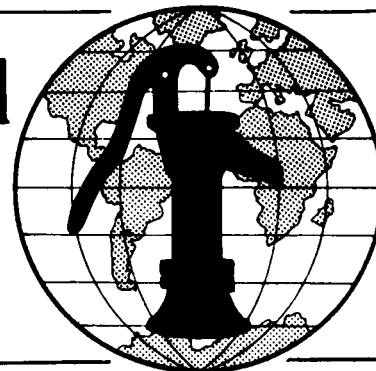


Water for the World



Methods of Water Treatment

Technical Note No. RWS. 3.M

A safe and adequate water supply is essential for the prevention of water-borne diseases. Drinking water must be free of organisms and chemical concentrations that are hazardous to human health. It should be free of suspended particles, bad tastes, colors and smells, and should not damage a water supply system. Water treatment is the process of making impure water safe to drink and use. Water that is both safe and acceptable is called "potable." It is best to develop a source that is naturally potable or that needs as little treatment as possible. Treatment processes are often expensive and always require regular attention. Since many water supplies, especially surface supplies, are not naturally potable, water treatment is often necessary.

This technical note describes basic treatment methods for individual household water supplies, simple community water systems, advanced community water systems, and water emergencies. It should be used in conjunction with "Selecting a Source of Surface Water," RWS.1.P.3, and "Selecting a Well Site," RWS.2.P.3, so that a water source needing as little treatment as possible is developed. See Table 1.

Basically, three types of water need treatment. Contaminated water contains disease-causing organisms called pathogens. The process of destroying these organisms is called disinfection. This is the most important type of water treatment in the control of diseases. Turbid water, which is clouded with suspended matter, needs to be settled or filtered to make it clear. This treatment process is called clarification.

Useful Definitions

BACTERIA - One-celled microorganisms which multiply by simple division and which can only be seen through a microscope.

BAFFLE - A wall or screen which redirects water flow in a tank or basin.

PATHOGENIC - Disease-causing.

POROUS MATERIAL - A medium full of tiny openings that water can pass through.

RAW WATER - Untreated water.

SLUDGE - Solids settled from water-carried wastes.

SUSPENDED MATTER - Small particles in water such as soil or plant debris which are light enough to remain suspended and which give water a hazy appearance.

WATERBORNE DISEASES - Diseases caused by drinking water containing pathogenic organisms.

Some well water has a high mineral or salt content or bad taste, color or odor. It needs a treatment process called conditioning. Conditioning makes unpleasant water aesthetically acceptable which may encourage people to use it.

To determine if a potential water source is potable, a sanitary survey and water analysis can be conducted. A sanitary survey is a field evaluation of local health and environmental conditions which helps determine the

acceptability of a potential water source. It is an important step in determining the need for water treatment. See "Conducting Sanitary Surveys to Determine Acceptable Surface Water Sources," RWS.1.P.2. A water analysis measures bacterial, physical and chemical characteristics of water. See "Taking a Water Sample," RWS.3.P.2, and "Analyzing a Water Sample," RWS.3.P.3, for details on water analysis.

four types of individual household water treatment: storage, filtration, boiling, and chemical disinfection. These methods can be used alone or in combination with each other, depending on the quality of the water supply.

Storage. The simplest water treatment is holding water in a container for at least two days before using it. This short-term storage of household water supplies will kill some disease-causing organisms and will settle much of the turbidity. Storing water for two weeks or longer can kill up to 90 percent of the disease-causing bacteria present. Storage containers can be made of metal, glass, plastic, or ceramic material. Earthen pots should not be used if it can be avoided because of the risk of bacterial growth in the porous clay walls. Household containers are normally from 10-30 liters in volume.

