Water

A Vital Necessity

Painful thirst has been experienced by very few Americans. We take for granted that we will always have enough water to drink. Most of us think of "food and water" in that order, when we think of survival essentials that should be stored. But if unprepared citizens were confined in a shelter, they soon would realize that they should have given first priority to storing adequate water. Therefore, having an ample supply of clean water is a top priority in an emergency. A normally active person needs to drink at least two quarts (half gallon) of water each day. People in hot environments, children, nursing mothers, and ill people will require even more. You will also need water for food preparation and hygiene. Plan for at least 1/2 gallon of water per person per day for basic hydration. If you want to cook grains and legumes, increase that to one full gallon per person per day. With an additional two or three gallons per person per day, you can be clean. On a limited supply of water, watch for signs of dehydration including: dark urine with a very strong odor; dark, sunken eyes; low urine output; fatigue; loss of skin elasticity; emotional instability; thirst; a “trench line” down center of the tongue; and delayed capillary refill in the fingernail beds. If you are in a survival situation without other sources of water, digging a well for water is not usually worth the energy and sweat.

For the purpose of emergency planning, the water you use on a daily basis should be categorized by the quality and quantities you actually require. For example, water for oral hygiene or drinking requires the highest quality, but the lowest quantity; water for cleaning your body or your clothes requires the lowest quality, water for cooking falls somewhere in-between. The differences among these three applications are important to understand, because if your community cannot furnish clean water to your home, you will have to furnish it for yourself; however, not all of your water has to be good enough to drink. You certainly do not need to flush your toilet with drinking water, yet all of the water that is piped into your home is clean enough to drink.

Drinking alcohol or salty foods will increase your water requirements and should be avoided. Also, if you have extremely little to drink, consider minimizing your protein intake, as protein takes water to digest. If you have no water, you should not eat at all. When one is sweating heavily and not eating salty food, salt deficiency symptoms especially cramping are likely to develop within a few days. To prevent this, 6 or 8 grams of salt (about 1/4 oz, or 1/2 tablespoon) should be consumed daily in food and drink. If little or no food is eaten, this small daily salt ration should be added to drinking water. Under hot conditions, a little salt makes water taste better.

For the kidneys to eliminate waste products effectively, the average person needs to drink enough water so that he urinates at least one pint each day. (When water is not limited, most people drink enough to urinate 2 pints. Additional water is lost in perspiration, exhaled breath, and excrement.) Under cool conditions, a person could survive for weeks on 3 pints of water a day if he eats little food and if that food is low in protein. Cool conditions, however, would be the exception in crowded belowground shelters occupied for many days. Under such circumstances four or five quarts of drinking water per day are essential in very hot weather, with none allowed for washing. Even minimum hydration rations for one person for one month take up a lot of storage space, so after you have obtained a six-month supply of drinking water for everyone in your family, any additional storage of water for cooking and cleaning may not be practical. With a bit of planning and a good supply of containers, you can safely postpone storage of your drinking water rations until several days after a pandemic has been declared; however, you may eventually need an alternate source of water for cooking and cleaning. For example, it does not really matter how dirty the water is if you only need it for flushing a toilet.

Remove as much silt as possible. This will extend the service life of your filter cartridges, if you do not have a proper water filter, you can remove most of the sediments from collected water by pouring it through a few coffee filters or layers of cloth. Filter the water down to 0.2 microns to remove organisms such as cryptosporidium and giardia lamblia, which cannot be killed with small amounts of bleach. Consider the purchase of a high quality, portable, water filter like the Katadyn Gravidyn, for treating the water you collect. Be sure that the device you purchase is easy to use by everyone and will meet the needs of your entire household for at least one full year. (The Gravidyn produces one gallon of 0.2 micron filtered water per hour, has no moving parts, requires no power, does not have to be attended, is good for 10,000 gallons, and costs about $160). Add a chemical treatment to the water to kill as many organisms as possible. A filter can remove viruses, but they are easily killed with a small amount of sodium hypochlorite, also known as ordinary laundry bleach (unscented Clorox or Purex).

Consider storing at least a two-week supply of water for each member of your family. If you are unable to store this quantity, store as much as you can. If supplies run low, never ration water. Drink the amount you need today, and try to find more for tomorrow. Purchase food-grade water storage containers from surplus or camping supplies stores to use for water storage. As soon as a pandemic is declared, fill as many storage containers as possible with municipal tap water. To be sure that your tap water will remain completely free of biological hazards for a full year, add 4 drops (1/8 teaspoon) of unscented chlorine bleach per gallon.

Save your disposable soft drink and water bottles for future storage of water, allow them to dry and then store them in new trash bags. When the pandemic is announced, sanitize these bottles and caps by immersing them in a solution of 1 tablespoon of chlorine bleach per gallon of water for two minutes. Then, fill them with water from your tap. Add 4 drops of unscented chlorine bleach per gallon as a preservative and this water will be safe to drink for at least one year. Save your plastic milk jugs, too, but do not plan to store drinking water in them. Due to the milk protein residues, you can never really get them clean enough. Instead, use them to store water for washing or flushing only. Milk jugs will biodegrade, so keep them out of the sunlight.

Safe water sources in your home include the water in your hot- water tank, pipes, and ice cubes. You should not use water from toilet flush tanks or bowls, radiators, chemically treated waterbeds. To use the water in your pipes, let air into the plumbing by turning on the faucet in your home at the highest level. A small amount of water will trickle out. Then obtain water from the lowest faucet in the home. To use the water in your hot-water tank, be sure the electricity or gas is off, and open the drain at the bottom of the tank. Start the water flowing by turning off the water intake valve at the tank and turning on a hot-water faucet. Refill the tank before turning the gas or electricity back on. If the gas is turned off, a professional will be needed to turn it back on. You will need to protect the water sources already in your home from contamination if you hear reports of broken water or sewage lines, or if local officials advise you of a problem. To shut off incoming water, locate the main valve and turn it to the closed position. Be sure you and other family members know beforehand how to perform this important procedure.

Water that you collect from any alternate source for washing your body or clothes should be treated with 8 drops of bleach per gallon; however, this water should still be considered potentially hazardous, even with the addition of bleach. The large volume that you require for washing makes filtration impractical, so you must not allow this water to come into contact with your face or any broken skin (remember cryptosporidium and giardia lamblia). If you need to wash your face or broken skin, boil this water first, or use drinking water instead. All cooking water that you collect from alternate sources should be boiled. If it reaches a full boil during cooking, you will not have to add bleach. You can boil water from just about any source and make it safe for drinking in a single step, but this process uses an awful lot of fuel. If you do not have enough water for properly washing pots and pans, wipe clean with a paper towel, then sanitize them by soaking them in bleach water for two minutes. 1 tablespoon of bleach per gallon is adequate for kitchen use. If your domestic water supply is ever interrupted, you can conserve water by using disposable cups, plates, and utensils.

Disinfecting Large Containers For Drinking Water Storage: First wash your container thoroughly using soap and water. Use a plastic bristle brush to remove any particulate matter adhered to the inside container surface. A high-pressure spray washer is also useful for this task. Thoroughly rinse all soap from the container. Spray or wipe the inside of the container with the 1:50 bleach solution. Be careful to drench all internal surfaces of the container including the lid or top. Repeat this step every 15 minutes twice more. Allow the disinfecting solution to sit in the container for 1 hour then discard it. Do not rinse the container with water after decontamination because this reintroduces new contaminates. The container is ready for use. It can be filled immediately after decontamination or the top can be secured and it can be filled later. If latter, repeat the use of the bleach disinfecting steps just prior to filling the containers with water.

Water Problems And Corrections

Many people determine the quality of the water they consume by how it smells, tastes or looks. Although these are important criteria, they are primarily aesthetic properties of the water. A glass of water may not look, smell or taste good, but it could still be suitable to drink from a health standpoint. The way water looks, smells and tastes can be used to help determine what type of treatment is necessary to improve the quality of the water. The following guidelines will help you determine if there are any problems with your water and what the most likely cause of those problems might be. All you need is a clear container to take a water sample and then use your senses of sight, smell and taste.

Water Problems

Appearance	**Reason**
Water is clear when first drawn from the raw water tap then becomes yellow or reddish in appearance, but clears upon standing for 24 hours.	Dissolved iron present.
Water is yellow or reddish when first drawn from the raw water tap but clears upon standing for 24 hours.	Un-dissolved iron present.
Yellow or brownish cast to water even after softening and/or filtering and does not clear up after standing for 24 hours.	Tannin (humic acid) in water. Comes from water passing through coal veins, peaty soils and decaying vegetation.
Black cast to water that clears upon standing for 24 hours.	Dissolved manganese present.
Milky water	Excessive air in the water caused by the well pump sucking air (excessive drawdown) or a malfunctioning pressure tank. Also, can be caused by high amounts of bicarbonate precipitates resulting from an increase in pH.
Blackening, tarnishing, or pitting of metal sinks, utensils, pipes, etc.	High amounts of salt (chlorides and sulfates) or hydrogen sulfide gas.
Green stains on sinks and other porcelain bathroom fixtures. Blue green cast to water.	Acidic water (pH below 6.8) reacting with brass and copper pipes and fittings.
Suspended matter in water.	Caused by riled up water in a surface supply or sand pumping from a well.
Soap curds and lime scum in wash basins and bathtubs. Whitish scale deposits in tea kettle and on the ends of plumbing fixtures (faucet, shower head, etc.).	Hard Water caused by calcium and magnesium salts in the raw water supply.
Stained aluminum cookware.	High dissolved mineral content and high alkalinity in the raw water.
Smell	**Reason**
Chlorine smell.	Normal chlorination of public or private well sources.
Fishy, musty or earthy smell.	Generally harmless organic matter. Commonly associated with surface water supplies.
Rotten egg odor from the raw water tap or directly from the well.	Dissolved hydrogen sulfide gas in the raw water.
Rotten egg odor only from the hot water tap.	Sulfates present in the raw water reacting with the magnesium anode which causes hydrogen sulfide gas. Can be corrected by removing the anode or replacing it with an aluminum anode.
Detergent odor and water foams when drawn. Also septic odor.	Leakage from a sewer system is entering the water supply.
Taste	**Reason**
Salty flavor to the water that may have a laxative effect in some situations.	High salt content (primarily sodium sulfate and magnesium sulfate).
Metallic taste.	High concentration of manganese, or possibly other metals.

When the cause of a water problem has been identified, then a method of treatment can be used to correct or minimize the problem. Before purchasing a treatment system, first have your water analyzed by a state certified laboratory to determine the quantity of foreign material in your water. The most common water tests are for: Coliform Bacteria, Nitrates, pH, Total Dissolved Solids, Hardness, Iron and Manganese

After the water is analyzed, you can use the following chart to determine what treatment methods are needed to correct the problem. You may have identified more than one problem. If this is the case, you may need more than one type of treatment. Many reputable water treatment companies have equipment that will treat more than one problem.

Water Corrections

Problem	Common Treatment Methods
Bacterial contamination	Treat using chlorination or other forms of disinfection (boiling, iodine, etc.) until the source of contamination is found and corrected or removed.
Fine sand, clay or other sediments	Remove using mechanical (fine screen) or sand filtration.
Odor and taste other than ROTTEN EGG SMELL	Corrected with activated carbon filters.
Hydrogen Sulfide Gas (ROTTEN EGG SMELL)	Remove using chlorination followed by sedimentation or use an oxidation filter (sometimes called an aeration filter) followed by an activated carbon filter to remove excess chlorine.
Small amounts of dissolved iron and manganese.	Remove with a common water softener. The water softener manufacturer should have a level of iron removal rating.
High amounts of dissolved iron and manganese	Remove using an oxidizing agent such as potassium permanganate or chlorine followed by a mechanical screen or use a green sand filter.
Suspended iron and manganese particles	Remove using mechanical (fine screen) or sand filtration.
Hard water	Treat using a water softener.
Acid water (pH less than 5.0)	Treat with a neutralizing filter (adds calcium carbonate).
Alkaline water (pH greater than 9.0	Treat by injecting a weak acid (acetic) acid or white vinegar.
Tannin (humic acid)	Remove using chlorination with a detention tank or a special anion exchange unit.
Volatile organic compounds, certain pesticides, trihalomethanes and radon	Remove using an activated carbon filter. Other treatment options include reverse osmosis or distillation.
Nitrates, heavy metals*	Remove with reverse osmosis or by distillation.

Collecting Water

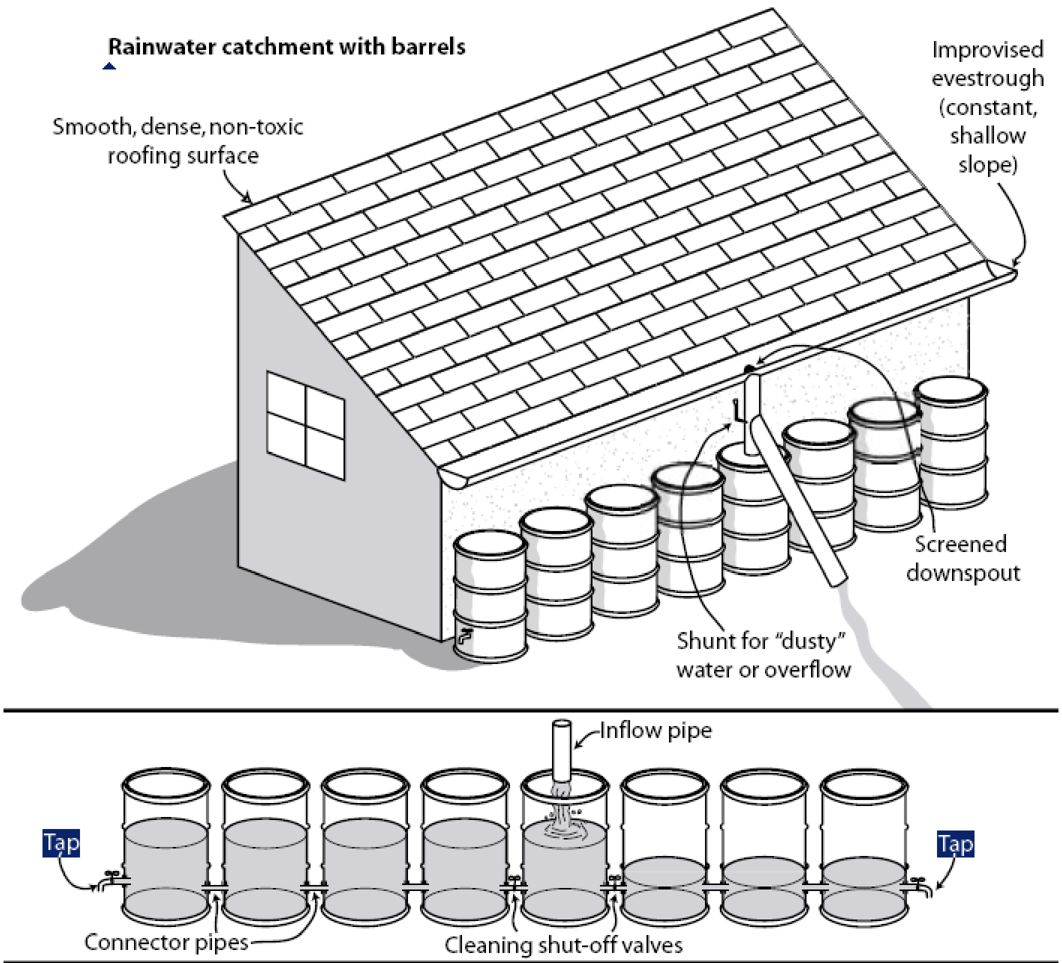
Before a supply of stored drinking water has been exhausted, other sources should be located. The main water sources are given below, with the safest source listed first and the other sources listed in decreasing order of safety.

