

# Water Treatment Technologies

For thousands of years, people have treated water intended for drinking to remove particles of solid matter, reduce health risks, and improve aesthetic qualities such as appearance, odor, color, and taste. As early as 2000 B.C., medical lore of India advised, “Impure water should be purified by being boiled over a fire, or being heated in the sun, or by dipping a heated iron into it, or it may be purified by filtration through sand and coarse gravel and then allowed to cool.”

The treatment needs of a water system are likely to differ depending on whether the system uses a groundwater or surface water source. Common surface water contaminants include turbidity, microbiological contaminants (*Giardia*, viruses and bacteria) and low levels of a large number of organic chemicals. Groundwater contaminants include naturally occurring inorganic chemicals (such as arsenic, fluoride, radium, radon and nitrate) and a number of volatile organic chemicals (VOCs) that have recently been detected in localized areas.

When selecting among the different treatment options, the water supplier must consider a number of factors. These include regulatory requirements, characteristics of the raw water, configuration of the existing system, cost, operating requirements and future needs of the service area. TABLE 8-1 lists some water treatment processes and the purposes associated with each.

## TERMINOLOGY

*Maximum contaminant level (MCL)*: This is the maximum permissible level of a contaminant in the water that is delivered to a user of a public water supply. These levels are established by the U.S. Environmental Protection Agency (EPA).

*Best available technology (BAT)*: The process or technology that is deemed most appropriate for a given circumstance. Granular activated carbon, for example, is considered the BAT for removing most pesticides from water.

## AESTHETIC OBJECTIVES

Certain contaminants, such as iron and manganese, impart undesirable qualities to drinking water but do not represent a health threat. These are classified as secondary contaminants and do not have enforceable maximum contaminant levels.

A number of technologies exist for the treatment of these contaminants and are discussed below.

### *Water Softening*

Water softening is a process for the removal of minerals which cause hardness, primarily calcium and magnesium. With hard water, large quantities of soap are needed to produce a lather and a hard scale may form on cooking utensils or laundry basins. Hard, chalk-like formations may also coat the interior of pipes and water heaters.

Most domestic water softeners operate on the ion exchange process, which causes the replacement of calcium and magnesium ions with sodium ions. The exchange takes place when hard water comes into contact with an exchange medium, usually a synthetic resin or gel zeolite. These are insoluble granular materials that possess the property of ion exchange. After a period of time, the exchange material must be regenerated. The sodium ion is restored to the resin or zeolite medium by passing a salt (NaCl) or brine solution through the bed. It should be noted that this type of water softening process increases the sodium content of the water and may make it unsuitable for people on a low-sodium diet.

### *Greensand for Iron and Manganese Removal*

Some water treatment plants utilize the ion exchange properties of zeolites (naturally occurring minerals) as an aid to iron and manganese removal. Zeolites, including greensands, are naturally occurring aluminosilicate minerals which will exchange sodium ions for calcium and magnesium ions as discussed above. If an oxidant such as chlorine (Cl<sub>2</sub>) or potassium permanganate (KMnO<sub>4</sub>) is added to the raw water, iron and

**Table 8-1. Water Treatment Processes**

Process/step	Purpose
<i>Preliminary treatment<sup>a</sup></i>	
Screening	Removes large debris (leaves, sticks, fish) that can foul or damage plant equipment
Chemical pretreatment	Conditions the water for removal of algae and other aquatic nuisances
Presedimentation	Removes gravel, sand, silt and other gritty material
Microstraining	Removes algae, aquatic plants and small debris
<i>Main treatment</i>	
Chemical feed and rapid mix	Adds chemicals (coagulants, pH adjusters, etc.) to water
Coagulation/flocculation	Converts nonsettleable to settleable particles
Sedimentation	Removes settleable particles
Softening	Removes hardness-causing chemicals from water
Filtration	Removes particles of solid matter which can include biological contamination and turbidity
Disinfection	Kills disease-causing microorganisms
Adsorption using granular activated carbon (GAC)	Removes radon and many organic chemicals such as pesticides, solvents and trihalomethanes
Aeration	Removes volatile organic chemicals (VOCs), radon, H <sub>2</sub> S and other dissolved gases; oxidizes iron and manganese
Corrosion control	Prevents scaling and corrosion
Reverse osmosis, electrodialysis	Removes nearly all inorganic contaminants
Ion exchange	Removes some inorganic contaminants, including hardness-causing chemicals
Activated alumina	Removes some inorganic contaminants
Oxidation filtration	Removes some inorganic contaminants (e.g., iron, manganese, radium)

<sup>a</sup>Generally used for treating surface water supplies

Source: Adapted from American Water Works Assn., *Introduction to Water Treatment*, Vol. 2, 1984

manganese will precipitate out of solution and be captured by the greensand. Greensands and other natural zeolites, however, are largely being replaced by synthetic organic resins that are more effective.