Storage containers must be covered to keep dirt and other contaminants

Treatment for Individual Household Supplies

Individual household water treatment methods are simple ways of killing some pathogenic organisms in small drinking water supplies. They are appropriate for communities without the resources or finances to construct and operate larger treatment systems. Local materials can be adapted to the design of these methods and the construction and operation skills needed are minimal. This technical note describes

Table 1. Methods of Water Treatment for Small Rural Communities

Method	Type of Treatment	Construction Cost	O & M Cost	Reliability	Construction Skill Required	O & M Skill Required
Storage	Clarification of mild turbidity	Low	Low	Small volumes of water only; used with filter and/or disinfection	Low	Low
Household filter	Clarification of turbid water; removes some pathogens	Low	Low	Up to 2700 liters/day; used with disinfection	Low	Low
Boiling	Complete disinfection	Low	High	Small volumes	Low	Low
Chemical disinfection by hand	Disinfection of clear water; kills most pathogens	Low	High	Difficult to determine; taste test only	Low	Medium
Plain sedimentation basin	Clarification of very turbid water	Medium	Low	Use with filtration and disinfection	Low	High
Slow sand filter	Clarification and disinfection	High	Low	Kills most pathogens with proper maintenance	High	Medium
Simple disinfection unit	Disinfection of clear water	Low	High	Frequent chlorine checks are necessary	Medium	High

from entering the water supply, to keep algae from growing, and to prevent evaporation. A screen at the inlet will remove large particles (see section on filtration). An outlet for drawing water as shown in Figure 1 can be added to reduce the risk of contamination. The storage container must be cleaned often to prevent organisms from growing in the settled sludge. Storing water will not kill all pathogens and is not effective for fine turbidity. Stored water should be boiled or chemically disinfected to make it completely safe to drink.

Filtration. Turbid water supplies can be clarified by filtration. This is the process of passing water through porous material to remove suspended particles. Several types of filters can be used for household water supplies. They are relatively ineffective against bacteria and fine turbidity, but they will strain out coarse materials. The filtering medium can become blocked or contaminated after prolonged contact with turbid water. It must be renewed frequently to avoid adding bacteria to the water supply. Filtered water should be boiled or otherwise disinfected before drinking.

Porcelain or ceramic filters are available commercially in some areas but they are usually expensive. They consist of a filter candle which filters water from one storage vessel to another or from one compartment to another within a single storage unit as shown in Figure 2a. They may also be attached directly to the taps of a water delivery system. Ceramic filters are relatively common in prosperous areas. They are effective for moderate turbidity, but must be cleaned whenever sediment builds up on the candle and reduces filtering efficiency and rate of flow. The candle is cleaned by scraping it with a brush and by occasionally soaking it in a mild chlorine solution.

Charcoal, ricehulls and other local materials are sometimes used as filter mediums for small water supplies. Charcoal improves the taste of some water supplies. These materials must be changed often to prevent recontamination and to maintain the required rate of flow.