- Water from covered deep wells and from water tanks (Caution: Although most spring water would be safe, some spring water is surface water that has flowed into and through underground channels without having been filtered.)
- Water collected from roofs.
- Water obtained by melting snow or from snow lying on the ground onto which fallout has fallen.
- Water from covered seepage pits or shallow, hand-dug wells. If the earth is not sandy, gravelly, or too porous, filtration through earth is very effective.
- Water from a deep lake would be much less contaminated by dissolved material and particles than water from a shallow pond would be.
- Water from shallow ponds and other shallow, still water.

Rainwater

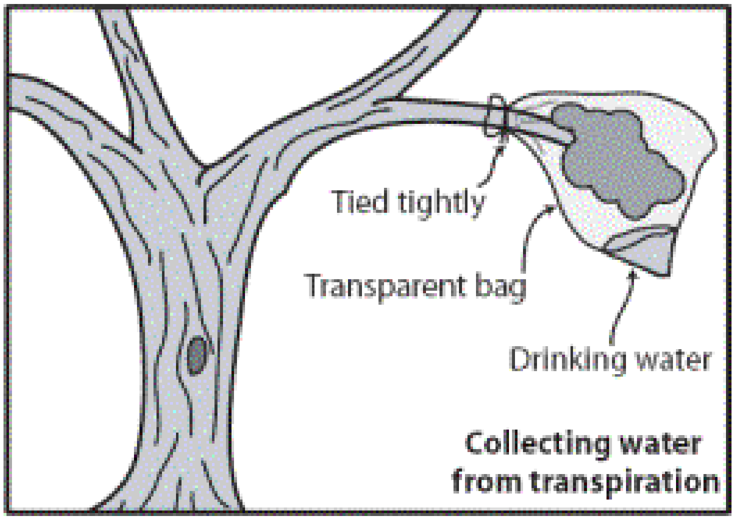
Rainwater is a source of clean water, so try to collect as much rainwater as possible. Allow the first runoff after a long dry spell to flow away, to clean dust and such from the roof or catchment. According to UNEP the ideal roofing for a water source is smooth, dense and non-toxic. They suggest that this includes “corrugated aluminum and galvanized iron, concrete, asphalt or fiberglass shingles, tiles with a neoprene-based coating, and mud”. They suggest avoiding the use of “natural” materials such as thatch as a source of drinking water, because such roofs may attract insects and rodents, and yield contaminated and discolored water. They also suggest that flat ground surfaces, such as runways, can be used as long as they are fenced off to prevent access and contamination from human and non-human animals.

One millimeter of rainfall will yield about 0.8 liters of water per square meter of catchment area. (In US imperial units, that means that each inch of rain will give about 6.4 gallons per square yard.) Loss is due to evaporation, and varies by climate. In cooler climates you will get closer to a full liter per square meter (or 8 gallons per square yard). Water storage containers should *always* be covered to prevent contamination. Also, pipes or openings to the tanks (except the faucet) should always be screened to prevent the access and breeding of mosquitoes or other insects. See the illustration for examples of several rainwater catchment options.



Transpiration

Trees and plants naturally release water through their leaves as they breathe. You can put a transparent bag, such as a clear garbage bag, over a branch as shown, below and seal it airtight. Water will condense and collect at the corner of the bag. You can make a small hole or slit to drain the water, and then tie or seal it shut again. Don't bag the branch for too long in hot weather, or it may die. Do not use poisonous plants.

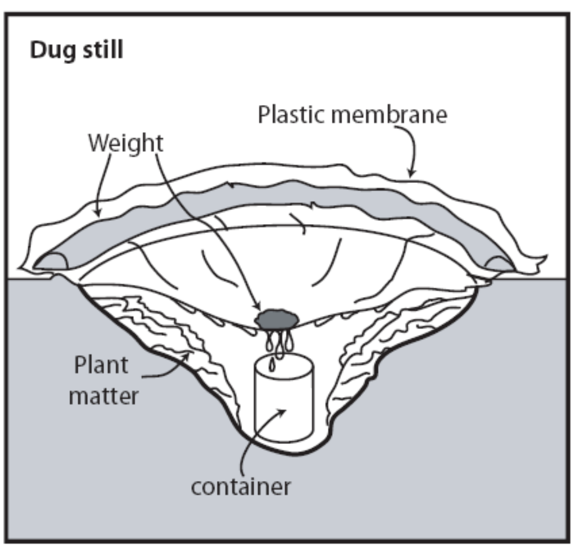


Distillation

Distillation works by evaporating water from a suspect source, which then condenses, leaving distilled water. This is an excellent way to get drinking water from seawater.

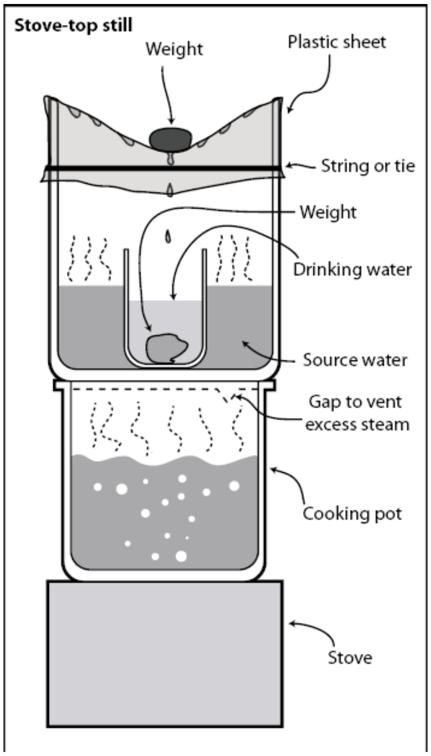
Dug Still

One of the simplest ways to get water in a dry area is to dig a hole, as shown at above right, and place a container in the middle. Then place a clear plastic sheet over the hole, with a stone in the middle and weighting on the edges. The water that evaporates out of the soil will condense and drip into the container. You can also use a flexible hose to suck water out of the container. You might be able to add succulent leaves or vegetable matter into the hole, to provide more water for evaporation. Look for the best spot to dig a hole like this, such as depressions or valleys, areas with green plants, or areas that look damp. Try to place the still in a sunny spot, so that you get more evaporation and condensation



Stovetop Still

Distillation works by evaporating water from a suspect source, which then condenses, leaving distilled water. This is an excellent way to get drinking water from sea water, and is the only method described here, which will remove salt. You can make a stovetop still, like the one shown, very easily. You place the still on top of a pot that is cooking and utilize the existing heat to distill fresh water

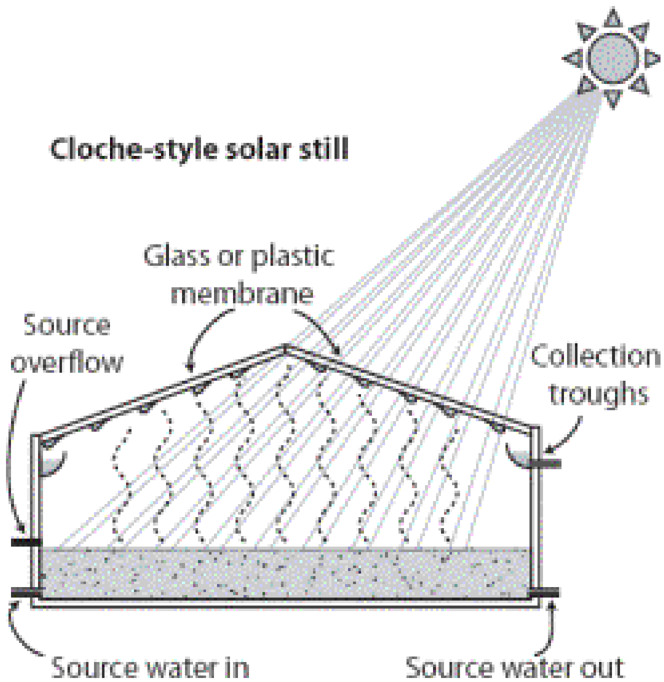


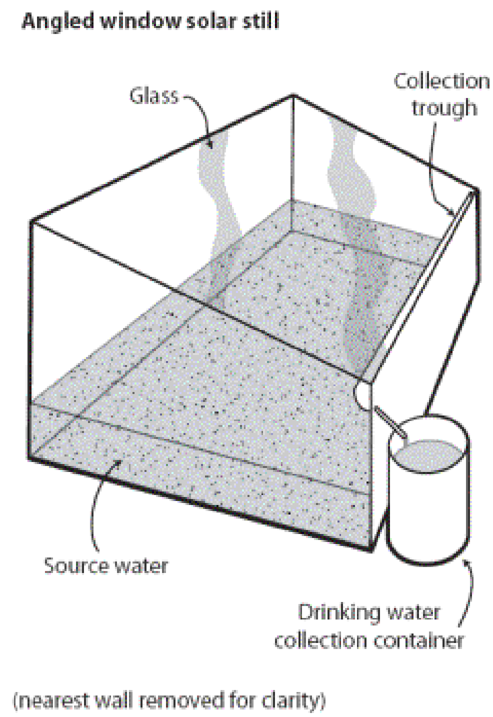
Solar Stills

Solar stills can be made easily and cheaply to provide a quick source of clean water. They provide enough water for personal use, but not enough for gardening, since they would have to be as large as the garden itself to provide enough water. They use solar radiation to evaporate water from a contaminated or questionable water source.

To make a solar still, make a small greenhouse out of the materials you have available. See the Cloche Style still for an example using windows or plastic. Make a container for the source water lined with black, so that the water will heat up as much as possible in the sun. You may want to insulate underneath the source container if you are going to place the still on the ground. Then place a shallow trough along the lower edge to capture the condensed droplets as they slide down the glass. Plastic sheeting can also be used, but some people report that droplets usually do not cling to plastic as well as glass, so they may drop back into the source container. However, the "clinginess" can be improved by lightly rubbing sandpaper over the interior surface of the plastic. If you do use plastic, make sure that it is pulled tight over the frame, or the wind may flap and tear it. You can make a solar still with a sloped glass covering like the one shown below. This same device can be used as a solar food dehydrator, or a cold frame for gardening. (This is an example of how you can create equipment appropriate to your bioregion and climate: for example, if you have rainy springs, hot dry summers, and moderate autumns, you can use this device to start your vegetables in the spring, while you are drinking rainwater, and then use it as a still to provide drinking water in the summer, and then to dry the produce in the fall.) You can make this kind of still (dehydrator, cold frame) from 3' by 6' patio door windows, which are regularly replaced at many apartment buildings. You may be able to buy them cheaply by the hundred. Admittedly, you might not be able to use them all yourself, but your neighbors will thank you when you share. (If you store glass in such numbers, be sure to store the panes with spacers so that they don't touch - water trapped between them will etch and mar the glass permanently.) This design would also work well on a rooftop.

A still can produce about 4 liters of water per square meter (1.26 liters per square yard), per day, on a good day. The upside of the solar still is that you can put your wash water back into the still to get drinking water again. You could even put urine in. For stills, keep in mind that the distilled water produced also has no trace minerals present, so it is not ideal as the sole drinking water source for young children over extended periods of time.



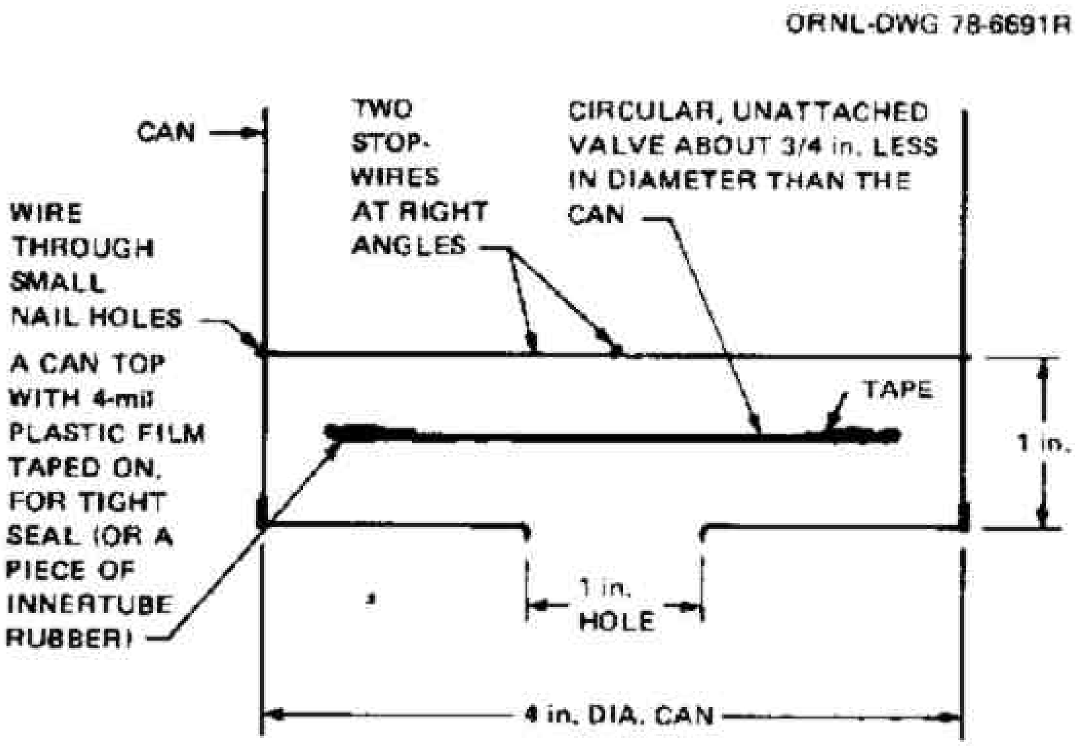


Water From Wells, Springs And Snow

Springs are generally an excellent source of clean water. However, in some situations water from a contaminated surface source can travel a short distance in an underground channel and only appear to be a spring. You may want to check. Springs appear in areas where the water table reaches the surface, generally on the side of a hill or other slope. The water is forced out to the surface. Check maps of your area for known spring sites. Also, spring-fed streams may be fuller in the dry-season than rain-fed streams. If you can identify spring-fed streams, you can follow them back to the source.