### **Phosphates for Iron and Manganese Sequestration**

Iron and manganese in their soluble forms may be stabilized or sequestered by adding polyphosphates or organic sequestering agents. Sodium hexametaphosphates at dosages of about 5 mg per mg of iron may be used. This application must take place ahead of any aeration or chlorination in order to be effective. Polyphosphate dosages should be limited to less than 10.0 mg/1, because excess phosphorus may stimulate bacterial slime growth in the distribution system. Chlorination, following the addition of polyphosphates, may help control these growths. Polyphosphates may also be used as corrosion inhibitors in systems that contain a large amount of steel, iron or copper pipe. Attention should be given, however, to local ordinances that may restrict the concentration of phosphates allowed in municipal discharges to receiving waterways.

## **TASTE AND ODOR CONTROL**

Tastes and odors are aesthetically objectionable, although rarely do they indicate a health threat. If the cause of the taste and odor can be determined, a specific treatment may be designed. Hydrogen sulfide gas (the “rotten egg” odor) may be removed by chlorination which converts (oxidizes) the odorous gas to free sulfur. The free sulfur has practically no taste but may make the water cloudy (milky appearance). If so, conventional or ion exchange filters may be effective.

Tastes resulting from high levels of iron or manganese may be removed by the ion exchange units previously discussed.

Activated carbon filters, or resins mixed with activated carbon, are often effective in removing tastes and odors, especially those associated with organic decay. Carbon filters will also remove the taste of chlorine.

Copper sulfate (CuSO<sub>4</sub>) is used to control algae growth in open reservoirs or impoundments. Algae

blooms are frequent causes of taste and odor complaints during summer months. Care should be taken when adding copper sulfate to reservoirs with resident fish populations.

## HEALTH OBJECTIVES

Virtually all regulations concerning water quality and treatment are aimed at the protection of public health through the elimination of waterborne disease. The primary means of accomplishing this is through disinfection of drinking water to inactivate bacteria, viruses and protozoa. Chlorination, discussed in chapter 4, is the most commonly employed treatment. There are other technologies, however, which address not only pathogen inactivation but also removal of particulates, heavy metals, pesticides or harmful gases. This section will address these technologies as they relate to the health effects of drinking water.

### **Ultraviolet Light**

Ultraviolet (UV) light produced from UV lamps has been shown to be an effective bactericide for both air and water. In disinfecting water, the quantity of radiation required is dependent on such factors as turbidity, color and dissolved iron salts, which adversely affect the penetration of ultraviolet energy through the water. For this reason, UV light is not satisfactory for disinfecting water with high turbidity.

Cylindrical UV disinfection units with standard plumbing fittings have been designed for in-line installation in water lines. The intensity of the light should be checked frequently and the sleeve around the bulb periodically cleaned. Some units have an externally operated plunger-type apparatus for this purpose.

A disadvantage of UV light is that it does not provide a disinfectant residual in the water as does chlorine. Thus, there is no barrier against recontamination of the water. For this reason, UV light is not approved by the EPA as a sole method of disinfection for public water systems. Another disadvantage is that a continuous source of electrical power is required to operate an ultraviolet light.

### **Ozone**

While ozone is widely used for disinfection and

oxidation in other parts of the world, its use is relatively new in the United States. Ozone is unstable at ambient temperatures and pressures and therefore must be generated on site and used quickly. It is generated by applying a high-energy electrical field to either pure oxygen or dried air. Disinfection takes place as ozone gas is added to flowing water. The half-life of ozone in water is fairly short, on the order of minutes, due to its decomposition back to oxygen. For this reason, a secondary disinfectant is required, as with UV light, so that a disinfectant residual can be maintained and measured throughout the distribution system. One advantage of ozone is that it forms few disinfectant byproducts such as trihalomethanes (THMs). Disadvantages are its relatively high cost and the complexity inherent in on site generation.