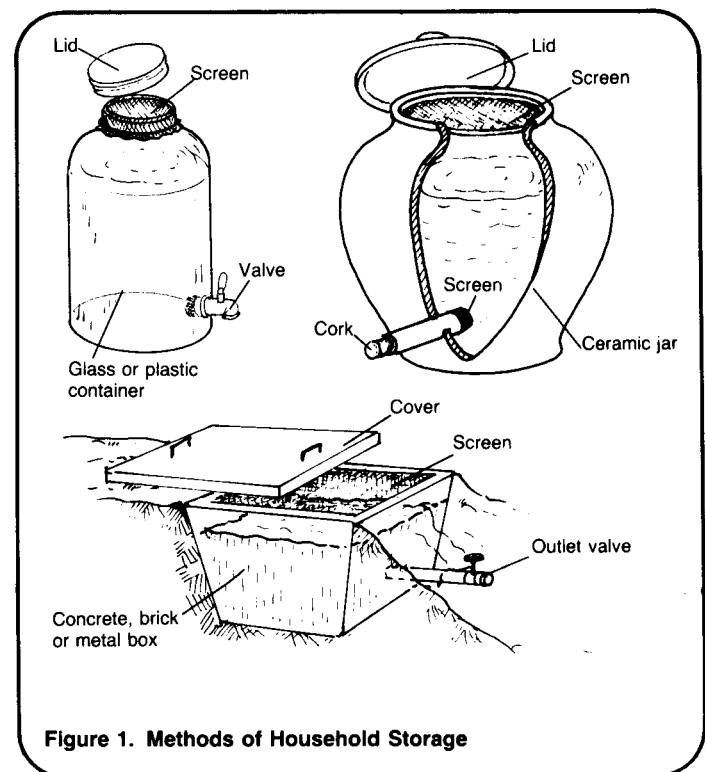


Figure 1. Methods of Household Storage

A sand filter shown in Figure 2b, is inexpensive and simple to construct and maintain. It is made of a large barrel partially filled with a layer of clean sand on top of a layer of small stones. Turbid water poured into the top of the barrel flows through the sand which traps the sediment. The resulting clear water flows out of a perforated pipe at the bottom of the barrel. A layer of gravel can be placed on top of the sand layer to prevent erosion of the sand where the turbid water is poured in. A continuous flow through a 208-liter barrel filter can process approximately 2700 liters of water per day. The sand layers must be changed every two to three weeks to keep up the flow rate and to prevent organisms from growing in the sediment trapped in the sand layers and recontaminating the water. The sand that is removed can be washed, dried and used again. Household sand filters are often used with rainfall catchments or other sources where water may contain small debris. They can filter large quantities of water quickly but do not kill pathogenic organisms. They must be carefully maintained because dirty filters can breed new organisms. A household sand filter only provides clarification of the water and prepares it for boiling or chemical disinfection.

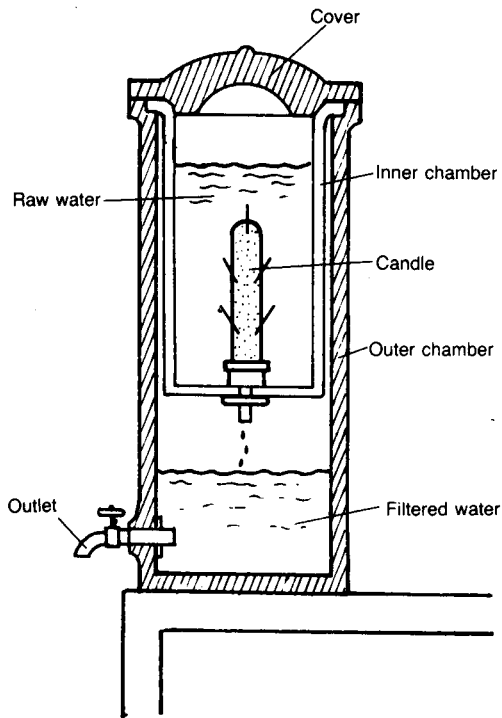


Figure 2a. Porcelain Filter

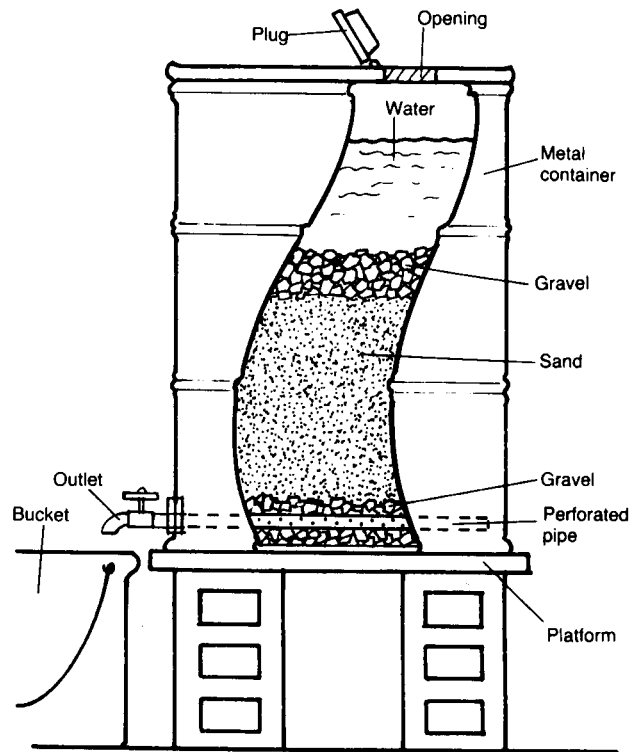


Figure 2b. Sand Filter

Boiling. Boiling water is the most effective way to disinfect relatively small quantities of water. All pathogenic organisms are destroyed in water brought to a rolling boil for two to three minutes. Cooking pots or large steel drums over fireplaces shown in Figure 3, are common vessels for boiling water for groups of less than 20 people. The water must be covered, cooled and stored in the same container it is boiled in to prevent recontamination. Constructing a boiling unit is simple and materials are inexpensive, but fuel required to boil the water (such as firewood, charcoal, kerosene or bottled gas) may be difficult to get and can be very expensive. The boiling method of water treatment is impractical for large quantities of water or large groups of people.