Snow can also be used as a source of water, but should be gathered from clean sources away from animal traffic (including humans) to avoid possible contamination. Ten portions of snow will yield about one portion of water, so if you are melting snow in a container on a fire for drinking, keep topping up the container so that the water doesn't boil and evaporate. (Unless you believe the water is suspect and want to boil it.) Don't try to melt snow in your mouth. In cold climates, this will rob your body of too much valuable heat. If water is cold, just sip it, don't gulp.

The wells of farms and rural homes would be the best sources of water for millions of survivors. Following a massive power loss, the electric pumps and the pipes in wells usually would be useless. Electric power in most areas would be cut off. Bail-cans could be used to reach water and bring up enough for drinking and basic hygiene. Fig. 8.10. Lower part of an expedient bail-can. The unattached, "caged" valve can be made of a material that does not have the springiness of soft rubber.



How to make a simple bail-can is illustrated in Fig. 8.10. An ordinary large fruit-juice can will serve, if its diameter is at least 1 inch smaller than the diameter of the well-casing pipe. A hole about 1 inch in diameter should be cut in the center of the can's bottom. The hole should be cut from the inside of the can: this keeps the inside of the bottom smooth, so it will serve as a smooth seat for a practically watertight valve. To cut the hole, stand the can on a flat wood surface and press down repeatedly with the point of a sheath knife, a butcher knife, or a sharpened screwdriver. The best material for the circular, unattached valve shown in Fig. 8.10 is soft rubber, smooth and thin, such as inner-tube rubber. Alternately, the lid of a can about 3/4 inch smaller in diameter than the bail- can may be used, with several thicknesses of plastic film taped to its smooth lower side. Plastic film about 4 mils thick is best. The bail (handle) of a bail-can should be made of wire, with a loop at the top to which a rope or strong cord should be attached. Filling-time can be reduced by taping half-pound of rocks or metal to the bottom of the bail-can.

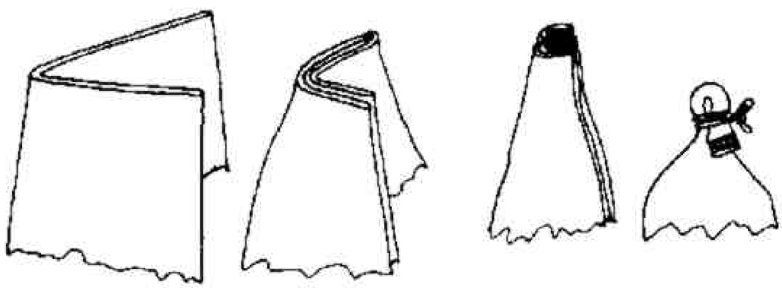
Carrying Water

Most families have only a few large containers that could be used for carrying water to a shelter and storing it in adequate amounts for several weeks. Polyethylene trash bags make practical expedient water containers when used as waterproof liners *inside* smaller fabric bags or pillowcases. (Plastic bags labeled a& being treated with insecticides or odor-controlling chemicals should not be used.)

Figure 8.1 shows a teenage boy carrying over 10 gallons (more than 80 pounds) of water, well balanced front and back for efficient packing. Each of his two burlap bags is lined with two 20-gallon polyethylene trash bags, one inside the other. (To avoid possible pinhole leakage it is best to put one waterproof bag inside another.) To close a plastic bag of water so that hardly any will leak out, first spread the top of the bag until the two inner sides of the opening are together. Then fold in the center so that the folded opening is 4 thicknesses, and smooth (see Fig. 8.2). Continue smoothly folding in the middle until the whole folded-up opening is only about 1-1/2 inches wide. Then fold the top of the bag over on itself so the folded-up opening points down. With a strip of cloth or a soft cord, bind and tie the folded-over part with a bow knot, as illustrated.

Fig. 8.1. Carrying 80 pounds of water in two burlap bags, each lined with two larger plastic trash bags, one inside the other.

Fig. 8.2. Folding and tying the mouth of a water-filled plastic bag.

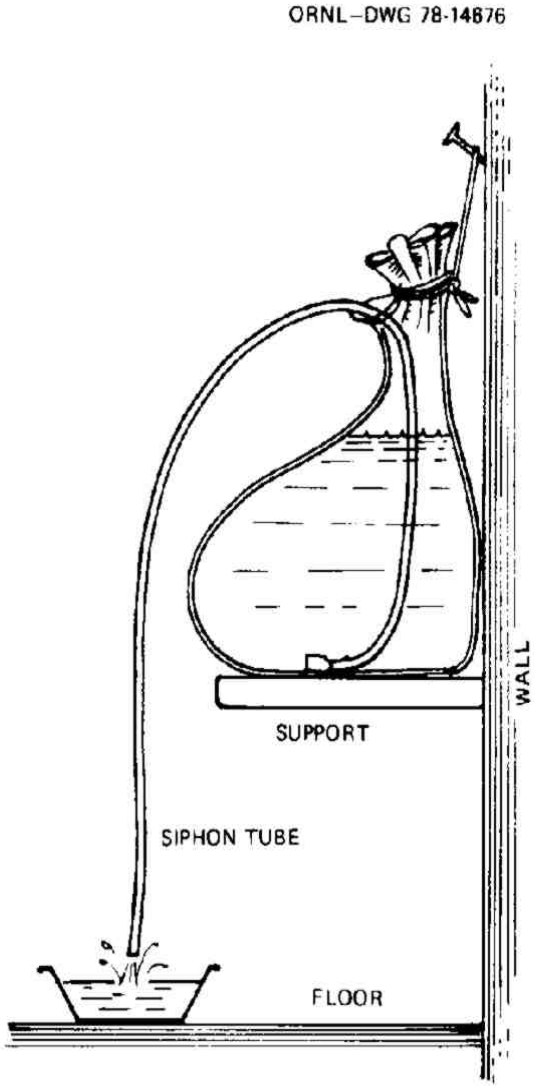


For long hikes, it is best to tie the water-holding plastic bags so that the openings 'are higher than the water levels inside. To transport this type of expedient water bag in a vehicle, tie a rope around the fabric outer bag near its opening, so that the rope also encircles and holds the plastic liner-bags just below their tied-shut openings. The other end of this rope should then be tied to some support, to keep the openings higher than the water level. To use two fabric bags or pillowcases to carry a heavy load of water contained in *larger* plastic liner- bags connect the two fabric bags as shown in Fig. 8.1. A small pebble, a lump of earth, or a similar object should be tied inside the opening of each bag before the two are tied together, to hold them securely. The bag that is to be carried in front should have the pebble tied about 4 inches further down from the edge of its opening than the pebble tied **in** the bag to be carried in back. This keeps the pebbles from being pressed against the carrier's shoulder by a heavy load. A pair of trousers with both legs tied shut at the bottoms can be used to carry a balanced load if pillowcases or other fabric bags are not at hand. Such a balanced load can be slung over the shoulder with the body erect and less strained than if the same weight were carried in a single bag-like pack on the back. However, trouser legs are quite narrow and do not provide room to carry more than a few gallons. To prevent water from slowly leaking through the tied-shut openings of plastic bags, the water levels inside should be kept below the openings.

Siphoning

Pouring water out of a heavy water-storage bag is inconvenient and often results in spillage. Dipping it out can result in contamination. If a tube or piece of flexible garden hose is available, siphoning (see Fig. 8.6) is the best way. A field-tested method is described below. To prevent the suction end of the tube from being obstructed by contact with the plastic liner of the bag, tape or tie a wire "protector" to the end, as pictured later in this section. To start siphoning,' suck on the tube until water reaches your mouth. Next fold over the tube near its end, to keep the tube full. Lower its closed end until it is near its position shown in Fig. 8.6. Then release your hold on the tube, to start siphoning. To cut off the water, fold over the tube and secure it shut with a rubber band or string.

Fig. 8.6. Using a tube to siphon water from a fabric bag lined with a larger plastic bag.



Water can be siphoned from a covered water storage pit into a belowground shelter so that the siphon will deliver running water for weeks, if necessary. The Utah family mentioned earlier siphoned all they needed of the 120 gallons of water stored in a nearby lined pit. A field-tested method of siphoning follows:

- Dig the water storage pit far enough away from the shelter so that the covering mounds will not interfere with drainage ditches.
- Use a flexible tube or hose which is no more than 25 feet long. For a single family, a flexible rubber tube with an inside diameter of inch (such as surgical tubing) would be best. A flexible 2-inch hose of the type used with mobile homes and boats serves well. As indicated by Fig. 8.7, the tube should be long enough to extend from the bottom of the water pit to within about a foot of the shelter floor.
- Make sure that the end in the water pit will not press against plastic and block the flow of water. This can be avoided by (1) making and attaching a wire "protector" to the end of the tube, as shown in Fig. 8.8, or (2) taping or tying the end to a rock or other object, to keep the end in the desired position.
- Protect the tube by placing it in a trench about 4 inches deep. This small trench is best dug before roofing either the storage pit or the shelter. Be sure a roof pole or board does not crush the tube. Cover the tube with earth and tie it so that the end in the storage pit cannot be accidentally pulled out of position.

Fig. 8.7. Water siphoned into a belowground shelter.

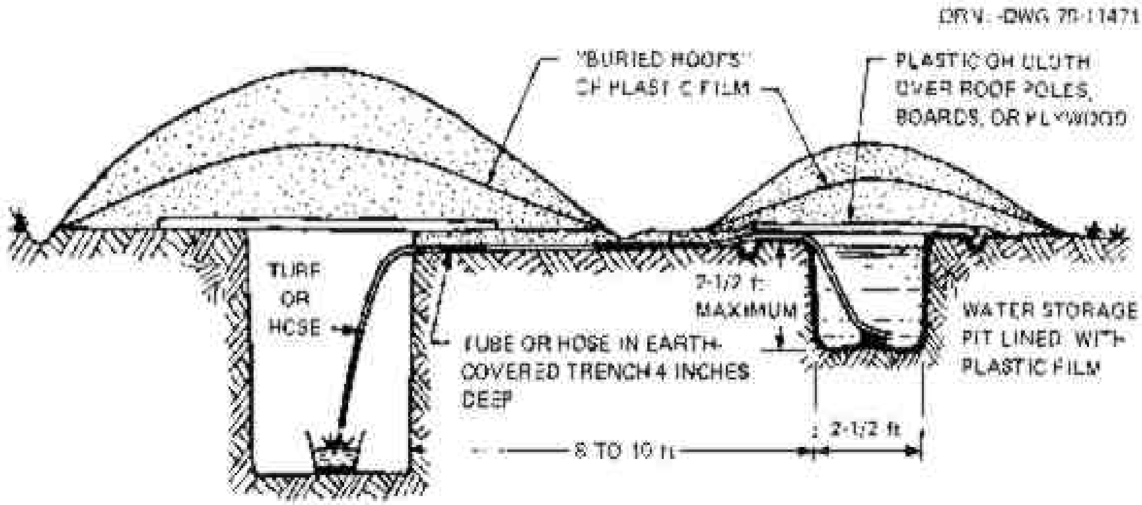
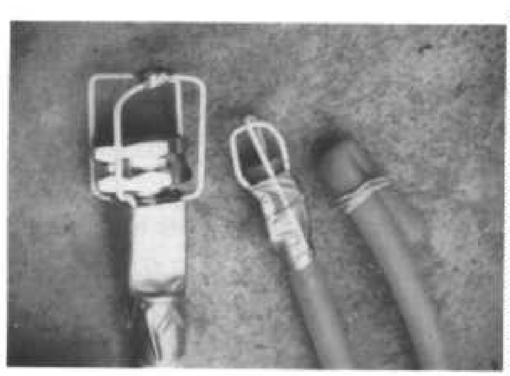


Fig. 8.8. Two wire "protectors," each made of two pieces of coathanger wire taped to a 1/2 inch flexible hose and a rubber tube. Shown on the right is a tube closed with a rubber band to stop a siphoned flow of water.



- To start the flow of water into the shelter, hold the free end of the tube at about the height of the surface of the water in the storage pit, while pulling gently on the tube so that the part in the shelter is practically straight. Exhale as much breath as you can, then place the end of the tube in your mouth, and suck hard and long. (The longer the tube or hose and the larger its diameter, the more times you will have to suck to start the flow of water.)
- Without taking the tube out of your mouth, shut it off airtight by bending it double near the end.
- Exhale, straighten the tube, and suck again, repeating until you feel a good flow of water into your mouth while still sucking. Shut off the flow by bending the tube double before taking it out of your mouth.
- Quickly lower the end of the tube (which is now full of water) and place the closed end in a container on the shelter floor. Finally, open the end to start the siphoned flow.

When you have siphoned enough water, stop the flow by bending the tube double. Keep it closed in the doubled-over, air-tight position with a strong rubber band or string, as shown in Fig. 8.8. To prevent loss of water by accidental siphoning, suspend the end of the tube a couple of inches higher than the surface of the water in the storage pit outside and close to where the tube comes into the shelter. (Despite precautions, air may accumulate in the highest part of the tube, blocking a siphoned flow and making it necessary to re-start the siphoning by repeating the sucking.)

Storing Water

When storing expedient water bags in a shelter, the water levels inside should be kept below the openings. Not many expedient shelters would be large enough to store an adequate volume of water for an occupancy lasting two or more weeks. Plastic-lined storage pits, dug in the earth close to the shelter, are dependable for storing large volumes of water using cheap, compact materials.

Fig. 8.3. Vertical section of cylindrical water storage pit lined with two 30-gallon waterproof plastic bags.