### **Aeration**

Aeration, also called air-stripping, mixes water with air to volatilize (or vaporize) certain organic contaminants. This technology is appropriate for removal of most volatile organic chemicals and certain pesticides. It does not remove inorganic chemicals (heavy metals), bacteria, viruses or cysts.

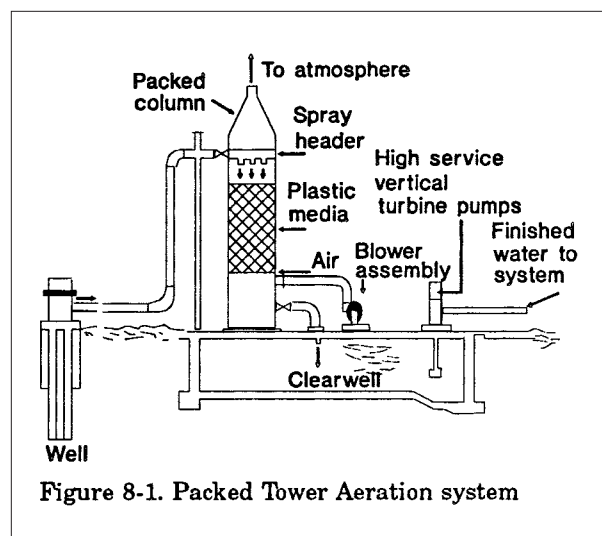
Packed tower aeration (PTA) is a waterfall aeration process that trickles raw water over a medium within a cylinder to mix water with air. The medium is usually composed of numerous hard plastic spheroid or box-type shapes, configured for maximum surface area. This medium is designed to break the water into tiny droplets, a process enhanced by the introduction of air blown from underneath the medium in the tower. As the air passes the water droplets, the organic contaminants are volatilized or "stripped" from the water and carried into the atmosphere. This technology has achieved removal rates of 95% or better for many of the volatile organic chemicals. The water is usually disinfected immediately following air stripping, because exposure to the atmosphere may introduce bacteria into the water. Water with high iron or manganese levels may tend to foul the plastic media, necessitating its periodic cleaning. One disadvantage of the packed tower process is the cost of the additional electricity required to run the blower. Another disadvantage is the physical size of the installation: towers may reach up to 8 feet in diameter and 30 feet in height, which could

represent a significant visual impact. Additionally, packed tower exhaust gases may require treatment to meet air emissions regulations (depending on location), which can significantly increase the costs of this technology.

### ***Ion Exchange***

As previously discussed, the technology of ion exchange is often employed for aesthetic purposes in the form of water softeners to remove hardness-causing minerals from water. However, this technology is also useful for the removal of inorganic chemicals or heavy metals. Flouride, radium, and to some degree nitrate, are all effectively treated with ion exchange.

The removal of these contaminants is accomplished through adsorption of the contaminant ions onto a resin exchange medium. As the name implies, one ion is substituted for another on the charged surface of the medium, usually a synthetic plastic resin. This resin surface is designed as either cationic (positively charged) or anionic (negatively charged). The medium is saturated with the exchangeable ion before treatment operations begin. During exchange, contaminant ions replace regenerant ions because they are preferred by the medium. After the medium reaches equilibrium with the contaminant ions, the medium is regenerated with a suitable solution, often sodium chloride or potassium chloride. Because of required “down time,” the shortest economical regeneration cycles are often once per day. Ion exchange waste is highly concentrated and requires careful disposal.



Advantages of ion exchange are its relative insensitivity to flow rate and its ability to achieve very low contaminant concentrations in finished water. The disadvantage is effluent peaking, which occurs when contaminant ions compete with other ions for exchange medium sites. It is most common with poorly adsorbed contaminants, such as nitrate. Effluent peaking necessitates more frequent regeneration of the exchange medium.

### ***Reverse Osmosis***

Reverse osmosis (RO) is another technology that is very effective in removing nearly all inorganic contaminants. It is also used to desalinate seawater. Reverse osmosis removes contaminants using a semipermeable membrane that permits only water and not dissolved ions (such as sodium and chloride) to pass through. Contaminated water is forced through the membrane by high pressure, leaving contaminants behind. Membranes are available in a variety of pore sizes and characteristics.

