APPALACHIA - SCIENCE
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Rt. 5 Box 423 ◦ Livingston, KY 40445

Water Purification Techniques

ASPI Technical Series

INTRODUCTION

Water Quality is important for good health, as many diseases are waterborne or transmitted through water in other ways. Besides disease organisms, water can be contaminated with salts, metals, minerals, toxics, or other materials. These can be dangerous to human health as well as adversely affecting the color, odor, and/or taste. All of the above contaminants can be removed or reduced to make water safe for drinking. Not all water used inthe home has the same quality requirements. We suggest this ranking: drinking water (highest quality), bathing and laundry, swimming and livestock and flushing toilets (lowest quality).

Because of the wide variety of possible contaminants in water, testing is recommended before choosing a treatment option. This will show what contaminants need to be removed or if no treatment is needed. Once a problem is identified, appropriate treatment can be considered. Your local health department often does bacterial and other testing or can recommend firms that do. Comprehensive water testing is becoming more accessible and more affordable. Test for all contaminants should be available for less than $100.

PARTICLE REMOVAL (Filters)

Mechanical Filters

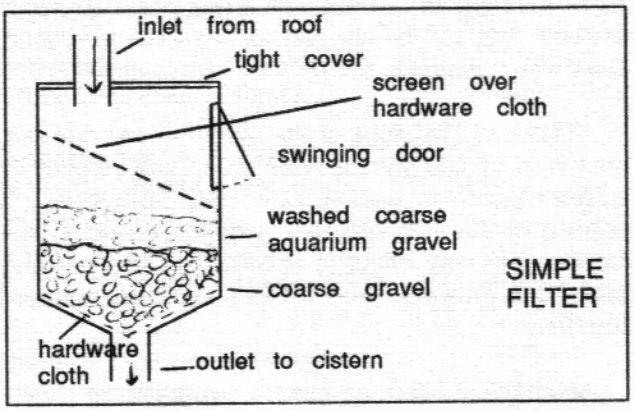
One of the most common contamination problems in rural water systems is solid particles. These can be removed from water with mechanical filters, which primarily screen out particles larger than their pore size. If using rainwater or surface water particles can be fairly large, so upstream filtering is called for to remove the material before it enters the system.

Removing particles with a rainwater system may involve diverting the first few minutes of every good rain to wash the roof, and installing screen filters and a gravel and charcoal filter box before the water enters the cistern. Because of the flow rates involved, this is about the only feasible type of filtration.

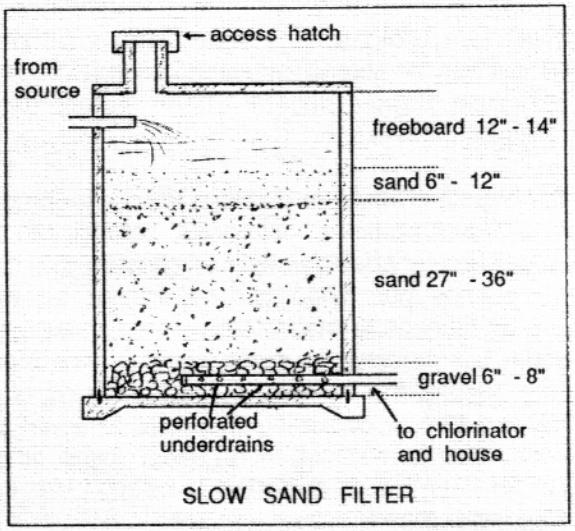
If you are using surface water from a pond or creek you may be able to reduce the particle problem by relocating or protecting the intake. Screen filters can also be used in-line.

Settling, sand filters, or cartridge filters can remove finer sediment particles. In ponds, settling can be accomplished by adding powdered gypsum at a rate of 12 pounds per 7,000 gallons without adverse effects on humans or marine life. Lime can be used to settle out particles in acidic water. In a water system, settling can be done by letting the water sit quietly in a tank or by adding chemicals to assist the process. Alum is most commonly used. Algae, which can make water cloudy and affect color and taste, can be killed with copper sulfate.

