Water Treatment

Water Storage

Quantity

A water ration of as little as a pint per day has allowed life raft survivors to live for weeks, but a more realistic figure is 1 gallon per person per day for survival. 4 gallons per person/day will allow personal hygiene, washing of dishes, counter tops, etc. 5 to 12 gallons per day would be needed for a conventional toilet, or 1/2 to two gallons for a pour flush latrine. For short-term emergencies, it will probably be more practical to store paper plates and utensils, and minimize food preparation, than to attempt to store more water.

In addition to stored water, there is quite a bit of water trapped in the piping of the average home. If the municipal water system was not contaminated before you shut the water off to your house, this water is still fit for consumption without treatment. To collect this water, open the lowest faucet in the system, and allow air into the system from a second faucet. Depending on the diameter of the piping, you may want to open every other faucet, to make sure all of the water is drained. This procedure will usually only drain the cold water side, the hot-water side will have to be drained from the water heater. Again, open all of the faucets to let air into the system, and be prepared to collect any water that comes out when the first faucet is opened.

Toilet tanks (not the bowls) represent another source of water if a toilet bowl cleaner is not used in the tank. Some people have plumbed old water heaters or other tanks in line with their cold water supply to add an always rotated source of water. Two cautions are in order:

1) make sure the tanks can handle the pressure (50 psi min.), and
2) if the tanks are in series with the house plumbing, this method is susceptible to contamination of the municipal water system.

The system can be fed off the water lines with a shutoff valve (and a second drain line), preventing the water from being contaminated as long as the valve was closed at the time of contamination. Water can only be realistically stored for short-term emergencies, after that some emergency supply of water needs to be developed

Water Collection

Wells

Water can only be moved by suction for an equivalent head of about 20'. After this cavitation occurs, that is the water boils off in tiny bubbles in the vacuum created by the pump rather than being lifted by the pump. At best no water is pumped, at worst the pump is destroyed. Well pumps in wells deeper than this work on one of the following principles:

1) The pump can be submerged in the well, this is usually the case for deep well pumps. Submersible pumps are available for depths up 1000 feet.

2) The pump can be located at the surface of the well, and two pipes go down the well: one carrying water down, and one returning it. A jet fixture called an ejector on the bottom of the two hoses causes well water to be lifted up the well with the returning pumped water. These pumps must have an efficient foot valve as there is no way for them to self-prime. These are commonly used in shallow wells, but can go as deep as 350 feet. Some pumps use the annular space between one pipe and the well casing as the second pipe this requires a packer (seal) at the ejector and at the top of the casing.

3) The pump cylinder can be located in the well, and the power source located above the well. This is the method used by windmills and most hand pumps. A few hand pumps pump the water from very shallow wells using an aboveground pump and suction line. A variety of primitive, but ingenious, pump designs also exist. One uses a chain with buckets to lift the water up. Another design uses a continuous loop rope dropping in the well and returning up a small diameter pipe. Sealing washers are located along the rope, such that water is pulled up the pipe with the rope. An ancient Chinese design used knots, but modern designs designed for village level maintenance in Africa use rubber washers made from tires, and will work to a much greater depth.

Obviously a bucket can be lowered down the well if the well is big enough, but this won’t work with a modern drilled well. A better idea for a drilled well is to use a 2' length or so of galvanized pipe with end caps of a diameter that will fit in the well casing. The upper cap is drilled for a screw eye, and a small hole for ventilation. The lower end is drilled with a hole about half the diameter of the pipe, and on the inside a piece of rigid plastic or rubber is used as a flapper valve. This will allow water to enter the pipe, but not exit it. The whole assembly is lowered in the well casing, the weight of the pipe will cause it to fill with water, and it can then be lifted to the surface. The top pipe cap is there mostly to prevent the pipe from catching as it is lifted.