Properly operated and maintained reverse osmosis units will attain upwards of 95% removal rates for most inorganic chemicals and can also remove radium, some pesticides and microbiological contaminants. This technology has effectively treated water with total dissolved solids as high as 8,600 mg/l (seawater). These units are compact and simple to operate. They are relatively insensitive to changes in flow rate and operate immediately, without any break-in. A disadvantage of RO is its high operating and capital cost. Managing the wastewater (brine) is also a potential problem.

### ***Granular Activated Carbon / Powdered Activated Carbon***

Along with aeration, granular activated carbon (GAC) and powdered activated carbon (PAC) are suitable treatments for removal of organic contaminants such as VOCs, solvents, PCBs, herbicides and pesticides.

Activated carbon is carbon that has been exposed to very high temperature, creating a vast network of pores with a very large internal surface area; one gram of activated carbon has a surface area equivalent to that of a football field. It removes contaminants through adsorption, a process in which dissolved contaminants adhere to the surface of the

carbon particles. GAC can be used as a replacement for existing media (such as sand) in a conventional filter or it can be used in a separate contactor such as a vertical steel pressure vessel used to hold the activated carbon bed. After a period of a few months or years, depending on the concentration of the contaminants, the surface of the pores in the GAC can no longer adsorb contaminants and the carbon must be replaced.

Several operational and maintenance factors affect the performance of granular activated carbon. Contaminants in the water can occupy adsorption sites, whether or not they are targeted for removal. Also, adsorbed contaminants can be replaced by other contaminants with which GAC has a greater affinity so their presence might interfere with removal of contaminants of concern.

A significant drop in the contaminant level in influent water can cause a GAC filter to desorb, or slough off, adsorbed contaminants, because GAC is essentially an equilibrium process. As a result, raw water with frequently changing contaminant levels can result in treated water of unpredictable quality.

Bacterial growth on the carbon is another potential problem. Excessive bacterial growth may cause clogging and higher bacterial counts in the treated water. The disinfection process must be carefully monitored in order to avoid this problem.

Powdered activated carbon consists of finely ground particles and exhibits the same adsorptive properties as the granular form. PAC is normally applied to the water in a slurry and then filtered out. The addition of PAC can improve the organic removal effectiveness of conventional treatment processes and also remove tastes and odors. Advantages of PAC are that it can be used on a short-term or emergency basis with conventional treatment, creates no headloss, does not encourage microbial growth and has relatively small capital costs. The main disadvantage is that some contaminants require large doses of PAC for removal. It is also somewhat ineffective in removing natural organic matter due to the competition from other contaminants for surface adsorption and the limited contact time between the water and the carbon.

## CORROSION CONTROL

Corrosion is the deterioration of a substance by chemical action. Lead, cadmium, zinc, copper and iron might be found in water when metals in water distribution systems corrode. Drinking water contaminated with certain metals (such as lead and cadmium) can harm human health. Corrosion also reduces the useful life of water distribution systems and can promote the growth of microorganisms, resulting in disagreeable tastes, odors, slimes and further corrosion.

Because it is widespread and highly toxic, lead is the corrosion product of greatest concern. In 1985, Oregon banned the use of lead solders, fluxes and pipes in the installation or repair of any public water system. In the past, solder used in plumbing has been 50% tin and 50% lead. Using lead-free solders, such as silver-tin and antimony-tin is a key factor in lead corrosion control.

The highest level of lead in consumers' tap water will be found in water that has been standing in the pipes after periods of nonuse (overnight or longer). This is because standing water tends to leach lead or copper out of the metals in the distribution system more readily than does moving water. Therefore, the simplest short-term or immediate measure that can be taken to reduce exposure to lead in drinking water is to let the water run for two to three minutes before each use. Also, drinking water should not be taken from the hot water tap, as hot water tends to leach lead more readily than cold.

Long-term measures for addressing lead and other corrosion by-products include pH and alkalinity adjustment; corrosion inhibitors; coatings and linings; and cathodic protection, all discussed below.

## ALKALINITY AND pH ADJUSTMENT

Adjusting pH and alkalinity is the most common corrosion control method because it is simple and inexpensive. pH is a measure of the concentration of hydrogen ions present in water; alkalinity is a measure of water's ability to neutralize acids. Generally, water pH less than 6.5 is associated with uniform corrosion, while pHs between 6.5 and 8.0 can be associated with pitting corrosion. Some

studies have suggested that systems using only pH to control corrosion should maintain a pH of at least 9.0 to reduce the availability of hydrogen ions as electron receptors. However, pH is not the only factor in the corrosion equation; carbonate and alkalinity levels affect corrosion as well.