Boiling has been used very successfully as a treatment method in the People's Republic of China where tea is a common beverage and hot drinking water is preferred. The Chinese boil a large kettle of water each morning while they are preparing breakfast,

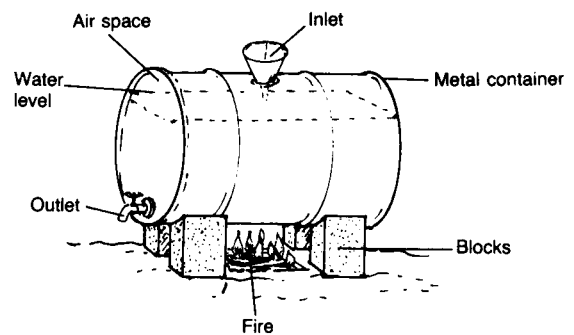


Figure 3. Method of Boiling Water

then pour the water into large thermos jugs and use it throughout the day. Using this method, the Chinese have drastically reduced the incidence of waterborne disease over the past thirty years.

Chemical disinfection by hand. Contaminated water can be disinfected with chemicals. Iodine, bromine, and chlorine can eliminate most disease-causing organisms in water but they do not kill all pathogens and are not

effective against organisms embedded in solid particles. Chemical disinfection is only appropriate for clear water supplies. Turbid water must be settled or filtered first.

Chlorine is the most widely used chemical disinfectant and is marketed in many forms. Directions for use are supplied in the purchased package and should be followed carefully. A small amount of chlorine powder or liquid can be added by hand to a water supply and allowed to set for thirty minutes to react with the contaminants present. Liquid laundry bleach is often the easiest form of chlorine stock to apply in this manner.

Chlorine added to a water supply reacts with soil particles and inorganic materials as well as disease-causing organisms. The amount of chlorine needed to disinfect a water supply is called the "chlorine demand." It changes according to the condition of the water to be treated. Extra chlorine must be added to turbid water, for example, to react with organic and inorganic material present and still kill the bacteria. The amount of chlorine left over in a water supply after disinfection is complete is called the "chlorine residual." This provides some continuing protection of the water supply against subsequent contamination. The level of chlorine residual in a chlorinated supply must be measured regularly to be certain the treatment remains effective.

Manual chemical disinfection is not always reliable. The quality of raw water often changes, and it is difficult to determine how much chemical is needed for proper disinfection. An insufficient amount will not disinfect the supply at all, and an overtreated supply can have such a bad taste or odor that no one will use it. A simple rule is to add a chlorine solution, such as laundry bleach, to a container of water just until a chlorine taste or odor is noticed.

Treatment for Simple Community Systems

Simple community water treatment methods are appropriate for groups larger than a single household. They are best suited for larger volumes of water and require more construction,

operation and maintenance skills than simple household methods. This technical note discusses three types of simple community treatment. They are plain sedimentation, slow sand filtration, and chemical disinfection dispensers. Depending on the quality of the water supply, they may be used separately or in combination.

Plain sedimentation. Plain sedimentation is a method of clarifying very turbid water. It involves holding water in or moving it slowly through a large basin until most of the suspended particles have settled to the bottom. Sedimentation is often a preparation for filtration.

A sedimentation basin is usually rectangular and made of concrete, but it may also be made of steel, stone, or local materials. It must be completely leak-proof. If filtration does not follow, it is desirable to cover the sedimentation basin to prevent algae growth or recontamination of the water. Figure 4 shows a typical sedimentation basin. Water enters it through an inlet near the top of one side of the basin, is slowed by a baffle, which is a wall or screen that redirects water flow, near the inlet. The water leaves the basin over a wire and through an outlet at the top of the other side. Valves or gates can be added to control the speed of the water. Floors of sedimentation basins