Springs

Springs or artesian wells are ideal sources of water. Like a conventional well, the water should be tested for pathogens, VOCs (Volatile Organic Compounds such as fuel oil or benzene), pesticides and any other contaminants found in your area. If the source is a spring it is very important to seal it in a spring box to prevent the water from becoming contaminated as it reaches the surface. It is also important to divert surface runoff around the spring box. As with a well, you will want to periodically treat the spring box with chlorine, particularly if the spring is slow moving. The spring may also be used for keeping food cool if a spring-house is built. If this is the case, it is still recommended to build a spring box inside the house to obtain potable water.

Surface water

Most US residents served by municipal water systems supplied with surface water, and many residents of underdeveloped countries rely on surface water. While surface water will almost always need to be treated, a lot of the risk can be reduced by properly collecting the water. Ideal sources of water are fast flowing creeks and rivers which don’t have large sources of pollution in their watershed. With the small amounts of water needed by a family or small group, the most practical way to collect the water is through an infiltration gallery or well. Either method reduces the turbidity of the collected water making it easy for later treatment.

Water Purification

Heavy Metals

Heavy metals are only a problem is certain areas of the country. The best way to identify their presence is by a lab test of the water or by speaking with your county health department. Unless you are down stream of mining trailings or a factory, the problem will probably affect the whole county or region. Heavy metals are unlikely to be present in sufficient levels to cause problems with short-term use.

Turbidity

Turbidity refers to suspended solids, i.e. muddy water, is very turbid. Turbidity is undesirable for 3 reasons:

1) aesthetic considerations

2) solids may contain heavy metals, pathogens or other contaminants,

3) turbidity decreases the effectiveness of water treatment techniques by shielding pathogens from chemical or thermal damage, or in the case of UV treatment, absorbing the UV light itself.

Organic compounds

Water can be contaminated by a number of organic compound such as chloroform, gasoline, pesticides, and herbicides. These contaminants must be identified in a lab test. It is unlikely ground water will suddenly become contaminated unless a quantity of chemicals is allowed to enter a well or penetrating the aquifer. One exception is when the aquifer is located in limestone. Not only will water flow faster through limestone, but the rock is prone to forming vertical channels or sinkholes that will rapidly allow contamination from surface water. Surface water may show great swings in chemical levels due to differences in rainfall, seasonal crop cultivation, and industrial effluent levels

Pathogens

Protozoa

Protozoa cysts are the largest pathogens in drinking water, and are responsible for many of the waterborne disease cases in the US. Protozoa cysts range is size from 2 to 15 µm (a micron is one millionth of a meter), but can squeeze through smaller openings. In order to insure cyst filtration, filters with a absolute pore size of 1µm or less should be used. The two most common protozoa pathogens are Giardia lamblia (Giardia) and Cryptosporidium (Crypto). Both organisms have caused numerous deaths in recent years in the US, the deaths occurring in the young and elderly, and the sick and immune compromised. Many deaths were a result of more than one of these conditions. Neither disease is likely to be fatal to a healthy adult, even if untreated. For example in Milwaukee in April of 2003, of 400,000 who were diagnosed with Crypto, only 54 deaths were linked to the outbreak, 84% of whom were AIDS patients. Outside of the US and other developed countries, protozoa are responsible for many cases of amoebic dysentery, but so far this has not been a problem in the US, due to better wastewater treatment. This could change during a survival situation. Tests have found Giardia and/or Crypto in up to 5% of vertical wells and 26% of springs in the US.

Bacteria

Bacteria are smaller than protozoa and are responsible for many diseases such as typhoid fever, cholera, diarrhea, and dysentery. Pathogenic bacteria range in size from 0.2 to 0.6 µm, and a 0.2 µm filter is necessary to prevent transmission. Contamination of water supplies by bacteria is blamed for the cholera epidemics which devastate undeveloped countries from time to time. Even in the US, E. coli is frequently found to contaminate water supplies Fortunately E. coli is relatively harmless as pathogens go, and the problem isn't so much with E. coli found, but the fear that other bacteria may have contaminated the water as well. Never the less, dehydration from diarrhea caused by E. coli has resulted in fatalities.