Two types of sand filters are commonly used: rapid and slow. Rapid sand filters remove sediment and cloudiness. These consist of around 3 feet of medium sand over 1 foot of gravel and can be operated by gravity (with 3 to 6 feet of water over sand) or in a closed vessel with pressure from a pump. Pressure sand filters for home use start around $300. Slow sand filters have the added benefit of reducing pathogen contamination in addition to sediment and cloudiness. Consisting of around 3 feet of fine sand over 6-8 feet of gravel, they are gravity fed with water standing 1 to 3 feet over a surface of the sand. In a slow sand filter, a biological mat builds as the water flows through it. *The slow sand filter is generally recognized as being the single best treatment process for improving the physical, chemical, and bacteriological quality of surface water.*



It is ideal for small water systems serving 25-3,000 people, but can be custom built from concrete materials to accommodate larger numbers. Size and cost depend upon water demand.Some method of disinfection after sand filtering is generally recommended.



SLOW SAND FILTER

Sand filters eventually clog and require periodic maintenance. Rapid sand filters are cleaned by backwashing: pumping clean water back through the filter to wash out the fine particles. With a slow sand filter, the top half inch or so of sand is removed. This is generally roasted to remove contaminants and saved for later return. After six inches or so have been removed, clean sand should be added to the bottom of the filter by double digging.

Cartridge filters consist of an element enclosed in a housing. Folded paper or wound string elements are used in disposable types. Elements cost $2-$5 each, housings $15. Cartridge filters are best used to remove sediment from bacteriologically pure well or spring water. With surface water or rainwater they can become a breeding ground for bacteria and algae. In these systems cleanable sediment filters are more appropriate. These use a fine polyester mesh element that can be washed as needed and reused. Cost with housing is $35-70.

The fossil skeletons of the marine algae diatoms, known as "diatomaceous earth" (DE), can be used as a filter medium to remove cloudiness from water. A coating of this fine material is deposited on a filter fabric. It is very effective at removing fine particles and cost around $300. DE should be replaced regularly.

Mechanical filters all require maintenance. Over time they become clogged and need to be cleaned or have elements replaced.

DISINFECTION

Bacterial contamination is often a major problem with rural water systems. Methods of removing bacterial contamination are known as disinfection. Many different types of disinfection are used. These include: micro-filtration, boiling or pasteurization, chlorine, distillation, reverse osmosis, iodine, ozone, and ultraviolet light. Many of these methods are also effective at removing other contaminants from water. (See Table 1.)

Microfiltration

Extremely fine ceramic filters are available that will remove bacteria from water. Their pore size is 1 micron (0.00004") or less. These are available as elements for standard or custom housings or as "filter candles" which can be attached through the bottom of a bucket to make a drip filter for drinking water. When they become clogged, they can be brushed clean and reused many times. There is concern about bacteria growing through the filter medium. Some use silver compounds to prevent this.

Cost with housing ranges from $50 - $150. Elements from $30 to $100. Hand pumped units are also available. The more expensive ones have finer and thicker ceramic.

Because of the flow rates involved these are only feasible as single faucet units to produce drinking water. Microfiltration is the simplest and cheapest disinfection method.

Boiling/Pasteurization

Heat can be a very effective way to disinfect water. Boiling is the simplest method. If water is brought to a rolling boil for two minutes. All bacteria, viruses, and other micro-organisms are killed. Boiling is very energy intensive, expensive, and inconvenient. It is mostly used in emergencies.

Pasteurization is another effective method of disinfection. Water is heated to 140 - 160 F for up to 15 minutes. This is very effective but also energy intensive and expensive if done the usual way with electric heat and circulating pumps. It is possible to pasteurize water on a stove top in small batches. Solar pasteurization is also receiving greater attention. Solar cookers or similar solar devices can be used to heat the water. In all cases care must be taken to prevent recontamination.

Chlorine

Chlorination is the most popular water disinfection method used in the U.S. Chlorine is very effective in killing microorganisms provided they are exposed to a high enough concentration for a long enough time.

Simple chlorination uses chlorine at a level of around one part per million (ppm) (one gallon chlorine bleach per 50,000 gallons water). Contact time of at least 30 minutes is needed. With a cistern this is not a problem. In a well system, chlorine is generally added at the pump to ensure adequate contact time.

Where 30 minutes of contact time is not possible, super chlorination is used. At levels of 5 ppm (one gallon chlorine bleach per 10,000 gallons water), contact time can be reduced to around five minutes. At this level taste can be too strong and carbon filtration may be needed to remove it.