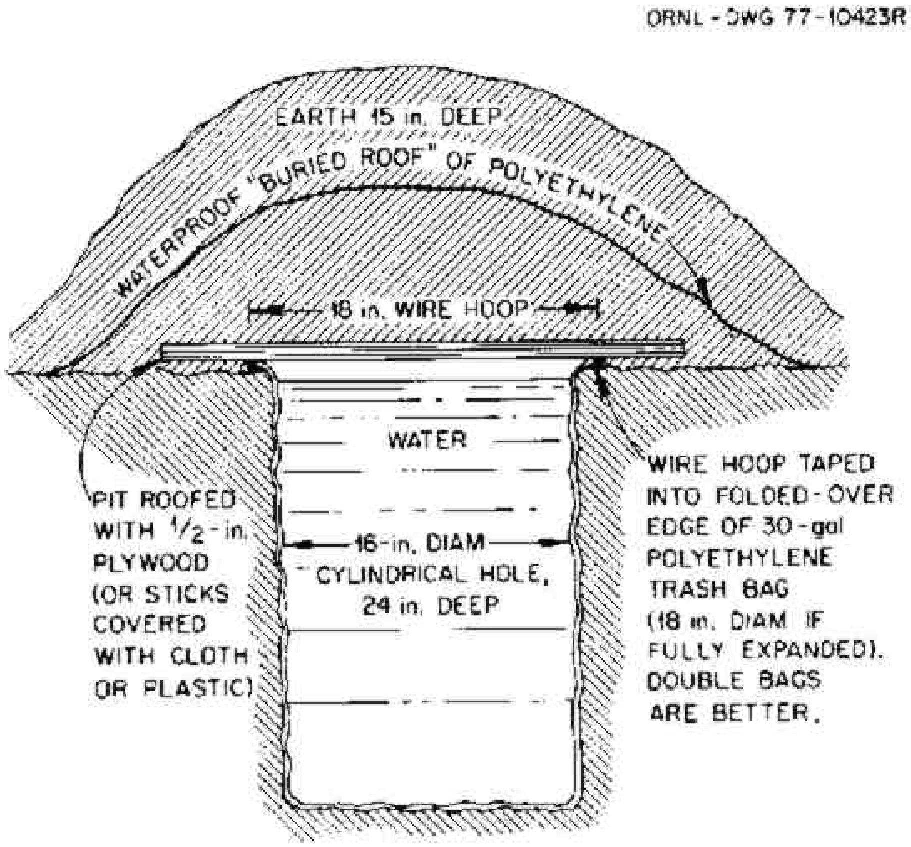


Figure 8.3 shows a cylindrical water-storage pit dug so as to have a diameter about two inches smaller than the inflated diameter of the two 30-gallon polyethylene trash bags lining it (one bag inside the other). Before a plastic bag is placed in such a pit, the ends of roots should be cut off flush to the wall with a sharp knife, and sharp rocks should be carefully removed. The best way to keep the upper edges of the pit lining bags from slipping into the pit is shown in Fig. 8.3: Make a circular wire hoop the size of the opening of the bag, and tape it inside the top. In firm ground, the upper edges of double bags have been satisfactorily held in place simply by sticking six large nails through the turned-under edges of the bags and into the firm earth.

Figure 8.3 shows how to roof and cover a water storage pit so as to protect the water. The "buried roof" of waterproof material prevents any contamination of the stored water by downward-percolating rainwater, which could contain bacteria or small amounts of radioactive substances from fallout. The thick earth cover over the flexible roofing gives excellent blast protection, due to the earth arching that develops under blast pressure. In a large Defense Nuclear Agency blast test, a filled water-storage pit of the size illustrated was undamaged by blast effects at an overpressure range which could demolish the strongest aboveground buildings (53 psi).

A simpler way to store water is illustrated in Fig.8.4. If the soil is so unstable that an un-shored water storage pit with vertical sides cannot be dug, the opening of the bag (or of one bag placed inside another) can simply be tied shut so as to minimize leakage (see Fig. 8.4). Fill the bag with water, tie it, and place it in the pit. Then bury it with earth to the level of the water inside. A disadvantage of this method is leakage through the tied-shut openings due to pressure of loose earth on the bag.

To lessen leakage, leave an air space between the filled bag and a roofing of board or sticks, so that the weight of earth piled on top of the roofing will not squeeze the bag. This storage method has another disadvantage: after the earth covering and the roof are removed, it is difficult to bail out the water for use because as water is bailed out, the loose surrounding earth moves inward and squeezes the bag above the lowered water level.

Fig. 8.4. These two 30-gallon polyethylene trash bags, one inside the other, held 16 gallons of water. The plywood roof and the earth placed over the water bag were removed before this picture was taken.

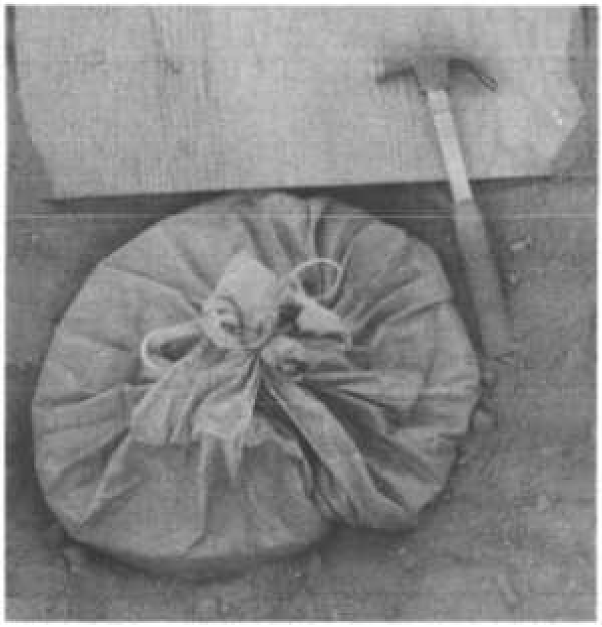


Fig. 8.5. View of plastic-lined water storage pit. This pit held about 200 gallons.

Large volumes of water can be stored in plastic lined rectangular pits. In order to roof them with widely available materials such as ordinary inch plywood or small poles, the pits should be dug no wider than 3 feet. Figure 8.5 pictures such a pit: 8 feet long, 27 inches wide, and 30 inches deep. It was lined with a 10-foot-wide sheet of 4-mil polyethylene. The edges of this plastic sheet were held in place by placing them in shallow trenches dug near the sides of the pit and covering them with earth. Earth was mounded over the plywood roof to a depth of about 30 inches, with a "buried roof" of polyethylene.

The earth cover and its "buried roof" were similar to the pit covering illustrated by Fig. 8.3. This rectangular pit contained about 200 gallons of water. No water leaked out after the pit had been subjected to blast effects severe enough to have flattened most substantial buildings. However, rectangular pits at higher overpressures failed, due to sidewall caving that caused leaks. In a subsequent blast test by Boeing Aerospace Company, a plastic-lined water pit was undamaged at the 200-psi overpressure range. First a rectangular pit 4 ft. wide, 12 ft. long, and 2 ft. deep was dug.

Then inside this pit a 2 x l0 x 2-ft. water-storage pit was dug, and lined with plastic film. After being filled full of water, the storage pit was covered with plywood, on which was shoveled 2 ft. of earth. Plastic garbage cans are usually watertight; most used metal garbage cans are not.

If thoroughly cleaned and disinfected with a strong chlorine bleach solution, watertight garbage cans can serve for emergency water storage, as can some wastebaskets. If new plastic film is available, it can be used as a lining to waterproof any strong box. To lessen the chances of the plastic being punctured, rough containers first should be lined with fabric. If shelter is to be taken in or near a building, water trapped in hot water heaters and toilet flush tanks or stored in tubs might be available.

Physical Treatment

The instructions below are for treating water of uncertain quality in emergency situations in the absence of instructions from local authorities when no other reliable clean water source is available and you have used all of your stored water. If you store enough water in advance, you will not need to treat water using these or other methods. In addition to having a bad odor and taste, contaminated water can contain microorganisms (germs, bacteria, and viruses) that cause diseases such as dysentery, typhoid, and hepatitis.

You should treat all water of uncertain quality before using it for drinking, food preparation, or hygiene. There are many ways to treat water, though none are perfect. Often the best solution is a combination of methods. Boiling or chlorination will kill most microorganisms but will not remove other contaminants such as heavy metals, salts, and most other chemicals. Before treating, let any suspended particles settle to the bottom, or strain them through layers of paper towel or clean cloth.

Boiling

Boiling is one guaranteed way to purify water of all pathogens. At sea level, water simply brought to a boil is safe, but add one minute to the boiling time for every additional thousand meters (3300 feet) in altitude. (It's something of a myth that water has to be boiled for five or ten minutes to be safe, this is just a waste of fuel.) In a large pot or kettle, bring water to a rolling boil for 1 full minute, keeping in mind that some water will evaporate. Let the water cool before drinking. Boiled water will taste better if you put oxygen back into it by pouring the water back and forth between two clean containers. This will also improve the taste of stored water. You can also add a chunk of charcoal or some pine needles, during boiling, and remove them before drinking, to improve taste.

Straining

Straining turbid (cloudy) water through a clean handkerchief or other fine, cotton cloth is a good way of straining out larger particles of suspended contaminants like dirt. It can also remove certain tiny organisms (like copepods) that may carry pathogens, though such organisms are not present in all climates. Straining turbid water will improve the effectiveness of most other treatment methods, and is a good first step.

Settling

Settling is one of the easiest methods to remove most suspended particles from water. Furthermore, if the water to be used is muddy or murky, settling it before filtering will extend the life of the filter. The procedure is as follows:

- Fill a bucket or other deep container three quarters full of the contaminated water.
- Dig pulverized clay or clayey soil from a depth of four or more inches below ground surface, and stir it into the water. Use about a 1-inch depth of dry clay or dry clayey soil for every 4-inch depth of water. Stir until practically all the clay particles are suspended in the water.
- Let the clay settle for at least 6 hours. The settling clay particles will carry most of the suspended fallout particles to the bottom and cover them.
- Carefully dip out or siphon the clear water, and disinfect it.

Home Distillation

Distillation involves boiling water and then collecting the vapor that condenses back to water. The condensed vapor will not include salt or most other impurities. Distilled water has a bland taste, because the dissolved minerals that give water a pleasing taste have been removed. Distilled water should be stored under sanitary conditions in plastic, glass or stainless steel containers. Household distillers are designed for providing water for drinking and cooking. It is not economical to distill water for other uses like flushing toilets, bathing, washing clothes, and cleaning. The distillation process removes almost all impurities from water. Distillers are commonly used for removing nitrate, bacteria, sodium, hardness, dissolved solids, most organic compounds, heavy metals, and radionuclide from water. Distillers remove about 99.5 percent of the impurities from the original water.

- Distillers can allow 0.3 to 0.5 percent of water impurities to exist in the storage container after distilling. Some volatile organic contaminants (VOCs), certain pesticides and volatile solvents, boil at temperatures very close to water (207-218 degrees Fahrenheit). These types of contaminants will not be substantially reduced in concentration by distillation. Properly equipped distillers can reduce VOC concentrations effectively.
- Although bacteria are removed by distillation, they may re-colonize on the cooling coils during inactive periods.

Distillers are commonly made of stainless steel, aluminum, and plastic materials. These materials do not absorb impurities from water and are easy to clean. There are two types of distillers: batch units and continuous flow units.

- **Batch Distillers:** Water is poured directly into the boiling chamber. The unit is turned on and the water is heated to boiling. When all the water in the boiling chamber is evaporated, the unit shuts off. Distilled water is removed from the storage container for household use. Batch units can range from 1gallon countertop units to 10gallon floor units. Batch distillers produce from 3 to 10 gallons of distilled water per day. The smallest distillers are about the same size as a coffee maker.
- **Continuous flow units:** Continuous flow or automatic units are connected to the water supply line. The water level in the boiling chamber is maintained by a float valve connected to the water supply. As distilled water is removed from the storage tank, the unit turns itself on and starts producing more distilled water. A discharge line periodically removes the concentrated impurities from the boiling chamber. Distilled water is either stored in a container or is piped to the use area.

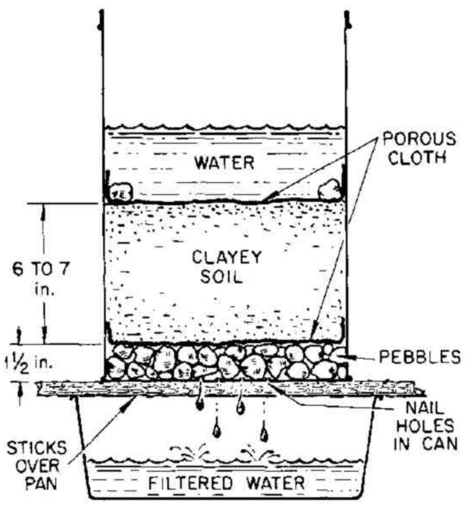
Expedient Filtering

To make the simple, effective filter shown below, the only materials needed are those found in and around the home. This expedient filter can be built easily by proceeding as follows:

1. Perforate the bottom of a 5-gallon can, a large bucket, a watertight wastebasket, or a similar container with about a dozen nail holes. Punch the holes from the bottom upward, staying within about 2 inches of the center. Place a layer about 1 inches thick of washed pebbles or small stones on the bottom of the can. If pebbles are not available, twisted coat-hanger wires or small sticks can be used.
2. Cover the pebbles with one thickness of terrycloth towel, burlap sackcloth, or other quite porous cloth. Cut the cloth in a roughly circular shape about 3 inches larger than the diameter of the can.
3. Take soil containing some clay almost any soil will do from at least 4 inches below the surface of the ground. (Nearly all fallout particles remain near the surface except after deposition on sand or gravel.). Pulverize the soil, then gently press it in layers over the cloth that covers the pebbles, so that the cloth is held snugly against the sides of the can. Do not use pure clay (not porous enough) or sand (too porous). The soil in the can should be 6 to 7 inches thick.
4. Completely cover the surface of the soil layer with one thickness of fabric as porous as a bath towel. The cloth also will remove some of the particles from the water. A dozen small stones placed on the cloth near its edges will secure it adequately.
5. Support the filter can on rods or sticks placed across the top of a container that is larger in diameter than the filter can. (A dishpan will do.). The contaminated water should be poured into the filter can, preferably after allowing it to settle as described below. The filtered water should be disinfected by one of the previously described methods. If the 6 or 7 inches of filtering soil is a sandy clay loam, the filter initially will deliver about 6 quarts of clear water per hour. (If the filtration rate is faster than about 1 quart in 10 minutes, remove the upper fabric and recompress the soil.)