Viruses

Viruses are the 2nd most problematic pathogen, behind protozoa. As with protozoa, most aterborne viral diseases don't present a lethal hazard to a healthy adult. Waterborne pathogenic viruses range in size from 0.020-0.030 µm, and are too small to be filtered out by a mechanical filter. All waterborne enteric viruses affecting humans occur solely in humans, thus animal waste doesn't present much of a viral threat. At the present viruses don't present a major hazard to people drinking surface water in the US, but this could change in a survival situation as the level of human sanitation is reduced. Viruses do tend to show up even in remote areas, so case can be made for eliminating them now.

Physical Treatment

Heat Treatment

Boiling is one guaranteed way to purify water of all pathogens. Most experts feel that if the water reaches a rolling boil it is safe. A few still hold out for maintaining the boiling for some length of time, commonly 5 or 10 minutes, plus an extra minute for every 1000 feet of elevation. If one wishes to do this, a pressure cooker would allow the water to be kept at boiling with out loosing the heat to evaporation. One reason for the long period of boiling may be to inactivate bacterial spores (which can survive boiling), but these spore are unlikely to be waterborne pathogens. African aid agencies figure it takes 1 kg of wood to boil 1 liter of water. Hardwoods and efficient stoves would improve on this. Water can also be treated at below boiling temperatures, if contact time is increased. A commercial unit has been developed that treats 500 gals of water per day at an estimated cost of $1/1000 gallons for the energy. The process is similar to milk pasteurization, and holds the water at 161° F for 15 seconds. Heat exchangers recover most of the energy used to warm the water. Solar pasteurizers have also been built that would heat three gallons of water to 65° C and hold the temperature for an hour. A higher temperature could be reached if the device was rotated east to west during the day to follow the sunlight. Regardless of the method, heat treatment does not leave any form of residual to keep the water free of pathogens in storage.

Reverse Osmosis

Reverse osmosis forces water, under pressure, through a membrane that is impermeable to most contaminants. The most common use is aboard boats to produce fresh water from salt water. The membrane is somewhat better at rejecting salts than it is at rejecting non-ionized weak acids and bases and smaller organic molecules (molecular weight below 200). In the latter category are undissociated weak organic acids, amines, phenols, chlorinated hydrocarbons, some pesticides and low molecular weight alcohols. Larger organic molecules, and all pathogens are rejected. Of course it is possible to have a imperfection in the membrane that could allow molecules or whole pathogens to pass through.

Using reverse osmosis to desalinate seawater requires considerable pressure (1000 psi) to operate, and for a long time only electric models were available. Competing for a contract to build a hand powered model for the Navy, Recovery Engineering designed a model that could operate by hand, using the waste water (90 percent of the water is waste water, only 10% passes through the filter) to pressurize the back side of the piston. The design was later acquired by PUR. While there is little question that the devices work well, the considerable effort required to operate one has been questioned by some survival experts such as Michael Greenwald, himself a survivor of a shipwreck. On the other hand the people who have actually used them on a life raft credit the availability of water from their PUR watermaker for their survival.

PUR manual watermakers are available in two models: The Survivor 06 ($500) produces 2 pints per hour, and the Survivor 35 ($1350) produces 1.4 gal/hr. The latter model is also available as the Power Survivor 35 ($1700), which produces the same water volume from 4 Amps of 12 VDC, and can be disconnected and used as a hand held unit. A number of manufactures, including PUR, make DC powered models for shipboard use. PUR recommends replacing the O rings every 600 hours on its handheld units, and a kit is available to do this. Estimates for membrane life vary, but units designed for production use may last a year or more.

Every precaution should be taken to prevent petroleum products from contacting the membrane as they will damage or destroy the membrane. The prefilter must also be regularly changed, and the membrane may need to be treated with a biocide occasionally Reverse osmosis filter are also available that will use normal municipal or private water pressure to remove contaminates from water, as long as they aren’t present in the levels found in sea water. The water produced by reverse osmosis, like distilled water, will be close to pure H2O. Therefore mineral intake may need to be increased to compensate for the normal mineral content of water in much of the world.