Chlorination can be done manually or with variety or systems that automatically feed chlorine into the water system at the proper rate. Automatic chlorinators range in price from around $100 to $500.

Before using a water system and after repairs are made, shock chlorination at 100 ppm (3 cups chlorine bleach per 100 gallons water) is recommended. The entire system should be washed and pipes allowed to sit overnight filled with this concentration. The water should then be diverted outside as waste. This much chlorine is not good for plants or septic systems.

One advantage of chlorine is that the residual chlorine in the water can prevent recontamination. It will continue to kill micro-organisms at low concentrations for a long time.

Chlorination, while popular, is not without problems. Reaction with iron, sulfur, ammonia, slime, organic materials and/or chemicals can reduce the effective level of chlorine. In addition some of the chemicals formed when chlorine reacts with organics and ammonia are toxic or carcinogenic. If these reactants are present, follow chlorination with slow carbon filtration or consider some other disinfection method.

Distillation

Distillation can be used to remove bacteria, salts, metals, and most other contaminants from water. It is ineffective only against volatile organic chemicals. Evaporation and recondensation separates the water from other contaminants. It too is very energy intensive and therefore expensive. Electric home units for drinking water production cost around $700. Solar distillation is possible and has been used in sunny tropical areas with some success. Cost can be high because of the amount of glazing required.

Reverse Osmosis

Reverse osmosis uses high pressure to force water through an ultra-fine membrane. This membrane separates at the molecular level, allowing small molecules like water to go through while excluding larger molecules like salts, metals, and organic chemicals. This is a very effective though expensive filtration method. Another disadvantage is that 4 to 9 gallons of water are required to make one gallon of drinking water, the rest will have higher contaminant concentrations but can be used for lower quality uses. Electricity is generally necessary to achieve the high pressures required. Small hand and battery powered units are available for emergency situations. They can produce drinking water from seawater. Cost is $700 and up. Home units for drinking water cost around $700. Larger electric-powered units are available. Cost is proportionally greater. With reverse osmosis units, membranes need periodic replacement.

Iodine

Iodine can also be used to disinfect water. It is added as tablets or solution to small batches of water or automatically mixed with pumped water. Effective contact time is fifteen minutes under most circumstances. Because it costs around twenty times more than chlorine it is used mostly for emergency and other special circumstances.

Ozone

Ozone is an activated form of oxygen. It is created with electricity and mixed with water. Ozone is such a powerful oxidizer that it kills micro-organisms and breaks down organic chemicals. Where organic, chemicals are a concern, carbon filtration generally follows ozonation. Drinking water units for home use can be hard to find. Energy use and cost is high.

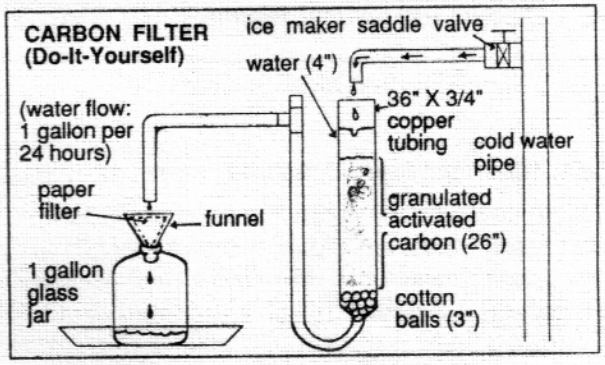
Ultraviolet Light

Ultraviolet light is another method of killing microorganisms in water. Water is circulated in a thin layer past an ultraviolet bulb encased in a quartz sleeve. The light energy kills micro-organisms very quickly. Clear water is needed for effective treatment. Particles in the water can shade the bacteria from the light. Some mechanism for cleaning the quartz sleeve is generally incorporated into the unit. A mechanism

for stopping water flow when light output is insufficient for disinfection is also included. Ultraviolet bulbs generally need replacement at least once a year. Drinking water units for home use are hard to find.