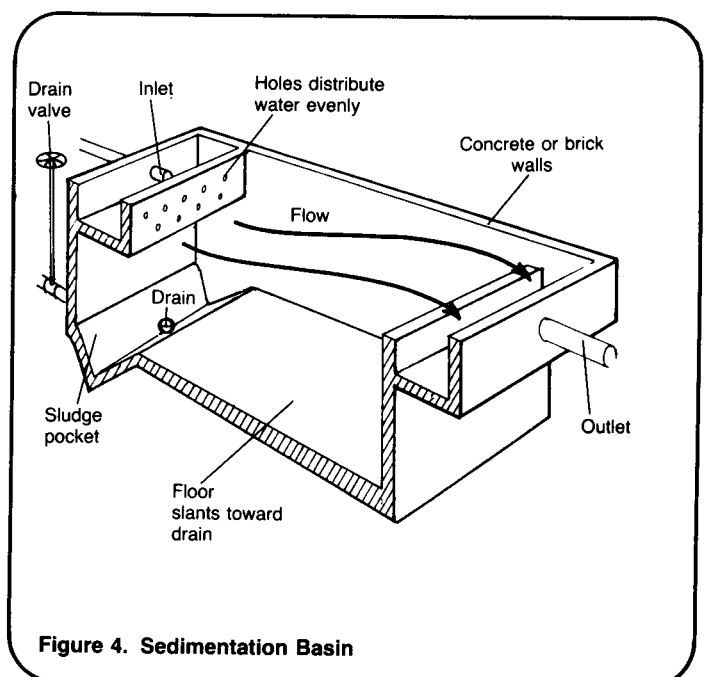


Figure 4. Sedimentation Basin

are often sloped to make removing settled sludge easier. The size of a sedimentation basin depends on the average daily water needs of the community it is serving. The basin can be designed to provide a constant flow or it can be filled and emptied as needed. Building a sedimentation basin requires trained designers and skilled construction workers.

Water is usually held in a retention type of sedimentation basin for at least two days. Very turbid water may need a chemical additive to induce settling (see section on advanced treatments). Water passing out of a sedimentation basin is clear, but needs to be disinfected to be certain it is safe to drink.

Slow sand filter. A slow sand filter shown in Figure 5, removes almost all bacteria from and clarifies large water supplies with low turbidity. It is often used in conjunction with a plain sedimentation basin for highly turbid water. It consists of a steel drum or large concrete tank partially filled with layers of small stones and very fine sand. The filter tank is flooded with water which slowly seeps through the sand. After several days, a thin slime called a schmutzedecke forms on top of the sand. The

schmutzedecke filters out bacteria and pathogenic organisms in the water passing through it. The filtered bacteria and pathogens either die or are eaten by the schmutzedecke life. The clean water passes out of the bottom of the slow sand filter through a drainage system of baked clay bricks or concrete pipes. The filtered water is usually stored in an outlet tank. Valves control the rate of draining water so that a constant depth of water remains on top of the sand to preserve the schmutzedecke. If the schmutzedecke dries out the benefits of bacteriological filtration will be lost.

Design of a slow sand filter system requires skill. The inlet and outlet arrangements, flow rates, tank sizes, sand sizes, and sand volumes must be calculated carefully. Construction of the filter tank does not require highly skilled labor, but construction costs are high and a large site is needed. Operation and maintenance skills and costs are low.

The filter should be cleaned every several weeks when the filter rate slows. It must be drained and several centimeters of sand scraped off the top of the sand bed. Raw water is allowed to flow through the sand again until the schmutzedecke has reformed. This