Distillation

Distillation is the evaporation and condensation of water to purify water. Distillation has two disadvantages: 1) A large energy input is required and 2) If simple distillation is used, chemical contaminants with boiling points below water will be condensed along with the water.

Distillation is most commonly used to remove dissolved minerals and salts from water. The simplest form of a distillation is a solar still. A solar still uses solar radiation to evaporate water below the boiling point, and the cooler ambient air to condense the vapor. The water can be extracted from the soil, vegetation piled in the still, or contaminated water (such as radiator fluid or salt water) can be added to the still. While per still output is low, they are an important technique if water is in short supply

Other forms of distillation require a concentrated heat source to boil water which is then condensed. Simple stills use a coiling coil to return this heat to the environment. These can be improvised with a boiler and tight fitting lid and some copper tubing (Avoid using lead soldered tubing if possible). FEMA suggests that, in an emergency, a hand towel can be used to collect steam above a container of boiling water. More efficient distillations plants use a vapor compression cycle where the water is boiled off at atmospheric pressure, the steam is compressed, and the condenser condenses the steam above the boiling point of the water in the boiler, returning the heat of fusion to the boiling water. The hot condensed water is run through a second heat exchanger which heats up the water feeding into the boiler. These plants normally use an internal combustion engine to run the compressor. Waste heat from the engine, including the exhaust, is used to start the process and make up any heat loss. This is the method used in most commercial and military desalinization plants

Inflatable solar stills are available from marine supply stores, but avoid the WW2 surplus models, as those who have used them have had a extremely high failure rate. Even new inflatable solar stills may only produce from 30-16 oz under actual conditions, compared to a rating of 48 oz/day under optimum conditions. Jade Mountain also offers the following portable models in travel cases: Traveler (WC106) 1 gpd, 23 lb., 24x26x10 folded $695Base Camp (WC107) 2 gpd, 51 lb., 48x48x4 folded $895Safari (WC108) 48x48x5 $1095 A ruggedized version of the Base Camp above.

Microfilters

Microfilters are small-scale filters designed to remove cysts, suspended solids, protozoa, and in some cases bacteria from water. Most filters use a ceramic or fiber element that can be cleaned to restore performance as the units are used. Most units and almost all made for camping use a hand pump to force the water through the filter. Others use gravity, either by placing the water to be filtered above the filter (e.g. the Katadyn drip filter), or by placing the filter in the water, and running a siphon hose to a collection vessel located below the filter (e.g. Katadyn siphon filter).

Microfilters are the only method, other than boiling, to remove Cryptosporidia. Microfilters do not remove viruses, which many experts do not consider to be a problem in North America. Despite this the Katadyn microfilter has seen considerable use around the world by NATO-member militaries, WHO, UNHCR, and other aid organizations. Microfilters share a problem with charcoal filter in having bacteria grow on the filter medium. Some handle this by impregnating the filter element with silver such as the Katadyn, others advise against storage of a filter element after it has been used.

The Sweetwater Guardian suggests using a freezer for short-term storage Many microfilters may include silt prefilters, activated charcoal stages, or an iodine resin. Most filters come with a stainless steel prefilter, but other purchased or improvised filters can be added to reduce the loading on the main filter element. Allowing time for solids to settle, and/ or prefiltering with a coffee filter will also extend filter life.

Iodine matrix filters will kill viruses that will pass through the filter, and if a charcoal stage is used it will remove much of the iodine from the water. Charcoal filters will also remove other dissolved natural or manmade contaminates. Both the iodine and the charcoal stages do not indicate when they reach their useful life, which is much shorter than the filter element. If you are depending on the stage for filtering the water you will have to keep up with how much water passes through it.

New designs seem to be coming out every month. The best selling brands seem to be the PUR, and Sweetwater Guardian. The Katadyn doesn't sell as well to outdoor enthusiasts due to its high cost, but for years it was state of the art for water purification and still has a loyal following, especially among professionals in relief work. Below is the data on a few of the more common units. Filter life is from manufacturer's literature and should be taken with a grain of salt.

