets were thus commonly used during World War II by U.S. soldiers for portable water purification, even being included in accessory packs for C-rations until 1945. The primary limitation of halazone tablets was the very short usable life of opened bottles, typically 3 days or less, unlike iodine-based tablets which have a usable open bottle life of 3 months. Sodium dichloroisocyanurate (NaDCC) has largely displaced halazone tablets for the few remaining chlorine based water purification tablets available today. It is compressed with effervescent salts, usually adipic acid and sodium bicarbonate, to form a rapidly dissolving tablets, diluted to 10 parts per million available chlorine (ppm av.cl) when drinking water is mildly contaminated and 20ppm when visibly contaminated. Chlorine bleach tablets give a more stable platform for disinfecting the water than liquid bleach (sodium hypochlorite) as the liquid version tends to degrade with age and give unregulated results unless assays are carried out – not practical on the spot. Still, despite chlorine-based halazone tablets falling from favor in for portable water purification, chlorine-based bleach may nonetheless safely be used for short-term emergency water disinfection. Two drops of unscented 5% bleach can be added per liter or quart of clear water, then allowed to stand covered for 30 to 60 minutes. After this treatment, the water may be left open to reduce the chlorine smell and taste. Guidelines are available online for effective emergency use of bleach to render unsafe water potable.[1][2] The Centers for Disease Control & Prevention (CDC) and Population Services International (PSI) promote a similar product (a 0.5% - 1.5% sodium hypochlorite solution) as part of their Safe Water System (SWS) strategy. The product is sold in developing countries under local brand names specifically for the purpose of disinfecting drinking water (CDC: SWSPSI: SWS).

Neither chlorine (e.g., bleach) nor iodine alone is considered completely effective against *Cryptosporidium*, although they are partially effective against *Giardia*. Iodine should be allowed at least 30 minutes to kill Giardia. Chlorine is considered slightly better against the latter. A more complete field solution that includes chemical disinfectants is to first filter the water, using a 0.2 micron ceramic cartridge pumped filter, followed by treatment with iodine or chlorine, thereby filtering out cryptosporidium, Giardia, and most bacteria, along with the larger viruses, while also using chemical disinfectant to address smaller viruses and bacteria that the filter cannot remove. This combination is also potentially more effective in some cases than even using portable electronic disinfection based on UV treatment, such as using a SteriPEN uv portable water purifier.

An alternative to iodine-based preparations in some usage scenarios are silver ion/chlorine dioxide-based tablets or droplets. Sold under names like Micropur Forte, Aquamira, and Pristine, these solutions may disinfect water more effectively than iodine based techniques while leaving hardly any noticeable taste in the water in some usage scenarios. Silver ion/chlorine dioxide based disinfecting agents will kill *Cryptosporidum* and *Giardia*, if utilized correctly. The primary disadvantage of silver ion/chlorine dioxide based techniques is the long purification times (generally 30 minutes to 4 hours, depending on the formulation used). Another concern is the possible deposition and accumulation of silver compounds in various body tissues leading to a rare condition called argyria that results in a permanent, disfiguring, bluish-gray pigmentation of the skin, eyes, and mucous membranes. The cost of chlorine dioxide treatment is about four times higher than the cost of iodine treatment.

## [edit] Ultraviolet purification

*Main article: Ultraviolet germicidal irradiation*

Ultraviolet (UV) light induces the formation of covalent linkages on DNA and thereby prevents microbes from reproducing. Without reproduction, the microbes become far less dangerous. Germicidal UV-C light in the short wavelength range of 100–280 nm acts on thymine, one of the four base nucleotides in DNA. When a germicidal UV photon is absorbed by a thymine molecule that is adjacent to another thymine within the DNA strand, a covalent bond or dimer between the molecules is created. This thymine dimer prevents enzymes from "reading" the DNA and copying it, thus neutering the microbe. Still, there are limits to this technology. Water turbidity (i.e., the amount of suspended & colloidal solids contained in the water to be treated) must be low, such that the water is clear, for UV purification to work well - thus a pre-filter step might be necessary.

A concern with UV portable water purification is that some pathogens are hundreds of times less sensitive to UV light than others. Protozoan cysts were once believed to be among the least sensitive, however recent studies have proved otherwise, demonstrating that both Cryptosporidium and Giardia are deactivated by a UV dose of just 6 mJ/cm sq.[12] However, EPA regulations and other studies show that it is viruses that are the limiting factor of UV treatment, requiring a 10-30 times greater dose of UV light than *Giardia* or *Cryptosporidium*[13].[14] Furthermore, studies have shown that UV doses at the levels provided by common portable UV units are effective at killing *Giardia*[15] and that there was no evidence of repair and reactivation of the cysts.[16]

Water treated with UV still has the microbes present in the water, only with their means for reproduction turned "off". In the event that such UV-treated water containing neutered microbes is exposed to visible light (specifically, wavelengths of light over 330-500 nm) for any significant period of time, a process known as photo reactivation can take place, where the possibility for repairing the damage in the bacteria's reproduction DNA arises, potentially rendering them once more capable of reproducing and causing disease.[17] UV-treated water must therefore not be exposed to visible light for any significant period of time after UV treatment, before consumption, to avoid ingesting reactivated and dangerous microbes.