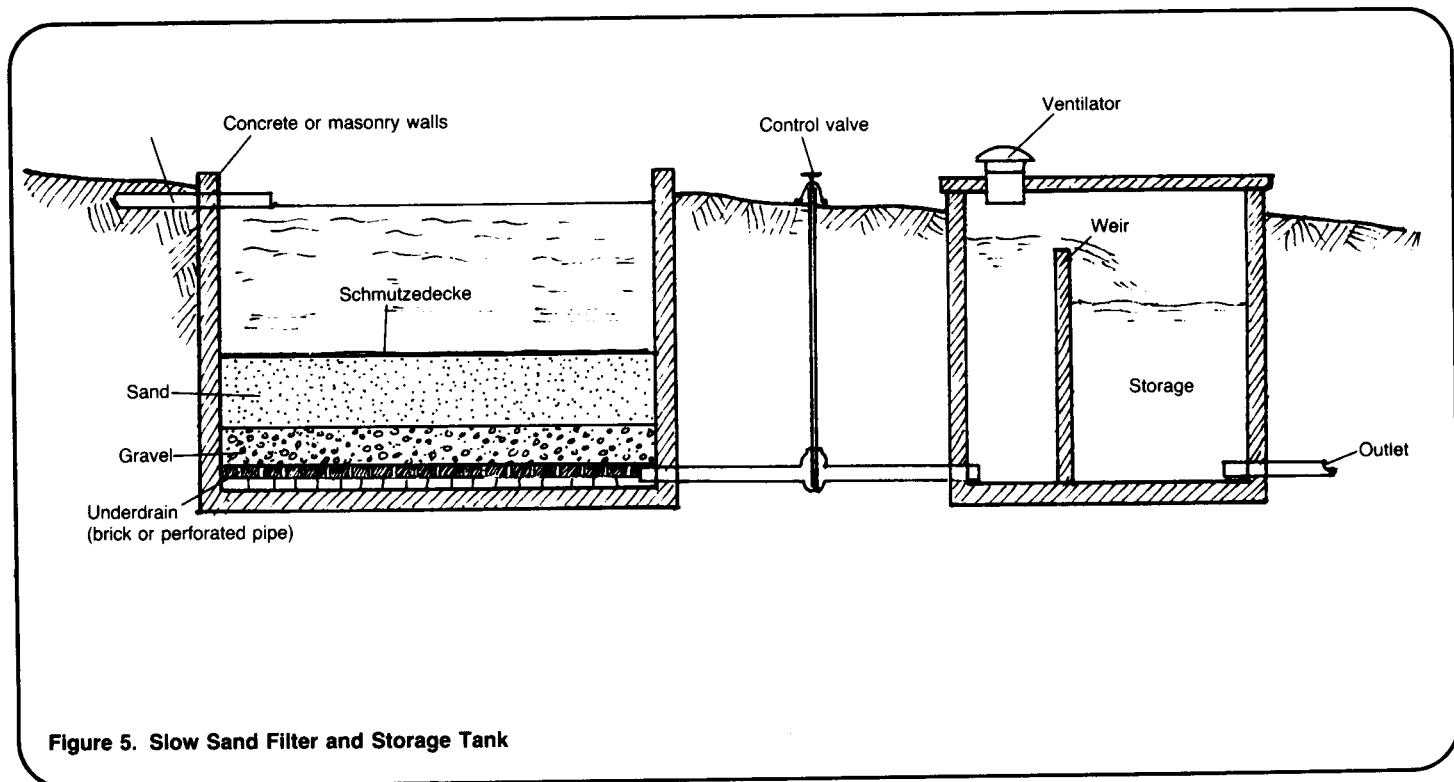


Figure 5. Slow Sand Filter and Storage Tank

usually takes a couple of days. The dirty sand can be cleaned and reused.

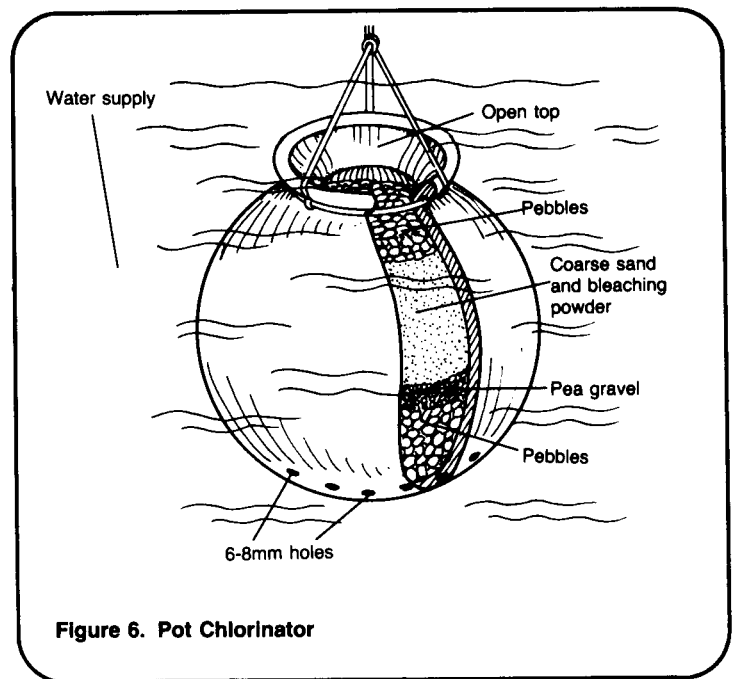
A slow sand filter can reduce the bacterial count of raw water by 85 percent. It can reduce turbidity significantly although sedimentation will still be needed for very turbid water. Chlorination often follows slow sand filtration. It further disinfects the supply and carries a chlorine residual into distribution pipes. Because of its capacity to improve the physical and bacteriological characteristics of a water source, the slow sand filter is an excellent means of treatment for rural communities with limited resources.