6. After several hours, the rate will be reduced to about 2 quarts per hour. When the filtering rate becomes too slow, it can be increased by removing and rinsing the surface fabric, removing about 1 inch of soil, and then replacing the fabric. The life of a filter is extended and its efficiency increased if muddy water is first allowed to settle for several hours in a separate container, as described below. After about 50 quarts have been filtered, rebuild the filter by replacing the used soil with fresh soil.

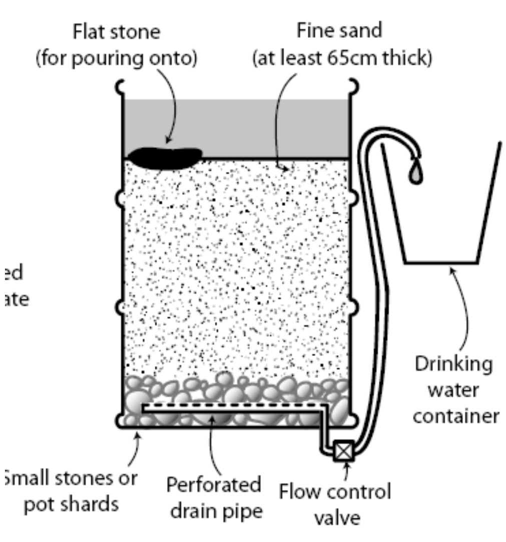
ORNL DWG 77-18431



EXPEDIENT FILTRATION

Expedient Slow Sand Filter

In slow sand filtration, the source water flows slowly through a bed of fine sand. To work, the water must be relatively clear, and the flow relatively constant. The water flows through at a rate of about 4 to 8 inches per hour. The minimum acceptable depth of sand to function effectively is 26 inches. The slow sand filter works because of a biologically active microbial film that forms on the top layer of the sand and may take up to one week to form. To get a quantity of fine, uniform sand, you can try sifting it through a mosquito net or other fine screen. The filter should be filled from the bottom up, to prevent the formation of air bubbles in the sand that would slow the flow of water. Eventually the sand filter will need to be cleaned, because the biofilm will thicken and slow the flow of water excessively. Fortunately, this thickening will not impair the safety of the filter. To clean, drain the water to slightly below the top of the sand, and scrape off the very top layer. Then fill up from the bottom.



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 pre-filtering 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, for a excellent field test of some common units. Note that the first price is for the filter, the second for the replacement filter. The weight is from manufacturer's literature. 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 4 µm, 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 what ever 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 for 13,000 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.
- ***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.

Reverse Osmosis

Reverse osmosis (RO) has become a common method for the treatment of household drinking water supplies. Effectiveness of RO units depends on initial levels of contamination and water pressure. RO treatment may be used to reduce the levels of: Naturally occurring substances that cause water supplies to be unhealthy or unappealing (foul tastes, smells or colors). Substances that have contaminated the water supply resulting in possible adverse health effects or decreased desirability. RO systems are typically used to reduce the levels of total dissolved solids and suspended matter.

Note: RO systems are normally used to treat only drinking and cooking water supplies so may not be preferred where larger supplies are being treated. RO systems are not appropriate for treating water supplies that are contaminated by coliform bacteria.

Where water contains more than one contaminant, the rejection rate for each contaminant may be reduced or one of the contaminants may be reduced in preference to the other contaminant. For example, cases have been reported where water supplies containing either high TDS levels or high sulfates in combination with nitrates show no decrease in nitrates after treatment. (Nitrates as used in this publication refers to nitrate-nitrogen or NO3-N.) Rejection rates need to be high enough to reduce the contaminant level in the untreated water to a safe level. To determine the needed rejection rate, it is necessary to consider the initial concentration. For example, if a water supply contains nitrates at a concentration of 20 milligrams per liter (mg/l), an RO unit rejecting at a rate of 85 percent, which means 15 percent remaining, would reduce the level to 3 mg/l (20 times 0.15 = 3). Water with very high levels of nitrates (such as 100 mg/l) would remain near or above health standard levels even after treatment. Nitrate levels this high are not expected in this region and indicate unusual problems that require special investigation and handling. The National Sanitation Foundation (NSF) recommends that special designs be used for RO units where the NO3-N level exceeds 40 mg/l. RO units use a lot of water. They recover only 5 to 15 percent of the water entering the system. The remainder is discharged as waste water. Because waste water carries with it the rejected contaminants, methods to re-cover this water are not practical for household systems. Waste water is typically connected to the house drains and will add to the load on the household septic system. An RO unit delivering 5 gallons of treated water per day may discharge 40 to 90 gallons of waste water per day to the septic system.

Initial Costs of the System: Be sure that all parts are included, especially when comparisons are being made. RO units range in cost from $300 to $3000 and vary in quality and effectiveness. Replacement membranes cost $100 to $200 and filter cartridges around $50.

Installation Costs: These costs are generally the responsibility of the purchaser, but who pays installation fees when renting or leasing? Is there enough space to accommodate the system being considered or will some modifications of space be needed?

Operating and Maintenance Costs: Electricity to pump the water is the only significant operating cost. Filter cleaning and/or replacement (both pre and post-filters) and RO membrane replacement need to be estimated.

Reverse osmosis is a proven technology that has been used successfully on a commercial basis. One of the better known uses of RO is the removal of salt from seawater. Household RO units typically deliver small amounts (2 to 10 gallons per day) of treated water and waste 3 to 20 times the amount of water treated. Reverse osmosis units remove many inorganic contaminants from household drinking water supplies. The removal effectiveness depends on the contaminant and its concentration, the membrane selected, the water pressure and proper installation. RO units require regular maintenance and monitoring to perform satisfactorily over an extended period of time. Before purchasing an RO unit or any other water treatment equipment, purchasers should test their water to be certain that treatment is needed and that the equipment being selected is appropriate to the problem requiring treatment. All costs need to be considered when comparing competitive systems and when making purchase or rental decisions.

Activated Carbon Filtration

Activated carbon (AC) filtration is most effective in removing organic contaminants from water. Organic substances are composed of two basic elements, carbon and hydrogen. Because organic chemicals are often responsible for taste, odor, and color problems, AC filtration can generally be used to improve aesthetically objectionable water. AC filtration will also remove chlorine. AC filtration does remove some organic chemicals that can be harmful if present in quantities above the EPA Health Advisory Level (HAL). Included in this category are trihalomethanes (THM), pesticides, industrial solvents (halogenated hydrocarbons), polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs). THMs are a byproduct of the chlorination process that most public drinking water systems use for disinfection. AC filtration is a viable alternative to protect private drinking water systems from organic chemical contamination. Radon gas can also be removed from water by AC filtration, but actual removal rates of radon for different types of AC filtration equipment have not been established.

Water Contaminants Not Removed by AC Filtration

Similar to other types of water treatment, AC filtration is effective for some contaminants and not effective for others. AC filtration **does not** remove microbes, sodium, nitrates, fluoride, and hardness. Lead and other heavy metals are removed only by a very specific type of AC filter. Unless the manufacturer states that its product will remove heavy metals, the consumer should assume that the AC filter is not effective in removing them.

Activated Carbon Filtration Equipment

AC filters can be placed in the three following categories: **pour-through**; **faucet-mounted**; and **high-volume**.

- **Pour-through** AC filters are the simplest. They work like a drip coffee maker. Water is poured in the top and filters by gravity through the filter to the bottom. They are quite slow and handle only small volumes of water.
- **Faucet-mounted** AC filters are small units attached on the end of a standard kitchen faucet. They are convenient to use, but because of their size require frequent change. Some units have bypass valves, so that just water for cooking and drinking is filtered.
- **High-volume** AC filters contain much more AC than either the pour-through or faucet-mounted models. High-volume units are designed to be installed in-line, generally under the sink. They are installed on the cold water line, and some units are installed with a bypass to separate cooking and drinking water from other uses. Under exceptional circumstances all water may need to be treated by AC filtration. A high-volume unit may be installed at the point of entry to the house if all water needs to be treated.

Eventually the AC filter loses its ability to remove contaminants, because it becomes clogged with material. In the case of taste and odor, the time to change the filter is easy to detect. However, in the case of other contaminants, it is more difficult to determine when the filter is no longer performing at an adequate level. Most manufacturers recommend a filter change after a certain volume of water has passed through the filter. Some AC units actually meter the water and automatically shut down after a specific quantity of water has passed through the filter. A general rule of thumb for high-volume AC filters is to change the filter after six months of use or 1000 gallons of filtered water.

Tests done by Rodale Press Product Testing Department indicated that filtering performance was reduced dramatically after 75 percent of the manufacturer's recommended lifetime. These results suggest that filters should be changed more often than suggested by the manufacturer. Some AC filters are claimed to last for five years, because they are rechargeable with hot water (145 degrees F). The heat is supposed to release adsorbed organic chemicals. Little information is available on the prolonged effectiveness of rechargeable AC units. General recommendations are somewhat useful guidelines, but there is no guarantee that they apply to any specific situation. Remember, the only certain way of knowing whether contaminant levels are acceptable or not is by having your water tested. A sediment filter installed ahead of any AC filter will prolong the life of the AC unit. Sediment can easily clog the pores of an AC filter within a short period of time. A good sediment filter can be purchased for only a fraction of the price of most high volume AC filters.

Bacteria Issue

AC filters can be a breeding ground for microorganisms. The organic chemicals that are adsorbed to the AC are a source of food for various types of bacteria. Pathogenic bacteria are those that cause human diseases such as typhoid, cholera, and dysentery. Public water systems must treat for disease causing bacteria; therefore, the likelihood of disease causing bacteria being introduced to an AC filter from public drinking water is remote. AC filtration should only be used on water that has been tested and found to be bacteria free or effectively treated for pathogenic bacteria.

Other types of non-pathogenic bacteria that do not cause diseases have been regularly found in AC filters. There are times when high amounts of bacteria (non-pathogenic) are found in water filtered through an AC unit. Research by R. L. Caldron and E. W. Mood (1987) shows little risk to healthy people that consume high amounts of non-pathogenic bacteria. We regularly take in millions of bacteria every day from other sources. However, there is some concern for certain segments of the population, such as the very young or old and people weakened by illness. Some types of non-pathogenic bacteria can cause illness in those whose natural defenses are weak. Flushing out bacteria that have built up in the filter can be accomplished by running water through an AC filter for about 30 seconds prior to use.

Water filtered after the initial flushing will have much lower levels of bacteria and ingestion of a high concentration of bacteria will have been avoided. The flushing procedure is most important in the morning or any other time of the day when the filter has not been used for several hours. Some compounds of silver have been used as disinfectants. Silver has been added to certain AC filters as a solution to the bacteria problem. Unfortunately, product testing has not shown silver impregnated AC to be much more effective in controlling bacteria than normal AC filters. Only in the first month of operation did there appear to be any advantage to using an AC filter that contained silver. EPA requires registration of all types of water treatment equipment that contain an active ingredient for the purpose of inhibiting the growth of microorganisms. Registration does not guarantee that the product is effective. It only guarantees that the active ingredient will not leach from the filter at levels that would be a health hazard.

Chemical Treatment

Chlorination

When using bleach, be very careful. It will burn any exposed bodily tissue it comes into contact with. The skin, respiratory tract and especially the eye are the tissues usually damaged by careless use of bleach. Even the diluted bleach solutions recommended for use here can cause damage. Use a mask, gloves and eye protection to avoid getting the solution on your skin, clothes, in your eyes, or inhaling it, as this will cause chemical irritation or burns. The simple treatment for bleach exposure is washing it off with water. It is important to use bleach in a well-ventilated area. Toxic chlorine fumes are released by bleach. These can damage the tissue lining the nose, throat, bronchial tubes, and lungs if inhaled so avoid this. The more highly concentrated the bleach, the more fumes released. Use cold water to dilute the bleach because hot water promotes its breakdown releasing more fumes. If you get bleach on you, wash it off with copious amounts of clean water. Thoroughly rise the skin or eye that comes into contact with bleach. This will remove the bleach. Washing should be done as quickly as possible because the bleach will damage tissue as long as it remains in contact with it. It takes a few minutes of washing to get the bleach off. If bleach gets into your eye, wash it for even longer. If bleach fumes get into the nose or back of the throat, irrigate the area using a salt and soda nasal wash (¼-tsp salt + ¼-tsp backing soda + 1-cup water) using an ear bulb syringe or just inhaling the solution from a cupped palm. There is no treatment for burned bronchial tubes or lungs except rest. A steam tent might help and cough medicine may help. The patient will recover in a few days but often have breathing difficulty and can be in pain with breathing over this time.

Bleach decomposes by releasing toxic chlorine gas with time. Exposure to air and sunlight speed its breakdown. Store bleach in opaque containers, keep the top on tight, and don’t open a new container of bleach until it is needed. Once bleach is mixed with water, it will deteriorate quickly; so don’t make more of the solution than you will need for use over the next week or so.

Cleaning Contaminated Surfaces And Objects Using Bleach

To use the bleach solution for disinfecting a surface or object, first wipe up the area with a towel and clean it with soap and water to remove the gross fluids, matter, or dirt. Then spray the appropriate solution on the surfaces or materials or wipe it on with a towel or sponge. Thoroughly wet the entire contaminated area with the bleach solution and let it sit undisturbed for 30 minutes. Wipe the remaining solution off the surface with a moist towel or rinse it off with clean water. Now the area or article is clean and free of contamination.

Dilute as follows for cleaning:
1:100 solutions are used for general household cleaning of surfaces.

- ½ tsp bleach to 1-cup of water (2.5 ml bleach to 250 ml water)
- 2 tsp bleach to 1-quart water (10 ml bleach to 1000 ml water)
- 3 tbsp bleach to 1-gallon of water (100ml bleach to 10 liters water)

1:50 bleach solutions are used for disinfecting surfaces contaminated with bodily fluids and waste like vomit, diarrhea, mucus, blood, or feces.

- 4 tsp bleach to 1-quart water (20 ml bleach to 1000 ml water)
- 6 tbsp bleach to 1-gallon water (200 ml bleach to 10 liters water)

Bleach is a strong and effective disinfectant. Its active ingredient, sodium hypochlorite, kills viruses, bacteria, mold, fungi, and protozoa on contact by denaturing their vital proteins. Bleach is effective, inexpensive and widely available making it a good choice for use as a disinfectant and purifier. Unscented household bleach is recommended because they can be used for water purification, disinfection, and cleaning. In the US, household bleach usually contains 6% sodium hypochlorite. Do not use scented bleaches, color safe bleaches, or bleaches with added cleaners. Because the potency of bleach diminishes with time, use bleach from a newly opened or unopened bottle. Plain unscented household bleach (6% sodium hypochlorite) is the most practical way to purify a large quantity of water.