Generally, an increase in pH and alkalinity can decrease corrosion rates and help form a protective layer of scale on corrodible pipe material. Chemicals commonly used for pH and alkalinity adjustment are hydrated lime ( $\text{CaOH}_2$  or calcium hydroxide), caustic soda ( $\text{NaOH}$  or sodium hydroxide), soda ash ( $\text{Na}_2\text{CO}_3$  or sodium carbonate), and sodium bicarbonate ( $\text{NaHCO}_3$ , essentially baking soda). Care must be taken, however, to maintain pH at a level that will control corrosion but not conflict with optimum pH levels for disinfection and control of disinfection by-products.

## CORROSION INHIBITORS

Inhibitors reduce corrosion by forming protective coatings on pipes. The most common corrosion inhibitors are inorganic phosphates, sodium silicates and mixtures of phosphates and silicates. These chemicals have proven successful in reducing corrosion in many water systems.

The phosphates used as corrosion inhibitors include polyphosphates, orthophosphates, glassy phosphates and bimetallic phosphates. In some cases, zinc is added in conjunction with orthophosphates or polyphosphates. Glassy phosphates, such as sodium hexametaphosphate, effectively reduce iron corrosion at dosages of 20 to 40 mg/l.

Sodium silicates have been used for over 50 years to inhibit corrosion. The effectiveness depends on the water pH and carbonate concentration. Sodium silicates are particularly effective for systems with high water velocities, low hardness, low alkalinity and a pH of less than 8.4. Typical coating maintenance doses range from 2 to 12 mg/l. They offer advantages in hot water systems because of their chemical stability. For this reason, they are often used in boilers of steam heating systems.

## COATINGS AND LININGS

Mechanically applied coatings and linings differ for

pipes and water storage tanks. They usually are applied prior to installation, although some pipes can be lined after installation. Although coal-tar products have been widely used for coating both tanks and pipes, they are currently under regulatory scrutiny due to the presence of polynuclear aromatic hydrocarbons.

The most common pipe linings are epoxy paints, cement mortar, polyethylene and the coal-tar enamels. The most common types of reservoir linings include vinyls, epoxys and coal-tar paints and enamels. The National Sanitation Foundation (NSF), an independent testing lab, maintains lists of paints and coatings that are acceptable for potable water applications.

## CATHODIC PROTECTION

Steel reservoirs can be subject to internal corrosion through the process of electrolysis which occurs when metallic ions are released by the steel and flow through the water, which is electrically conductive. This can be overcome by installing a “sacrificial anode,” usually composed of magnesium or zinc, in the water and connecting it to the positive side of a DC power source. The wall of the reservoir is connected to the negative side of the power supply. This tends to reverse the flow of electrons, from the anode (hence the term sacrificial), through the water and back to the reservoir wall. This essentially turns the steel wall of the reservoir into a cathode, or negative terminal, with respect to its surroundings and the migration of metallic ions from the steel is retarded.

## FILTRATION TECHNOLOGIES

Filtration is the process of removing suspended solids from water as the water passes through a porous bed of materials. Natural filtration removes most suspended matter from ground water as the water passes through porous layers of soil into aquifers (water-bearing layers under the ground). Surface waters, however, are subject to runoff and are inherently vulnerable to other sources of contamination such as sewage overflows, industrial discharges, and fuel or chemical spills. Surface waters must therefore be filtered by some method in addition to being disinfected prior to use.

Current filtration technologies include cartridge filters, diatomaceous earth, slow sand, and conventional rapid sand filtration. The relative advantages of each of these types of filtration will be discussed in this section.

### **Cartridge Filtration**

Although the technology of cartridge filtration has been used for years in industries such as food and beverage, electronics, laboratories, and oil refining, it has only recently extended into the field of drinking water. Increasing public awareness of water contamination problems has led to a demand for filtration systems that are appropriate for small water systems. Cartridge filtration systems offer the benefits of filtration without the burdens of coagulant chemicals and settling basins that are associated with conventional filtration plants. The disadvantage, of course, is that cartridge filters require periodic replacement and are most appropriate for relatively low-flow situations.