[These prices are now several years out of date. You'll need to investigate current pricing]

Basic Designs Ceramic Filter Pump ($29/$15, 8 oz.) Cheap flimsy filter, claimed to filter up to 500 gallons with a 0.9 μm ceramic filter. Not EPA rated, may not have passed independent lab tests, prone to damage, filter element must be submerged in water.

General Ecology- First Need Deluxe ($70/$30, 20 oz) This filter uses a structured matrix micro strainer, though General Ecology won't reveal what the structure is. It has survived independent lab tests, and filters particles to 4μm, while actually removing viruses (the only filter capable of doing this) through electrostatic attraction. The filter cartridges can't be cleaned (other than by back flushing), but are good for 100 gallons. Pump design isn't the best. Other models are available from the manufacturer.

Katadyn PF ($295/$145, 22.7 oz). The original microfilter using a 0.2 μm silver impregnated ceramic candle. An extremely thick filter allows it to be cleaned many times for up to 14,000 gallons capacity. While the Katadyn seems well made, one reader of this list reported breaking the candle, and Backpacker Magazine broke the case during a field test. The pump, while probably indestructible, is somewhat slow and hard to use, requiring 20 lbs. of force on a small handle. The PF also lacks a output hose as the Katadyn engineers felt if would be a source of contamination.

Katadyn Combi ($185/$75 (ceramic)/$19 (carbon), 29 oz) A cheaper version of the PF incorporating both ceramic and carbon stages. Much faster filter than the PF.

Katadyn Minifilter ($139/$59, 8.3 oz) A smaller and cheaper version of the PF, easier to pump, but generally not well received. Good for 200 gallons.

Katadyn Expedition ($680/$77, 13 lb.) Similar filter to the PF (exact same cartridge as the Drip Filter Below), but designed for much higher production, stainless steel case with spade type D handle, produces 0.75 gpm. Filter good for 26,000 gallons.

Katadyn Drip Style Filter ($240, $77, 12.5 lb.) Filter elements similar to those in the PF are mounted vertically in top 3 gallon plastic bucket, water drips through filters into second 3 gallon bucket with faucet. 1 qt, per hour with the 2 filters included, a third filter can be added to increase rate 50%. Each filter good for 13,000 gallons. The mounting hardware for the filters is available for $10 to allow you to make your own filter of whatever size is needed. Each mounting kit requires a ½" hole in the bottom of the raw water container.

Katadyn Siphon Filter ($92, 2 lb.) Similar design to PF filter element, but a siphon hose replaces the pump, filters 1-2 quarts per hour (allow 1 hour for the filter to "prime" itself via capillary action), but multiple filters can be used in the same container. Collection vessel must be lower than raw water container. Good for13,000 gallons.

MSR Miniworks ($59/$30, 14 oz) MSR's smaller filter, using a 0.3 µm ceramic element. Pump is well designed, and easy to use. Main drawback is that the clean water discharge is from the bottom of the filter, and no hose is provided. While the bottom is threaded for a Nalgene bottle, it is a pain in the butt to fill a canteen or 2 liter bottle. Claimed to filter 100 gallons, Backpacker Magazine feels this may be one of the few filters without a grossly inflated rating.

MSR Waterworks ($140/$30/$30, 17 oz) MSR's first filter with a 0.2 µ ceramic and membrane stage and a carbon stage. Other wise similar to the Miniworks.