For adults the Federal Emergency Management Agency (FEMA) recommends adding 16 drops (1/8 teaspoon) of household bleach to each gallon of drinking water to get rid of virus, mold, fungi, bacteria and protozoa. This treatment is not safe for infants until it has been run through a good filter. Allow the water to sit for 30 minutes after adding the bleach before using it. If it still does not smell of bleach, discard it and find another source of water.

Chlorine Dosage Calculations And Measurements
Tables I-1 and I-2 provide volumes in drops (dp), milliliters (mL), teaspoons (tsp), tablespoons (tbls), cups (cp), liters (L), and gallons (gal) of liquid bleach, dry calcium hypochlorite (HTH), and a concentrated calcium hypochlorite solution that, when added to the indicated volume of water, will provide the approximate chlorine dose indicated. The chlorine residual achieved using these values will be dependent on the chlorine demand exerted by the water that is chlorinated. If there is no chlorine demand, the residual should equal the dose. The greater the chlorine demand, the lower the residual will be. Note that for all chlorine residual concentrations in water, values in parts per million (ppm) are equivalent to values in milligrams per liter (mg/L) (for example, 10 ppm = 10 mg/L). If your measuring device is not as precise as the number you come up with, it is generally advisable to round the calculated number up to ensure you provide at least the dose you intended to provide. For water destined for drinking, it is always important to provide a 30-min contact time after adding the chlorine and mixing, then to test the water to ensure the desired residual has been achieved.

Conversion Factors
Table I-3 is useful in converting from one unit of measurement to another. It shows equivalent values for common units of measurement. Unit volumes increase from left to right and top to bottom. All volumes on the same horizontal line (row) are equal. So, looking at the “ounce” row, we can see that 1 oz, 444 dp, 30 mL, 6 tsp, and 2 tbls are all equal to each other. Continuing to the right on the same row indicates that 1 oz is also equal to 0.125 or 1/8th cp (see table I-4), 0.063 pints (pt), 0.031 quarts (qt), and so on across the table.
The values moving down a single column represent how many of the units at the top of the column make up one of the units on the left of the table.

Table I-1. Rounded-up volumes of 5% liquid bleach that will provide approximately the indicated chlorine dose when added to the listed volume of water

Gallons to be Chlorinated	1 mg/L	2 mg/L	5 mg/L	10 mg/L	100 mg/L
5	6 dp	0.75 mL	1.9 mL	3.8 mL	8 tsp
10	0.75 mL	1.5 mL	3.8 mL	1.5 tsp	16 tsp
25	2 mL	3.8 mL	2 tsp	4 tsp	1 cp
36	3 mL	5.5 mL	2.75 tsp	2 tbls	1.25 cp
50	4 mL	1.5 tsp	4 tsp	3 tbls	1.75 cp
100	7.7 mL	3 tsp	3 tbls	5 tbls	3.25 cp
400	2 tbls	4.25 tsp	0.75 cp	1.5 cp	3 qt
500	3 tbls	0.33 cp	1 cp	1.75 cp	1 gal
1000	0.33 cp	0.67 cp	1.75 cp	3.25 cp	2 gal

Table I-2. Volumes of 70% available chlorine HTH (or solution concentrate*) that will provide approximately the indicated chlorine dose when added to the listed volume of water

Gallons to be Chlorinated	1 mg/L	2 mg/L	5 mg/L	10 mg/L	100 mg/L
5	0.9 mL	1.7 mL	4.1 mL	8.3 mL	0.25 tsp
10	1.7 mL	3.3 mL	8.3 mL	16.6 mL	0.5 tsp
25	4.1 mL	8.3 mL	20.7 mL	41.4 mL	1.25 tsp
36	6 mL	11.9 mL	29.8 mL	0.9 mL	1.75 tsp
50	8.3 mL	16.6 mL	0.6 mL	0.25 tsp	2.5 tsp
100	16.6 mL	33 mL	0.25 tsp	0.5 tsp	5 tsp
400	0.92 mL	1.9 mL	1 tsp	2 tsp	19 tsp
500	1.3 mL	0.5 tsp	1.25 tsp	2.5 tsp	0.5 cp
1000	0.5 tsp	1 tsp	2.5 tsp	5 tsp	1 cp

Table I-3. Equivalent volumes

	drop	mL	tsp	tbls	ounce	Cup	pint	quart	liter	gal
drop	1	0.067 0.013	0.004		0.002					
mL	15	1	0.200	0.067	0.033	0.0042	0.0021	0.0011	0.0010	
tsp	74	5	1	0.333	0.167	0.021	0.010	0.005	0.005	0.001
tbls	222	15	3	1	0.500	0.063	0.031	0.016	0.015	0.004
ounce	444	30	6	2	1	0.125	0.063	0.031	0.030	0.008
cup	3550	237	48	16	8	1	0.500	0.250	0.240	0.063
pint	7100	473	96	32	16	2	1	0.500	0.480	0.125
quart	14200	946	192	64	32	4	2	1	0.960	0.25
liter	15000 1000	203	68		34	4.2	2.1	1.06	1	0.26
gal	56775 3785	768		256	128	16	8	4	3.785	1

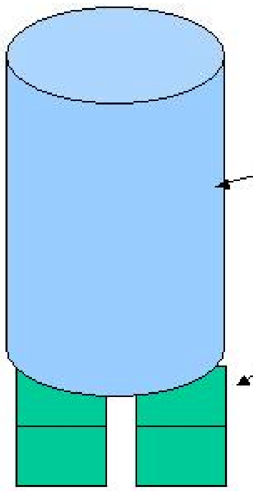
Table I-4. Common fractions and their decimal equivalents

Fraction	Decimal		Fraction	Decimal
1/16	0.0625		9/16	0.5625
1/8	0.125		5/8	0.625
3/16	0.1875		11/16	0.6875
1/4	0.25		3/4	0.75
5/16	0.3125		13/16	0.8125
3/8	0.375		7/8	0.875
7/16	0.4375		15/16	0.9375
1/2	0.500		16/16	1.0000

Iodine

As a second choice, you can use household, medical iodine to purify water as well. 2% USP strength tincture of iodine can be used. Add 5 drops to each quart of clear water, and let stand 30 minutes. If the water is cloudy, add 10 drops to each quart. Commercial water purification tablets should be used as directed.

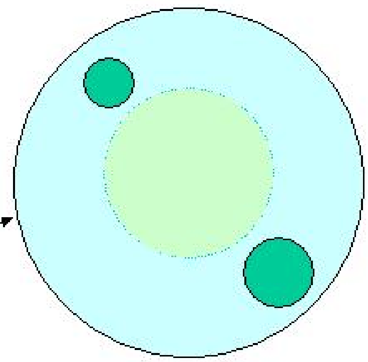
Setting Up the Raw Water Storage & Pretreatment Tank (Step 1)



55 gallon food-grade plastic drum (do NOT cut the entire top off the drum). Since this is for raw water, just clean it out really well, at this time do not disinfect it. The drum will just get contaminated again anyway in Step 2.

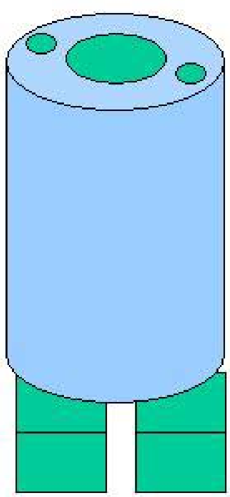
Concrete blocks or wood to elevate the tank 12 inches off the floor. The full drum will weigh in excess of 450 pounds when full of water, so make sure the elevation material can handle the weight!

View of the top of the drum. There are 2 'bung' holes, one is course threaded, the other is fine threaded. Carefully cut out the area in light green, leaving the bung holes. You'll need the the threaded hole in a bit.



My drum is 35" tall x 22" in diameter. The distance between bung holes is 11". The top cutout should be 8" and centered.

Filling the Raw Water Pretreatment Tank (Step 2)



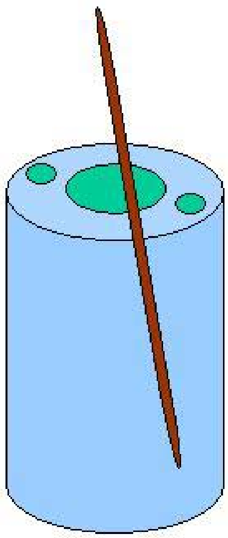
Once the cutout is done and the tank is elevated, place a clean cotton cloth large enough to cover the entire top of the drum completely. I used a circular cut cotton cloth, 30" in diameter.

There should be enough 'slack' in the cloth to sag a little into the 8" cutout. I used bungee type cords (Wal-Mart has them) to keep the cloth in place. Fasten 2 bungee cords around the perimeter of the drum, holding the cloth in place firmly.

Slowly pour the raw water through the 8" opening. This will rough strain any floating debris. Previously I tried coffee filters but they clogged up really fast and would take a LONG time to fill the drum if they worked (which they don't). After repeated tries, I was only able to filter about 3 quarts and used 3 coffee filters doing it!

Fill the drum almost full, leave 4 or 5 inches of space from the top of the drum. If you use a 5 gallon bucket, it will be fairly easy to guess how many it buckets it will take to almost fill the drum.

Once the drum is filled, carefully unhook the bungee cord and remove the cloth, rinse it well and air dry in sunlight (ultraviolet in sunlight helps disinfection). You will be reusing this cloth over and over as you process more batches of water.



Pre-treating the Raw Water (Step 3)

At this point, it is time to pre-treat the filtered raw water. I use commercially available HTH granular chlorine (swimming pool calcium hypochlorite) at 65% strength. By using HTH instead of household bleach, it accomplishes 2 tasks at once, 1.) the concentration of active chlorine is enough to 'burn off' algae, some minerals, destroy a good portion of bacteria and viruses and reduce dissolved gasses in the raw water. 2.) It adds alkalinity and calcium carbonate to the water which is necessary in the next chemical step. The contaminated raw water will 'eat' most, if not all, of the chlorine you add.

For the raw water dosing, I use between 1 to 3 tablespoons of HTH dissolved in 1 gallon of clean water (depending on how 'dirty' the water looks by eye-balling it), mix well and pour it all into the tank. Mix the raw water with a blunt wooden stick for several minutes.

Complete initial mixing is very important and the higher the chlorine dosage, the faster the disinfection and longer contact time produces better results.

I will let the drum sit overnight (6 to 12 hours is good) to allow an extended contact time for the chlorine to do it's thing. Since I have the chemical test strips, after the 12 hour contact time, I'll test for free chlorine residual and hope to have between .5 to 2.0 ppm. If you don't have test strips to measure the chlorine residual in the raw water, it is not critical. The chlorine still 'burned off' a lot of contaminants.

Coagulating the Raw Water (Step 4)

After the raw water in the drum has had enough contact time with the chlorine, it is time to add alum for coagulation. Alum (aluminum sulfate), in a pinch, can be bought in the spice section of a grocery store, but small bottles bought this way are quite expensive. Kathy in Florida cued me to this fact. I paid roughly $3.00 for a shade less than 3 ounces at the local grocery store. As an alternative for my 'treatment plant', I purchase a 25 pound bag of 100% aluminum sulfate for $29.88 + shipping from this link since I plant to process a lot of batches of water:

http://www.cqconcepts.com/chem_aluminumsulfate.php

Store the alum in a moisture proof container (plastic bucket with a lid) and use gloves (and a face dust mask) when handling this chemical. A little of this stuff goes a long way. The actual amount of alum required will depend entirely on the quality and composition of your own raw water source. You will have to observe the coagulation process and floc formation, then gradually adjust the amount of the alum solution you add, either a bit more or less, to get large rapidly settling floc particles. After coagulation and floc settling, if the water is still 'cloudy' or 'milky' looking, try decreasing the alum dosage.

For my initial raw water coagulation alum dose:

1. Take a 2 teaspoons of alum, mix into a gallon of clean water. Mix until it has all dissolved.

2. From the alum solution, take ¼ cup and add to the raw water drum, immediately begin stirring vigorously. Continue to stir vigorously for several minutes (6 to 7 minutes and I worked up a sweat), the alum must be completely mixed into the water.

3. Slowly (very slowly) continue to stir the water for another 6 to 7 minutes. This last gentle stirring enables the small floc particles to be able to collide and stick together, making larger particles big enough to settle to the bottom of the drum by gravity.

Coagulating the Raw Water – Continued (Step 5)

4. Allow the water to sit quietly for several hours (mine, 8 to 10 hours) and the floc settles nicely. If there is quite a lot of suspended floc after 2 hours, add a touch more alum solution and repeat 2 & 3 mixing/stirring steps. Allow a few more hours of settling. If the floc has settled, but the clear water has a 'milky' appearance, decrease the alum dose on the next batch. It is a LOT easier to add more alum, impossible to remove an over-dosage.

5. The goal here is to have very clear water (close to 55 gallons) with only a few floc particles still suspended. The majority of the 'gunk' and debris should have settled to the bottom of the raw water drum. You may or may not have any residual chlorine left in the water. Please notice that I keep saying the RAW water, it will not be fit to drink until final chlorination and filtration.

6. So assuming you have nice clear water with a sludge layer of 'gunk' on the bottom of the drum, we proceed to the next step, transferring the coagulated and clarified water to the next treatment process, filtration.

7. The last hardware requirement is a manually operated siphon pump, like the type here at this link:

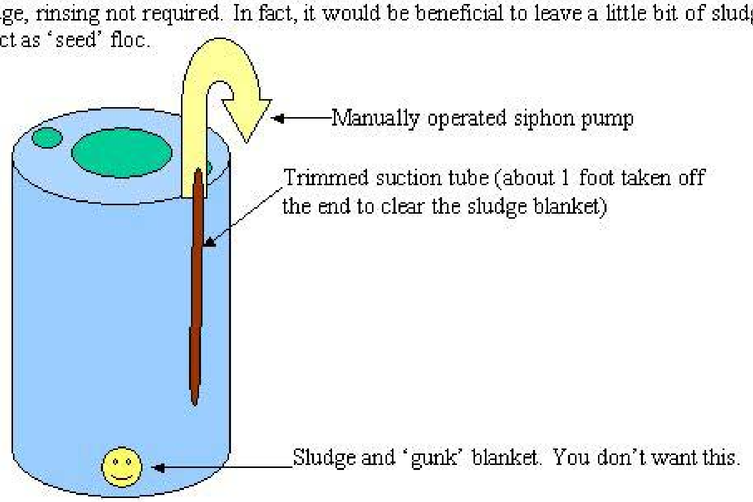
http://www.bayteccontainers.com/siphonpump.html

I'm not recommending this company, their price is too high for simple plastic siphons. Again, Wal-Mart has the exact same one, at a lot cheaper price (I paid $10 for mine). As the siphon comes out of the bag, it has a long suction tube that reaches to the bottom of the drum (into the sludge and gunk, remember?). Trim 1 foot off the suction tube to get above the sludge blanket. The siphon pump screws into the threaded bung hole you left when to cut to hole in the top of the drum.