Chemical disinfectant dispensers.

Storage, sedimentation, and filtration reduce the bacterial content of large quantities of water but rarely disinfect a supply entirely. More complete treatment of a clear water supply can be achieved with chemical disinfectants, if regular operation and maintenance are possible. A chemical disinfectant dispenser can be used to add a small amount of chemical to a well or storage tank at a constant rate. Chlorine is the most widely used chemical disinfectant because it is relatively inexpensive and available in many areas. (See section on chemical disinfection by hand.)

Simple chlorinators that dispense chlorine at a constant rate into a water supply can be bought or made with local materials. Design and adjustment of chlorinators require careful attention. Regular testing and maintenance are necessary to ensure their effectiveness.

There are two types of simple chlorinators. A diffuser is used in non-flowing water supplies like wells, cisterns and tanks. It consists of a pot or other container filled with coarse sand and chlorine powder and submerged in a water supply. The chlorine seeps into the water through holes in the container. A single pot diffuser, shown in Figure 6, holding 1.5kg of bleaching powder in 3kg of coarse sand can serve up to 60 people for two weeks. Diffuser chlorinators have slow rates of disinfection and are most effective in wells or tanks that



do not dispense more than 1000 liters of water per day. More pots would be required for larger wells.

A drip-feed chlorinator is a container or tank which feeds chlorine solution at a constant rate into a reservoir of slowly flowing water. Figure 7 shows a drip chlorinator. It consists of a tank, usually a steel drum or concrete container about 200 liters in capacity; a cover; a floating feed valve, which can be in a bowl or a wooden float; and outlet; and a flexible tube leading from the valve to the outlet. The tank is filled with chlorine solution, and the bowl and valve float on top of the solution. A hole in the bottom of the valve is blocked with a stopper which has two holes in it. One hole has a flexible tube passing through it which runs from the bowl to the outlet of the tank. The other hole has a smaller tube passing through it which rises in the bowl to just below the level of the chlorine solution in the tank. This placement causes the chlorine solution to flow up through the small tube, collect in the bowl, drip down the other tube to the outlet, and then into the water supply. The flow into the bowl can be altered by raising or lowering the small tube. Regular attention to the level of the solution and occasional replacement of parts are necessary for drip-feeders.