Filter cartridges are manufactured from a number of materials, including cotton, nylon, polyester or polypropylene (similar to “felt”), nylon, carbon, and glass fibers. Filtration levels range from 100 microns

down to 0.5 microns. Maximum flow rate is usually around 50 gpm, depending on the types of filters and the micron ratings selected. Higher flow rates may be accommodated by placing multiple series of filters in parallel.

A common arrangement for a series of cartridge filters is to place them in the order of decreasing micron size. A roughing filter, or pre-filter, would be placed first in line to remove algae or other large debris. This filter might be in the 10 - 20 micron range. Some systems have used sand filters as a pre-filter, and provided backwash capability so that this filter can be periodically cleaned rather than replaced as a cartridge would be. An intermediate cartridge filter, in the 1- 10 micron range, would then be placed in line. The final filter, if one micron or smaller, should assure removal of *Giardia* or *Cryptosporidium* cysts without clogging prematurely. Independent verification of cyst removal efficiency, such as is done by the National Sanitation Foundation, should be obtained prior to installing a cartridge filter.

One type of cartridge filter that is relatively new to the drinking water industry is the “bag” filter. These filters are mounted in housings identical to those for typical cartridge filters. The bags are usually manufactured of polyester or polypropylene felt, sewn together, and then turned inside out to avoid leakage through the threads. They are available in ratings from 50 down to 0.5 microns. Like the cartridge filters, the bags are discarded when they become clogged. Although the bags are more expensive to replace than cartridges, they will usually have a greater capacity for holding particulate material. All filters (bags or cartridges) in a cartridge filter system should have pressure gauges on each side of the filter so that headloss, or accumulation of debris, can be monitored continuously and the filters changed when necessary.

### **Diatomaceous Earth**

Diatomaceous earth (DE) material consists of fossil skeletons of microscopic diatoms. They are mined and then processed to produce fine, porous, angular media from 5 to 50 microns in size. This type of filtration is widely used for swimming pools, but has also been used successfully to remove turbidity and *Giardia* cysts from drinking water.



Photo 8-1. Bag filters for *Giardia* removal, installed in steel housings.

DE filters use a very thin layer (less than 1/4 inch) of diatomaceous earth as a filter material, which is coated on a fine screen called a septum. It is operated under pressure in an enclosed vessel, or under a vacuum in an open vessel. Additional diatomaceous earth, known as “body feed”, is added to the influent water during the filtration process to prolong the filter run. Higher body feed doses are needed for higher concentrations of suspended solids in the raw water. When the filter becomes plugged, it is backwashed and agitated so that the diatomaceous earth falls off the septum and is flushed from the filter tank.

Operation and maintenance of diatomaceous earth filters requires the following:

1. Preparing slurries of filter body feed and precoat diatomaceous earth.
2. Adjusting body feed dosages for effective turbidity removal.
3. Periodic backwashing, perhaps every 1 to 4 days, depending on raw water quality.
4. Disposing of spent filter cake.
5. Maintenance of pumps, mixers, feeders, valves, etc.

Advantages of DE filtration include its small space requirement, ability to remove *Giardia* cysts, and the fact that turbidity and bacteria can be effectively removed, depending on the grade of diatomaceous earth used. Disadvantages are its limited effectiveness in high turbidity waters, possible clogging with algae, the need for continuous operation, and the need for periodic maintenance of the various mechanical parts. There is also a lack of regional experience with DE plants; there are currently only a few potable water DE filter plants operating in Oregon.

### **Slow Sand Filtration**

Slow sand filtration represents a technology that has been used for years in areas outside of the United States. Only recently has it been re-examined in this country as a cost-effective, efficient, and relatively simple system for water filtration.

In a slow sand filter, raw water passes by gravity through a bed of sand, about 36 inches deep, which is supported underneath by a layer of gravel. Filtered



Photo 8-2. Slow sand filter, with schmutzdecke being scraped.

water is collected by an underdrain system which is placed within or underneath the gravel. A thin layer of biologically active microorganisms forms on top of and throughout the sand bed. These organisms filter out sediment and kill harmful bacteria. After a period of time, the filter bed will begin to clog due to trapped particulate matter. The filter is cleaned by scraping a thin layer (usually less than one inch) of sand from the top of the filter, and the filter is then put back into operation. The time between filter scrapings varies from two weeks to several months, depending on raw water quality. Eventually, the scraped sand will need to be replaced -usually when the filter bed has decreased to a depth of about 24 inches.