Carbon Filters

Carbon, generally in the form of granular activated carbon, can be used to remove organic chemicals from water, including pesticides, chlorination products, as well as many tastes, odors, and colors. Carbon filters are available as cartridge filters for in-line use, or as loose granules for homemade drip filtering. Fish tank charcoal can be used in roughing filters, but its effectiveness there is limited. Carbon removes organic chemicals by attracting and holding the molecules. For greatest effectiveness the water needs to flow slowly through the carbon. A drip filter is the most effective way to use carbon for treating drinking water. Many cartridge type carbon filters are available for countertop or undersink installation. Slow flow increases their effectiveness. Eventually carbon reaches its adsorption limit and must be replaced or it may begin releasing these chemicals back into the water. Carbon filters can also serve as a growth site for bacteria. They should be installed after bacterial treatment. Particles are also removed by most carbon filters. Carbon block filters using granular carbon fused with a binder are especially effective as particulate filters. Other ion exchange filters are available for iron, sulfur, or nitrates.



Ion Exchange

The best known example of ion exchange is a water softener, since sodium ions replace ions of calcium and magnesium to reduce these hardness - causing minerals. Softening of drinking water is not recommended as sodium can have negative health effects, especially for those with heart, kidney, or circulatory problems. Salt water is used to recharge water softeners when their exchange capacity is exhausted. This can be done manually or automatically or by water softener service companies that replace the tanks periodically. Use caution when discharging the salt water from recharging as it can contaminate surface and ground water.

Other Treatment

Other treatment systems are available to remove specific contaminates from water, including lead, nitrates, sulfur, iron, and other compounds. A variety of technologies is used depending upon the contaminant. Some are as simple as cartridges from special absorption resins, while others use aeration or chlorination in combination with special media filters. If you have a special water problem, consult a reputable water treatment company.

Multi-Quality Systems

The cost of producing drinking quality water from contaminated raw water can be high in small systems. In many cases it only makes sense to treat to this high level the water that actually will be consumed. Water for lower quality uses can be treated only to the needed safe level. Such a multi-quality system may require more care but can significantly lower costs while protecting health.

RESOURCES

Carbon filters:
Building and plumbing supply, numerous other sources

Granular Activated Carbon (for do-it-yourself filter):
Calgon, P.O. Box 1346, Pittsburgh, PA 15230.

Reverse Osmosis Filters:
Healthful Hardware, P.O. Box 3217, Prescott, AZ 86302, (602) 445-8225

Real Goods, 966 Mazzoni St, Ukia, CA 95482-3471, (800) 762-7325

Disposable sediment cartridges:
building and plumbing supply

Cleanable sediment filters:
EKAT, 150 Gravel Lick Rd, Dreyfus, KY 40426
(606) 986-6146

Lehman Hardware, P.O. Box 41, Kidron, oH 44636, (216) 857-5757

Cleanable ceramic micro-filters:
EKAT (see above)

Lehman Hardware (see above)

TABLE 1: Water Contamination Problems and Treatments

PROBLEM	TREATMENT							
	Mechanical Filtration	Micro Filtration	Boiling/Pas-teurization	Chlorination	Distillation	Reverse Osmosis	Carbon	Ion Exchange
Sediment	●	●			●	●	●	
Cloudiness	●	●			●	●	●	
Bacteria		●	●	●	●	●		
Hardness					●	●		●
Organic Chemicals							●	
Salts					●	●		
Color					●		●	
Odor/Taste							●	
Iron/ Manganese				●○	●			●
Metals					●	●		
Sulfur				●○	●			●
Nitrates					●	●		●

KEY: ● = generally effective treatment. ●○ = effective with another treatment

REFERENCES

Treatment of Microbial Contaminants in Potable Water Systems, Jerold T. Troyan and Sigurd P. Hansen, Noyes Data Corp., 1989.

Slow Sand Filtration, N.J.D. Graham, Halsted Press, 1988.

The Home Water Supply - How to Find, Filter, Store, and Conserve It. Stu Campbell, Garden Way, 1983, 236 pp.

Planning for an Individual water System, American Association for Vocational Instructional Materials, 1983, 157 pp.

How Safe is Your Water, Kenneth M. Stone, Garden Way, 1981.

Suggested Reading

Buyer's Guide to Water Purification Devices, Debra Lynn Dadd, Earthwise, P{.O. Box 279, Forest Knolle, CA 94933.

But Not a Drop to Drink, Steve Coffel, McMillan and Co., 1989.

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