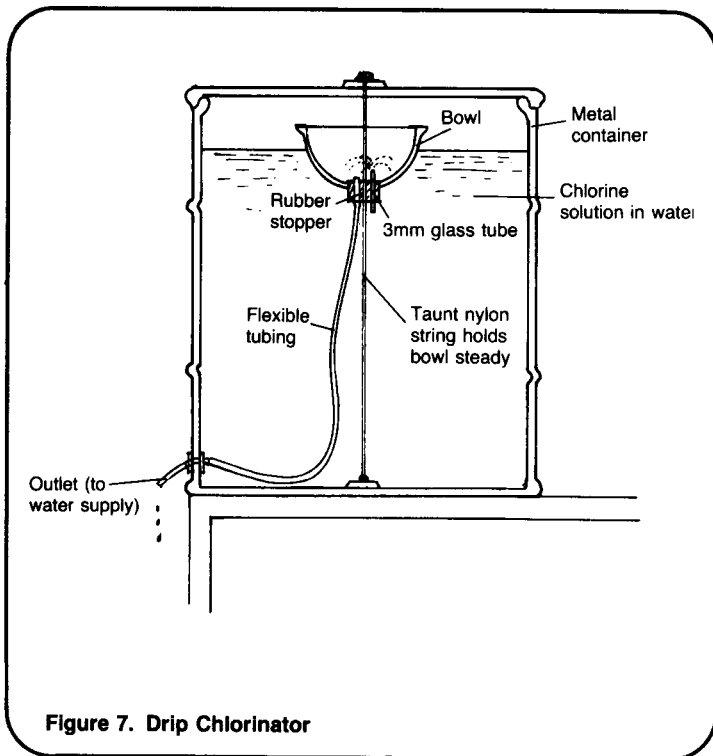


Figure 7. Drip Chlorinator

Treatment for Advanced Community Systems

Advanced treatment processes for community water supplies are those that require highly skilled construction and operation and are usually very expensive. They are rarely appropriate to rural water supply systems, but several are described briefly here.

Conditioning. Conditioning is the elimination of minerals and other substances that give water a bad color, taste or odor. Conditioning water supplies is less important than disinfection, but pleasant water encourages people to use a safe source.

Aeration is a conditioning process that exposes water to oxygen in the air. It changes iron and manganese in water to solid particles so they can be removed. Aeration will also remove gases, bad tastes and odors. Many methods of aeration can be used on small water supplies, but an expert's advice is recommended. All require energy to expose the water to air.

Desalination. Desalination is the process of removing salt from a water supply. It is a highly technical and very expensive process. Solar distillation is the simplest method of desalination, but it is rarely appropriate for small water supplies. Choosing a salt-free water source is recommended.

Clarification. Coagulation and flocculation are chemical processes that speed sedimentation. They prepare water for filtration and can reduce bacteria levels. An alum solution added to turbid water causes suspended matter to form larger particles which settle quickly. Coagulation and flocculation are often used in treatment systems for large towns and cities.

A rapid sand filter is a tank containing sand in selected sizes. It is used for clarification of turbid water. Water is forced quickly through the sand bed. A schmutzedecke has no time to develop in a rapid sand filter as it is backwashed often. A pump is necessary to backwash the filter. Construction and operation costs are high because the system of valves, pumps, and dosing devices require skilled operation and laboratory control. Regular maintenance is required.

Disinfection. Mechanized chlorinator units can be used to feed a chlorine solution into a pumped water supply. The chlorine is in either liquid or tablet form, and several different types of mechanized units are available. They all require a power source, sophisticated maintenance, and laboratory control.

Treatment Plants. A small, pre-fabricated package treatment plant may be an economically viable alternative for some small communities. Such treatment plants are highly mechanized systems which combine several different processes to clarify, disinfect and condition large volumes of water. They require a reliable source of energy, skilled construction, operation and maintenance personnel, and constant supplies of chemicals. They are expensive to buy, to operate and to maintain. They are rarely appropriate to

small rural water supply systems, although they can sometimes be used at hospitals, schools, or other locations where trained operating personnel are available.

Emergency Water Treatment

Methods of emergency water treatment are those which can be used on short notice. Disasters which cause a complete disruption of water supplies demand a fast appraisal of local conditions and available water resources. Emergency water treatment is needed when the current source becomes contaminated, when a treatment facility has been destroyed, or when a change in water source is necessary. A protected water source should be used under emergency conditions if at all possible.

Disinfection is the priority treatment process to prevent outbreaks of waterborne diseases. Boiling water or adding chlorine or iodine tablets to supplies are suitable methods of disinfecting small quantities of drinking

water. For large groups, an automatic chlorination unit of some kind is most efficient and effective. Diffusers or drip-feeders are designs most easily improvised from available materials. More sophisticated mechanized chlorination units may be used if a reliable power source is available.

Summary

In any water treatment situation, the priority treatment process is disinfection. The absence of pathogenic organisms in a water supply is essential to good health. Clarification of water supplies is often necessary for efficient disinfection. Conditioning is important to develop an aesthetically pleasing supply. A water treatment system must eliminate any current contamination, be able to reduce any subsequent contamination, and deliver an adequate amount of safe water. A carefully planned water treatment system may be the only way to provide a safe and adequate supply of drinking water to a small rural community.