PUR Pioneer ($30/$4, 8 oz), newly introduced low-end microfilter. 0.5 µm, 1 lpm filter rate, 12 gallon capacity

PUR Hiker ($50/$20, 12 oz) PUR's microfilter only design, filters to .5 µm. Well liked, as are the other PUR filters. Very compact. 200 gallon capacity

PUR Scout ($70/$35/$15, 12 oz) Combines a iodine resin stage, a 1.0 µm filter, and a activated charcoal filter. 200 gallon capacity

PUR Explorer ($130/$45, 22 oz) PUR's top of the line model. Bulky, but well made, with a high output (1.4 lpm, faster than any of the hand held models listed and one of the easiest to pump) Has a 1.0 µm filter plus a iodine resin stage, 300 gallon capacity

Sweetwater Walkabout ($35/$13, 8.5 oz.) Sweetwater's low end filter, 0.2 µm, .7 lpm, 100 gal capacity

Sweetwater Guardian ($60/$20, 11 oz) Uses a glass fiber and carbon filter, filters to .2 µm, claimed to last for 200 gallons. An iodine resin stage can be added that will kill viruses, and will last for 90 gallons. Pump is well designed, but it takes a few seconds to pull a captive pin to fold for storage. Available in white or OD.

Timberline Eagle ($20/$13, 8 oz) At 1 µm, this filter only does protozoa, but is much easier to pump, lighter, and cheaper. Filter is attached to pump, and must rest (but doesn't have to be submerged) in water to be purified. Looks flimsy, but seems to hold up. Claimed to last for 100 gallons. It is also possible to build your own microfilter using diatomaceous earth, sold for swimming pool filters (DE). Usually pressure is required to achieve a reasonable flow rate. A DE filter will remove turbidity as well as pathogens larger than 1 um. [This type of diatomaceous earth is NOT the type you want for food storage. Don't get them confused.

Slow Sand Filter

Slow sand filters pass water slowly through a bed of sand. Pathogens and turbidity are removed by natural die-off, biological action, and filtering. Typically the filter will consist of 24 inches of sand, then a gravel layer in which the drain pipe is embedded. The gravel doesn't touch the walls of the filter so that water can't run quickly down the wall of the filter and into the gravel. Building the walls with a rough surface also helps. A typical loading rate for the filter is 0.2 meters/hour day (the same as .2 m^3/m^2 of surface area). The filter can be cleaned several times before the sand has to be replaced.

Slow sand filter construction information:

Slow sand filters should only be used for continuous water treatment. If a continuous supply of raw water can't be insured (say using a holding tank), then another method should be chosen. It is also important for the water to have as low turbidity (suspended solids) as possible. Turbidity can be reduced by changing the method of collection (for example, building an infiltration gallery, rather than taking water directly from a creek), allowing time for the material to settle out (using a raw water tank), prefiltering or flocculation (adding a chemical such as alum to cause the suspended material to floc together.)

The SSF filter itself is a large box, at least 1.5 meters high. The walls should be as rough as possible to reduce the tendency for water to run down the walls of the filter, bypassing the sand. The bottom layer of the filter is a gravel bed in which a slotted pipe is placed to drain off the filtered water. The slots or the gravel should be no closer than 20 cm to the walls. again to revent the water from bypassing the sand. The sand for a SSF needs to be clean and uniform, and of the correct size. The sand can be cleaned in clean running water, even if it is in a creek. The ideal specs on sand are effective size (sieve size through which 10% of the sand passes) between 0.15 and 0.35 mm, uniformity coefficient (ratio of sieve sizes through which 60% pass and through which 10% pass) of less than 3, Maximum size of 3 mm, and minimum size of 0.1 mm.

The sand is added to a SSF to a minimum depth of 0.6 meters. Additional thickness will allow more cleanings before the sand must be replaced. 0.3 to 0.5 meters of extra sand will allow the filter to work for 3-4 years. An improved design uses a geotextile layer on top of the sand to reduce the frequency of cleaning. The outlet of a SSF must be above the sand level, and below the water level. The water must be maintained at a constant level to insure an even flow rate throughout the filter. The flow rate can be increased by lowering the outlet pipe, or increasing the water level. One common idea for maintaining the water level is to use a elevated raw water tank or pump, and a ball valve from a toilet.

While the SSF will begin to work at once, optimum treatment for pathogens will take a week or more. During this time the water should be chlorinated if at all possible (iodine can be substituted). After the filter has stabilized,