## [edit] Solar water disinfection

*Main article: SODIS*

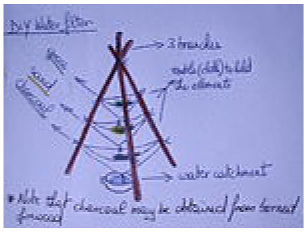
In solar water disinfection (SODIS), microbes are destroyed by temperature and UVA radiation provided by the sun. Water is placed in a transparent plastic PET bottles, which is first oxygenated by shaking partially filled capped bottles prior to filling the bottles all the way. The completely water-filled and capped bottles are exposed to sunlight, preferably on a corrugated metal roof, slanted slightly to maximize the exposure to solar radiation. In practice, the water-filled bottles are placed for six hours in full sun, or for two days in partial sunlight for weather conditions involving partially overcast days, which raises the temperature of the water and gives an extended dose of solar radiation to the water in the bottles, killing almost all microbes that may be present. The combination of the two effects (UVA and heat) provides a simple method of disinfection for use in tropical developing countries, or in survival situations. The use of glass bottles may or may not provide the same degree of SODIS disinfection as using PET bottles. This is because most glass bottles are non-transparent or opaque over the wavelengths of sunlight required for successful UV disinfection from the solar spectrum required for SODIS to work, and glass bottles are usually thicker than PET bottles, which further reduces the dose of UVA to the water inside glass bottles versus PET bottles. For cases where the UVA is blocked, or reduced, only the heating effects without adequate UVA exposure are typically at work if glass bottles are used, potentially leaving dangerous amounts of bacterial and viral loads within the water.

## [edit] Solar distillation

*Main article: Solar still*

Solar distillation may use a pre-manufactured and easily portable still, commonly referred to as a solar still, but it has its roots in a makeshift still that can be constructed simply from readily available components, typically being placed over a small pit that is dug into the ground. The solar still relies on sunlight to warm and evaporate the water to be purified. The water vapour condenses, usually on a plastic sheet suspended as an inverted cone, dripping into a collection cup placed beneath its center. For more continuous use, thin tubing or a hose is sometimes routed into the collection cup beneath the inverted cone, permitting repeated removal of water without disturbing the inverted cone upon which water condenses. This is potentially an important method to prevent losing moisture to atmospheric air, such as can occur in the desert, if the inverted cone is removed each time distilled water is removed from the cup. An alternative method based on the same technique is to tie a plastic bag over a branch of vegetation, to capture water released by the vegetation during photosynthesis. Note that while the solar still shares exposure to UV and infra-red radiation with SODIS, along with the use of plastic materials (sheeting in place of a PET bottle), a solar still relies on a completely different mechanism for operation and the two methods should not be confused. In an extreme survival situation, a solar still can be used to prepare safe drinking water from usually unsuitable water sources, such as one's own urine, or even sea water.

### [edit] Homemade water filters



A homemade waterfilter for making drinking water

Water filters can be made on-site using local materials such as grass, charcoal (e.g. from firewood burned in a special way). These filters are often used by soldiers and outdoor enthusiasts.[18] Due to their low cost they can be made and used by anyone. The reliability of such systems is highly variable. Such filters can do little, if anything, to mitigate germs and other harmful constituents and can give a false sense of security that the water so produced is potable. Water processed through an improvised filters should be undergo secondary processing such as boiling to render it safe for consumption.

## [edit] Prevention of water contamination

Only in very high-use wilderness areas is it recommended that **all** waste be packed up and carted out to a properly designated disposal point. Bury human waste well away from existing campsites and water sources to prevent site & source contamination, & reduce self contamination.

## [edit] Alternatives

A more popular solution to Chlorine Dioxide water purification are $ClO_2$ generators, however their use is steadily falling out of fashion in industry as these systems generally require the use of strong acids to work and can take several hours to reach their full yield with poor efficiency. The requirement to store the hazardous gas in a pressurized chamber poses a risk some sites prefer not to take. Newer dosing systems have proven to provide a safer alternative producing $ClO_2$ in solution and offering a huge leap in efficiency converting around 95% instantly only requiring the use of weak FDA approved acids offering a much safer method of producing $ClO_2$ as there is no storage which proves a more effective Chlorine Dioxide Water Treatment.[19]

## [edit] See also

- Desalination
- Traveler's diarrhea

- Water quality
- Wilderness acquired diarrhea

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