As the name implies, the filtration rate of this technology is slow - from 50 to 100 gallons per day per square foot of filter area. This translates into a rather large space requirement if the system is to serve more than a few hundred people. Another consideration is the operational requirement that a double unit be constructed, so that one filter can remain on-line while the other is off-line for scraping, sand replacement, or repairs.

One obvious advantage of slow sand filtration is its applicability to small water systems with source waters of relatively good quality. Another advantage is that no coagulant chemicals are required, therefore fewer labor hours are required. This technology is simple and reliable, relatively low cost, and has proven effective at removal of *Giardia* cysts.

Disadvantages include the space requirement

mentioned above, limitations on raw water quality (ideally less than 10 NTU), and the relatively slow filtration rate.

### **Conventional Filtration**

Also known as rapid-sand filtration, this is the most prevalent form of water treatment technology in use today. This filtration process employs a combination of physical and chemical processes in order to achieve maximum effectiveness, as follows:

*Chemical feed and rapid mix:* Chemicals are added to the water in order to improve the subsequent treatment processes. These may include pH adjusters and coagulants. Coagulants are chemicals, such as alum, that neutralize positive or negative charges on small particles, allowing them to stick together and form larger particles that are more easily removed by sedimentation (settling) or filtration. A variety of devices, such as baffles, static mixers, impellers, and in-line sprays can be used to mix the water and distribute the chemicals evenly.

*Flocculation:* In this process, which follows the rapid mixing, the chemically treated water is sent into a basin where the suspended particles can collide, agglomerate (stick together), and form heavier particles called “floc”. Gentle agitation of the water and appropriate detention times (the length of time water remains in the basin) help facilitate this process.

*Sedimentation:* Following flocculation, a sedimentation step may be used. During sedimentation, the velocity of the water is decreased so that the suspended material, including flocculated particles, can settle out by gravity. Once settled, the particles combine to form a sludge that is later removed from the bottom of the basin.

*Filtration:* With most of the larger particles settled out, the water now goes to the filtration process. At a rate of between 2 and 10 gpm per square foot, the water is filtered through an approximate 36" depth of graded sand. Anthracite coal or activated carbon may also be included in the sand to improve the filtration process, especially for the removal of organic contaminants and taste and odor problems.

*Clearwell:* The final step in the conventional filtration process, the clearwell provides temporary storage for the treated water. The two main purposes for this storage are to have filtered water available for backwashing the filter, and to provide detention time ( or contact time) for the chlorine (or other disinfectant) to kill any microorganisms that may remain in the water.

### **Package Plants**

Representing a slight modification of conventional filtration technology, package plants are usually built in a factory, mounted on skids, and transported virtually assembled to the operation site. These are appropriate for small community systems where full water treatment is desired, but without the construction costs and space requirements associated with separately constructed sedimentation basins, filter beds, clearwells, etc. In addition to the conventional filtration processes, package plants are found as two types: tube-type clarifiers and adsorption clarifiers.

*Tube Settlers:* This modification of the conventional process contains many metal “tubes” that are placed in the sedimentation basin, or clarifier. These tubes are approximately 1 inch deep and 36 inches long, split-hexagonal shape, and installed at an angle or 60 degrees or less. These tubes provide for a very large surface area upon which particles may settle as the water flows upwards. The slope of the tubes facilitates gravity settling of the solids to the bottom of the basin, where they can be collected and removed. The large surface settling area also means that adequate clarification can be obtained with detention times of 15 minutes or less. As with conventional treatment, this sedimentation step is followed by filtration through mixed media.

*Adsorption Clarifiers:* The concept of the adsorption clarifier package plant was developed in the early 1980's. This technology uses an upflow clarifier with low-density plastic bead media, usually held in place by a screen. This adsorption media is designed to enhance the sedimentation/ clarification process by combining flocculation and sedimentation into one step. In this step, turbidity is reduced by adsorption of the coagulated and flocculated solids onto the

adsorption media and onto the solids already adsorbed onto the media. Adsorption clarifiers are cleaned by air scouring followed by water flushing. Cleaning of this type of clarifier is initiated more often than filter backwashing because more solids

are removed by the clarifier. As with the tube-settler type of package plant, the sedimentation/clarification process is followed by mixed-media filtration and disinfection to complete the water treatment.