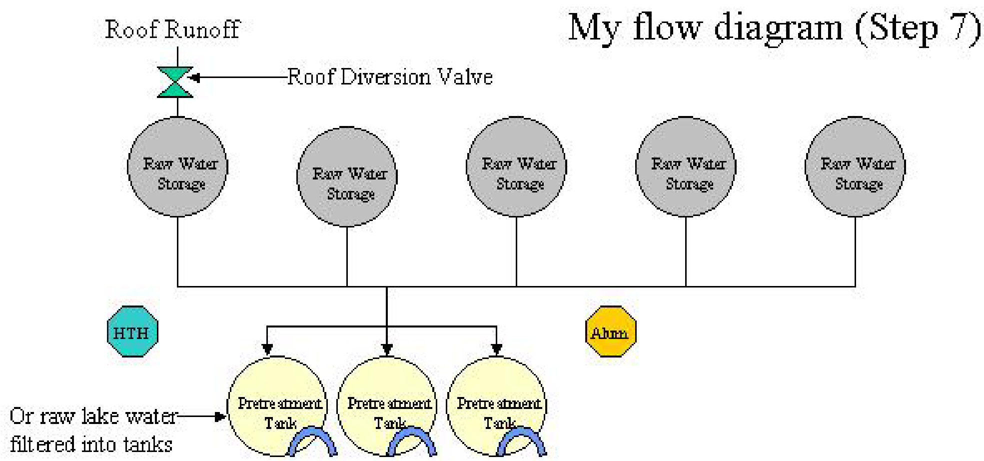
8. No need to tighten the siphon pump into the bung hole, just snug will do. Once you get the water flow going, it will continue without pumping until you stop the siphon action.

Transferring the Raw Water – Continued (Step 6)

9. Once you get the water flow going, it will continue without pumping until you stop the siphon action. Use this pump only for raw water transfer. Take the pump back out before you refill the drum for the next batch. Before filling again with raw water, tip the drum over and get rid of the sludge, rinsing not required. In fact, it would be beneficial to leave a little bit of sludge in the drum to act as 'seed' floc.



10. At this point, you can either fill your gravity ceramic filter (use another cotton cloth to catch any stray floc particles when filling the filter) with this clarified water or go on to the next phase of treatment. Since the ceramic type filters have a limited output (maybe 15 to 30 gallons per day), I have chosen to use another 55 gallon drum as a slow sand filter in the next set of steps.



To get the volume of water I wish to process, up to the filtration point so far, I am using 3 pre-treatment tanks. While one is being filled and pre-chlorinated with a contact time of several hours, the second tank is undergoing the coagulation and settling process, also with a wait time of several hours. The third tank is my current feeding drum, feeding the filter with the clarified water. I simply rotate the process use of each tank and it should give me a pretty steady flow as each drum continues the water treatment chemical actions.

3 pre-treatment drums may not be necessary for everyone. Simply 1 drum and a ceramic drip filter might be enough to satisfy most household needs.

In my case, I am shooting for 200 gallons per day. The list of materials for 1 pre-treatment setup: One 55 gallon plastic drum, cotton cloth cut to fit, one siphon pump, one 5 gallon bucket, HTH pool chlorine (granular), alum and a stirring stick.

Slow Sand Filters

If you surface water sources for household use, slow sand filtration - or more accurately biologically active filtration - may be an effective choice for water treatment. Slow sand filters can remove up to 99.99 percent of turbidity, bacteria, viruses, and Giardia lamblia cysts without the need for chemical flocculents or the use of electrical power. Slow sand filtration is a preferred technology for customers who:

- Wish to use surface water (ponds, streams, springs)
- Use daily volumes that make cartridge use impractical
- Have no access to electrical power
- Cannot or do not wish to use chemical treatment

Rapid Sand vs. Slow Sand Filtration

Two types of sand filters are used for water treatment - rapid sand and slow sand. Rapid sand filters filter at a rate of 1 to 2 gallons per minute per square feet (gpm/ft2) and use physical straining to trap solids in the pores between sand particles throughout the bed. To increase the capacity to filter, rapid sand filters often use flocculent (polymers) to stick particles together into larger particles that can then be more easily strained out. To clean the filter, flow is reversed through the filter bed at a high rate that fluidizes the bed, actually expanding the spaces between sand particles and flushing trapped material to waste. This process is performed frequently, often daily. The injection of flocculent needs to be constant and precisely metered. Jar testing is necessary to determine the effectiveness of dosing of the flocculent. A skilled worker is necessary to maintain a rapid sand filter properly.

Slow sand filters work very differently. The much slower flow rate of .04 to .16 gpm/ft2 results in a much different character to the sand bed. Because of the slow rate, particles tend to settle in the very top layers of the sand. More importantly, a rich biological matrix develops in the top layers of the sand. The matrix, commonly called the Schmutzedecke, is composed of a wide variety of tiny organisms including bacteria, algae and various other single and multiple cell organisms. This matrix lives off whatever is passing through it in the water stream.

Pore size of the bed is less important because a bacteria passing through can't touch anything without being stuck and consumed. This way slow sand filters can remove particles smaller than the space between sand particles. At some point, the biological layer begins to plug up with the filtered material and debris. Flow becomes substantially reduced.

Maintaining a Slow Sand Filter

Most of the maintenance issues involving slow sand filtration can be minimized with careful preparation and planning. Backwashing a slow sand filter using the same method as in a rapid sand filter would create havoc with the biological layer because fluidizing of the bed would damage the matrix and disrupt the intricate interrelationships of sand and microscopic life. How do you clean a slow sand filter? Slow sand filters usually are returned to operational status by scraping and removing the top layer of sand because that is where the clogging takes place. To accomplish this, the filter vessel is drained. Workers using either shovels or tractors scrape the top 1/2-inch of sand and discard it. Then the filter is refilled with water. Since the biological layer has been removed, filtered water is run to waste until the biological layer re-establishes itself - ranging anywhere from days to weeks. After many scrapings, the sand bed gets shallower and at some point new sand needs to be placed on the bed. After some years, small amounts of material accumulate deeper in the sand bed to an extent that require removal of all the sand and replacement. Scraping the filter bed is probably the most significant labor expense in slow sand filter maintenance. One report estimated that scraping requires 25 to 50 hours per 1,000 square feet per year, approximately two to five hours per month.

In recent years, a new method of cleaning slow sand filters has emerged. Operators of a West Hartford, CT, slow sand filter developed a method called wet harrowing. Water above the sand is drained slowly to a depth of 15 inches or so. The upper layer of sand is raked or harrowed while water is being drained off above the filter bed. The harrowing releases fine suspended particles that have accumulated. These particles are washed off by the water as it drains through valves above the filter bed. Advantages of wet harrowing are significant. The most obvious is the labor savings. The filter does not have to be drained completely, and the sand does not have to be physically removed. More importantly, the biological layer is stirred up, but not destroyed by exposure to air. This means that the filter does not need to go through a lengthy re-ripening period. Often the filter is back to normal operation within hours instead of days to weeks.

Since sand is not being removed, the sand bed retains its original depth and does not require periodic additions of new sand. Typically, if a slow sand filter is designed and operated properly, the sand should not need replacement for five to ten years. How do you know when the filter needs to be cleaned? As material is pulled from the water in the Schmutzedecke layer, head loss increases. This head loss can be easily measured with the use of piezometers; clear tubes open to the atmosphere extending on the outside from the bottom of the filter to above the normal waterline. As head loss increases, the level of water in the tube will drop as atmospheric pressure overcomes the push of water through the filter. When the water level in the tube drops to 15 to 18 inches below the level in the filter, the filter needs to be cleaned.

Pretreatment to Reduce Maintenance

Sediment tanks to remove settled solids, and course media roughing filters to reduce excess turbidity, reduce the solids load on slow sand filters. If turbidity exceeds 20 nephelometric turbidity unit (ntu) for any time exceeding a few days, a roughing filter should be installed. Roughing filters can reduce turbidity by 50 to 80 percent and reduce the amount of maintenance on slow sand filters considerably. Roughing filters are built as either upflow, downflow or horizontal flow depending on solids loading and method of cleaning desired. Media is usually layered course to fine gravel. Selecting the right filter for the application is a very important step. For high demand situations, slow sand filters may require too much land area to be practical. Where high turbidity is a problem certain times of the year, pretreatment must be addressed.

These things considered, slow sand filters can provide high quality water from surface water sources. They are particularly valuable for the small rural homestead or community. New methods including wet harrowing, reduce the steps involved in maintaining slow sand filters and allow the filters to be returned to service rapidly by personnel with minimal training. Surface water is sometimes the only available safe water source for rural homeowners. But treating surface water can present real headaches for the water treatment professional. Typical problems encountered can be caused by high suspended solids, turbidity, coliform bacteria, viruses, *Giardia* and agricultural runoff.

Conventional remedies usually involve media filtration, cartridge filters and chlorination, which can require high maintenance and cost. The careful metering of chemicals makes some health officials wary of their use by homeowners. However, slow sand filtration can help solve some of these problems. Slow sand filters have been used for more than 150 years. Today, they are popular in developing countries and in some municipalities and state parks in the United States. The proven ability of slow sand filters to remove turbidity, bacteria and viruses resulted in renewed interest by the U.S. Environmental Protection Agency (EPA) and the American Water Works Association (AWWA) in the 1980s. Recently, innovative packaging of slow sand filter plants has made this technology available to rural homeowners.

Common features of slow sand filters include the following:

- 2 or more vessels 6 to 8 feet deep
- An underdrain assembly for collecting treated water
- A gravel support layer around and over the underdrain
- A sand layer on top of the gravel 3 to 4 feet deep
- Controls to regulate flow rate
- Head loss measurement devices
- Filtration rate of .04-.16 g/ft^2/minute.

Raw water enters the vessel at the top . When operating, the vessels are kept full, leaving a three-foot layer of water -- the supernatant -- above the filter sand. This layer provides some treatment through sedimentation, but more importantly provides head to drive the water through the filter sand for extended periods of time. The slow filtration rate allows the development of a naturally occurring layer of organisms to thrive in the top few inches of sand. This layer, the Schmutzedecke, is responsible for removing up to 99.99 percent of bacteria, viruses, *Giardia* cysts and turbidity in the water passing across it. The Schmutzedecke is composed of a wide variety of life forms including algae, bacteria copepods, rotifers and many other invertebrates. Deeper in the bed, other processes occur that remove even more contaminants. Sedimentation, mechanical filtration and static electrical charge continue to polish the water. The flow rate -- the speed and consistency of the flow -- is very important. Violent pressure changes that occur by opening and closing valves and rapidly changing the rate of flow can affect the filter's ability to work properly. Careful design of flow controls and the use of storage tanks to accommodate varying usage demands are important features in slow sand filter systems.

As the filter works, suspended solids build up in the Schmutzedecke, which will eventually need cleaning. Head-loss meters are necessary to monitor solids accumulation. Site glasses open to the atmosphere and attached to the bottom of the filter vessel show the condition of the filter. As solids accumulate, the water level in the tube drops. The filter should be cleaned when the level drops between 12 inches and 24 inches. The frequency of cleaning depends on raw water quality, but typically filters are cleaned every 2 to 10 weeks.

Sand Filter Drawbacks

Two problems often encountered by end-users of slow sand filters are high turbidity and organics in the water. High turbidity -- greater than 20 nephelometric turbidity units (ntu) -- can quickly clog a slow sand filter, resulting in short periods between cleaning. This may be one reason why slow sand filters became unpopular in the early 20th century. There are simple remedies, however. Sedimentation tanks and gravel roughing filters are very effective at reducing turbidity. Roughing filters can reduce turbidity by 50 to 80 percent and can provide excellent pretreatment for slow sand filters. Conventional slow sand filters are not effective at removing organics, which tie up chlorine, or pesticides. However, by using a layer of granular activated carbon (GAC), organic carbon and pesticides can be significantly reduced. This minimizes exposure to pesticides and reduces the amount of chlorine required to establish any necessary residual. Reducing chlorine and organics lowers costs and the risk of producing and exposing customers to trihalomethanes (THMs).

Another problem with slow sand filters is construction costs. Traditionally, slow sand filters have been made of concrete and pipe. The innovative use of molded polyethylene structures has distinct advantages. First, the engineering cost is reduced because it is amortized over the number of filters manufactured. Second, the cost of producing polyethylene filter vessels is much less than the construction and pouring of concrete forms. Finally, the materials used in polyethylene components can be certified as non-toxic, while materials for cast-in-place filters require testing of each installation. Additional advantages of polyethylene slow sand filters include transportability, durability and rapid set-up time. A polyethylene filter plant can be installed, loaded and started in hours compared with a built-in unit, which might require months to construct.

The best and simplest slow sand filter setup for a rural user is gravity-fed from a spring. Water is piped from the spring directly into the slow sand filter. Treated water flows into a storage tank that distributes the water downhill to the end-user; gravity ensures continual water pressure. But this configuration is not always possible. From a stream or pond, water may be pumped directly into the filter using an appropriately sized pump or a pump, pressure tank and pressure switch. After the storage tank, another pump, pressure tank and pressure switch can be used to provide water at suitable pressure to the user. Additions to the system may include chlorinators after the filter, ultraviolet (UV) after the filter and roughing filters before the filter if high turbidity or solids loads are anticipated. When designed and operated properly, the filter should be harrowed every two months. The sand should last 5 to 10 years. Even a small slow sand filter is capable of filtering 1,400 gallons per day. For the last 150 years, slow sand filters have been making drinking water safe throughout the world. With the recent discoveries of better maintenance methods, amendments to media and innovative packaging, this technology provides another tool for treating challenging water problems.

Installation

For a Bio-Sand filter to operate properly, it must be installed and commissioned correctly. Make a checklist and use it to ensure that you have everything you'll need before you head out to install a filter. A filter maintenance guide (such as a laminated sheet) should be left with the users of each filter. This guide could be attached to the filter or placed on a wall adjacent to the filter. Always consider the safety issues related to moving the filter. There can be injuries due to strains of the back, arms, and knees. Watch out for crushing or pinching of fingers and toes under or behind the filter. Keep in mind the size of the filter (12" x 12" x 36") and its weight (160 Lbs - plus an additional 100 Lbs of media). It can be difficult and awkward to move this large object. It is important to determine a good location for the filter. Locating the filter inside the home is important not only for filter effectiveness, but also for the convenience of the user. If the users can access the filter easily, they will be more likely to use and maintain it. Once filled with media, the filter should not be moved. The filter should be placed:

- In a protected location away from sunlight, wind, rain, animals, and children
- Preferably inside the home
- Near the food preparation or kitchen area (depending on the space and layout of the house)
- Where it can and will be used and maintained easily
- On level ground
- So that water can easily be poured in the top
- Where there's adequate room for hauling and pouring pails of water into the filter, and storing the filtered water

Placing the Media

Tools Needed:

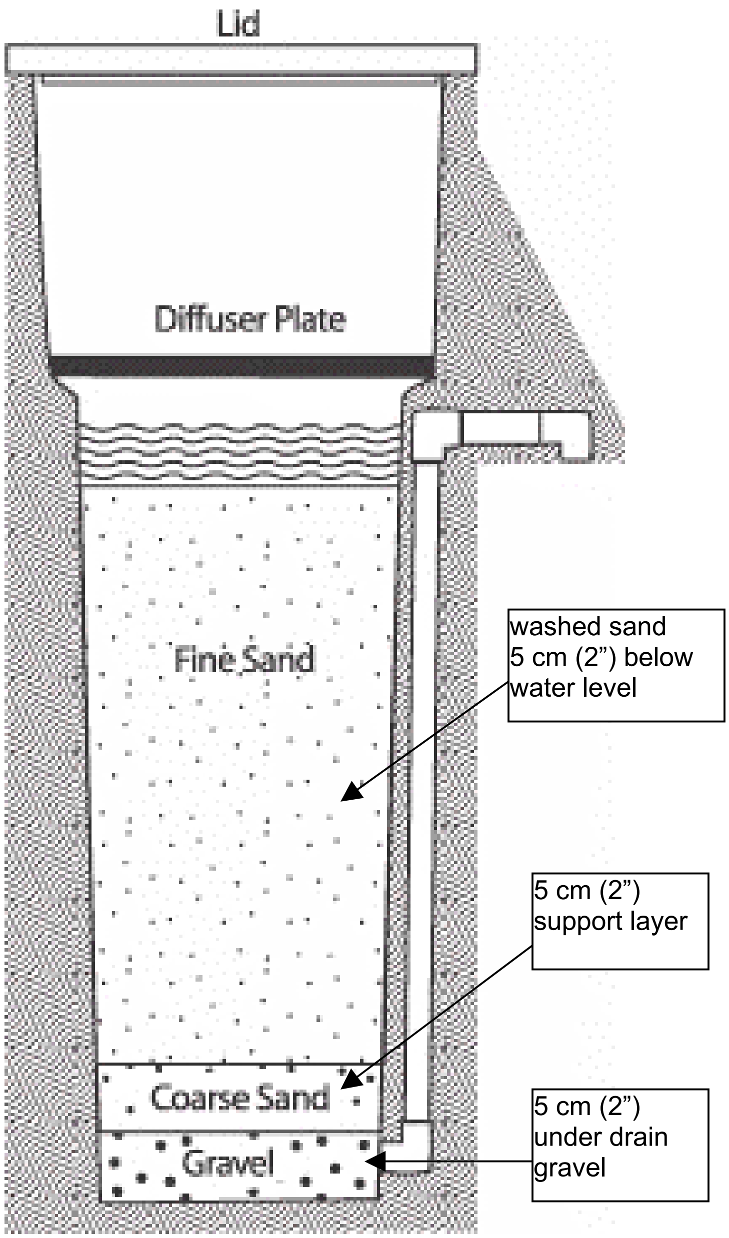
- Approximately 3 liters of washed ½" gravel
- Approximately 3 ¼ liters of washed ¼" gravel
- Approximately 25 liters of washed sand
- A stick (approximately 40" long, 1" x 2" is preferred)
- Measuring tape
- At least 2 buckets of water

1. Ensure that the drain hole (the standpipe opening at the bottom inside of the filter) is clear and unobstructed (i.e. is not covered by concrete and is not plugged by any debris.) The flow rate through the copper pipe without any media in the filter should be 1 liter / 25 seconds. *Tip: This step should have been done when the filter was removed from the mold, however, double check now before you get too far into the installation.*
2. Ensure that the inside of the filter has been cleaned out (including dirt, dust, and oil from the mold).
3. Place a stick inside the filter so that it's touching the bottom of the filter.
4. Draw a horizontal line on the stick where it meets the top edge of the filter.
5. Measure and mark a line 2" down from the first line.
6. Fill the filter half full of water. *The media must always be added with water already in the filter to prevent pockets of air from being trapped within the media.*
7. Add approximately 2" of under drain (½") gravel to the filter.
8. Level out the gravel, and use the stick to measure how much has been added. Place the bottom of the stick on the gravel. When the 2nd line on the stick lines up with the top edge of the filter, you have added enough gravel. *Ensure that the gravel covers the drain hole near the bottom of the filter.*

9. Measure and mark a line 2” down from the second line.
10. Add approximately 2” of support layer (¼”) gravel to the filter.
11. Level out the gravel, and use the stick to measure how much has been added. Again, place the bottom of the stick on the gravel. When the 3rd line on the stick lines up with the top edge of the filter, you have added enough gravel.

Quickly pour approximately 20 liters of washed sand to the filter (ensuring that there is always water above the surface of the sand). Note: A random distribution of different sand grain sizes is critical to the proper operation of the filter. Adding the sand quickly maintains the random distribution by not allowing the different sizes of grains to settle into layers.

12. Continue adding smaller quantities of sand until water starts to pour out of the spout. (Again, make sure that there is always water above the surface of the sand. Add water if necessary.) When the water stops pouring out of the spout, the water level is equalized. The water level in the filter is determined by the spout. Due to a siphoning effect, the water will stop coming out of the filter when the water is at the same level as the bottom of the spout.



13. Smooth out the sand and then measure the depth of the water above the sand bed.

14. **If the water depth is less than 2”:** remove sand until the depth is 2” (with the sand surface level and the water level equalized).
15. **If the water depth is more than 2”:** repeat steps 13 to 17 until the water depth is 2”.
16. Smooth out the surface of the sand so that it’s as level as possible.

Flushing the Filter

Tools Needed:

- Diffuser
- 40 – 80 liters of water

1. Place the diffuser plate on the ledge inside the filter. Ensure that it fits snugly. Note: The diffuser must not be touching the surface of the water at its resting level. That would greatly reduce the amount of oxygen in the standing water layer, affecting the survival of the Schmutzedecke.
2. Place a receiving container under the spout. The water that it captures can be reused.
3. Pour the cleanest available water into the filter (turbidity < 30 NTU).
4. Observe the water coming out of the spout.
5. Continue adding water to the filter until the water coming out of the spout is clear. This may take 40-80 liters (10-20 Gallons). Note: If the outlet water doesn’t run clear after 100 liters (25 Gallons), the gravel or sand was too dirty to start with. It is probably easiest to take the media out, wash it in pails, and then place it back in the filter.

Test Flow Rate

Tools Needed:

- Measuring container with 1 liter mark
- Stopwatch
- Bucket

1. Fill the filter to the top with water.
2. Place your measuring container under the spout to collect the outlet water.
3. Measure the time it takes to fill the container to the 1 litre mark. It should take between 50 – 80 seconds.
4. If it takes longer than 80 seconds, the flow rate is too slow.

- The filter will still work, but it may clog faster and more often, requiring more maintenance
- If it takes too long to get a pail of water, the user may not like the filter and may use untreated water
- The flow rate can be improved by “swirling” the top layer of the sand and then scooping out the dirty water

- ► If a few “swirl & dumps” do not improve the flow rate substantially, the sand is either too fine or too dirty – you will have to rewash the sand

5. If it takes less than 50 seconds to fill the measuring container to 1 litre, the flow rate is too fast.

- ► The filter may not function effectively
- ► The media should be replaced with finer media (less washed)
- ► A less preferable option is to run a considerable amount of water through the filter until the flow rate decreases (due to the capture of finer particles and faster growth of the biolayer)

Note: The flow rate through the filter decreases as the height of the water in the influent reservoir drops. As the water level reaches the diffuser, treated water may only drip out of the filter spout. It can take 40 – 90 minutes for the 20 liters in the reservoir to completely pass through the filter.

Disinfect the Spout

Tools Needed:

- ► 3’ of garden hose that just fits over the filter spout
- ► 1 hose clamp (if available)
- ► Funnel (can be made from the top of a soda or water bottle)
- ► Bleach solution (1/2 teaspoon bleach to 2 liters of water). *Note: Do NOT pour chlorine bleach into the top of the filter!*

1. Place the garden hose over the filter spout.
2. Clamp the hose in place with the hose clamp.
3. Place the funnel on the other end of the garden hose.

4. Hold the funnel higher than the top of the filter, and pour 2 liters of bleach solution into the funnel.
5. Hold in place for 2 minutes.
6. Remove the garden hose and drain the bleach solution
7. Wipe the outside of the spout with a clean, bleach-soaked cloth.
8. Add 20 liters of water to the top of the filter to flush the bleach out. Instruct the user not to use this water for drinking or cooking.
9. Place the lid on the filter.

Operations

Establishing the Biolayer

- ► The schmutzdecke or biolayer is the key bacteria removing component of the filter
- ► Without it, the filter removes some contamination through screening of the particles and microorganisms (only 30-70% removal efficiency)

- A good schmutzdecke will remove 90-99% of biological pathogens
- It may take 10 – 20 days to establish the schmutzdecke
- The water from the filter can be used during the first few weeks while the schmutzdecke is being established if a safer water source is not available, but chlorination is recommended at least during this time period
- The schmutzdecke is NOT usually visible – it is not a green slimy coating on top of the sand

Daily Use

1. Educate all of the users, including children, on how and why the filter works and on the correct operation and maintenance. Children are frequently the main users of the filter.
2. Slowly pour raw (untreated) water into the filter daily (at least 20 liters, twice per day)
3. Using the same source of water every day will improve the filter effectiveness
4. Use the best source of water (least contaminated) available – the better the raw water is, the better the treated water will be
5. Pre-filter or settle raw water if not relatively clear – less than 50 NTU - A simple test to measure the turbidity is to fill a 2 liter clear plastic soft drink bottle with raw water. Place the bottle on top of large print such as the CAWST logo on this manual. If you can see the logo, the water probably has a turbidity of less than 50 NTU.
6. The diffuser must always be in place when pouring water into the filter – never pour water directly onto the sand layer
7. The lid should always be kept on the filter
8. Use a designated bucket for fetching raw water
9. Use a designated safe storage container to hold the treated water that has:

    - a small opening to prevent recontamination due to dipping with cups or hands
    - a tap or spigot

10. Place the receiving container as close to the spout as possible (i.e. place it on a block) to reduce dripping noise and prevent recontamination. The dripping noise can be irritating. The closer you place the container to the spout, the less dripping noise there is. A container with a small opening also reduces dripping noise.
11. Water must always be allowed to flow freely from the filter – never plug the spout or connect a hose to it. Plugging the spout could increase the water level in the filter, which could kill the biolayer due to lack of oxygen. Putting a hose or other device on the spout can siphon or drain the water in the filter, dropping the water level below the sand layer.
12. No food should be stored inside the filter. Some users want to store their food on the diffuser plate because it is a cool location. The water in the top of the filter is contaminated, so it will contaminate the food. Also, the food attracts insects to the filter.
13. The treated water should be chlorinated after it passes through the filter to ensure the highest quality of water and to prevent recontamination (1-5 drops/liter or up to 1 teaspoon/gallon)

Maintenance

Once a filter has been built, installed, and is operational, though minimal, there is some key maintenance that is required. The two primary requirements are disinfecting the spout and cleaning the biolayer when the flow rate is insufficient. Follow-up visits to ensure proper use and maintenance of the filters should be built into the hygiene education program.

Disinfection

- The spout will become contaminated during normal use via dirty hands, animals, or insects
- Clean the spout every day with soap and water or a chlorine cleaning solution
- Wash the receiving container every second day with soap and water or a chlorine cleaning solution
- Do NOT pour chlorine bleach into the top of the filter!
- The entire filter should be cleaned regularly (lid, diffuser, outside surfaces)

Swirl and Dump

The flow rate through the filter will decrease over time as the schmutzdecke develops and fine particles are trapped in the upper layer of the sand. Users will know when the “swirl & dump” is required because the flow rate will drop to an unacceptable level. The filter is still effectively treating the water at this point; however the length of time that it takes to get a bucket of water may become too long and be inconvenient for the user. Alternately, you can measure the flow rate (as above) and if it is less than 0.3 liters/minute, “swirl & dump” maintenance is required.

1. Remove the lid of the filter.
2. Add 4 liters (1 gallon) of water to the top of the filter.
3. Remove the diffuser.
4. “Swirl” your hand around in the standing water at least 5 times – the water will become dirty. You can insert your fingers up to the first knuckle in the sand layer while “swirling” around across the entire surface area of the sand, but do not mix the surface layer deep into the filter.
5. Scoop out some dirty water with a small container (i.e. a cup or a pop bottle cut in half).
6. Discard the dirty water outside the house in an appropriate location (remember it is contaminated water).
7. Repeat this “swirl and dump” technique until all the water has been dumped out of the filter.
8. Replace the diffuser.
9. Pour 20 liters (5 gallons) of water into the top of the filter.
10. Measure the flow rate (as above).
11. Repeat steps 1 through 10 until the flow rate is acceptable (close to 1 liter/minute).
12. Wash your hands with soap and clean water - you have been handling contaminated water.

The following general checks can be made at any time by the users:

1. Check that the filter is in an appropriate location (indoors, protected from the weather, animals, and insects) and is level
2. Look for drips of water or wet spots under the filter, which indicate a leak in the concrete box
3. Check that the lid is tight fitting and clean on the inside and outside
4. Make sure the diffuser is clean and is sitting properly on the concrete lip
5. Make sure the holes in the diffuser are not plugged – periodic cleaning may be needed
6. Check that the surface of the sand is smooth and level (use a small straight object to smooth the sand ONLY if necessary)
7. Make sure the surface of the sand is 2” (5cm) below the water level.
8. Note: the sand may settle over time and more will have to be added. Add (or remove) sand if the standing water depth is not 2”.