Tech Brief

A NATIONAL DRINKING WATER CLEARINGHOUSE FACT SHEET

Filtration

Summary

Filtration is the process of removing suspended solids from water by passing the water through a permeable fabric or porous bed of materials. Groundwater is naturally filtered as it flows through porous layers of soil. However, surface water and groundwater under the influence of surface water is subject to contamination from many sources. Some contaminants pose a threat to human health, and filtration is one of the oldest and simplest methods of removing them. Federal and state laws require many water systems to filter their water. Filtration methods include slow and rapid sand filtration, diatomaceous earth filtration, direct filtration, packaged filtration, membrane filtration, and cartridge filtration.

Filtration Keeps Water Safe

Why filter drinking water?

Natural filtration removes most suspended matter from groundwater as the water passes through porous layers of soil into aquifers. Surface water, however, may be subject to direct animal, human, and industrial contamination that can cause disease or illness in humans, so they must be filtered by a constructed treatment system.

What regulations govern filtration?

The Surface Water Treatment Rule under the 1986 Safe Drinking Water Act (SDWA) Amendments requires that many surface water supply systems and groundwater under the influence of surface water filter their water supplies.

What processes precede filtration?

Conventional filtration processes are normally preceded by coagulation, flocculation, and sedimentation. Direct filtration processes are preceded by coagulation and flocculation only; the floc is removed directly by the filters.

Filtration processes may include one or all of the following pretreatment procedures:

Chemical feed and rapid mix: Chemicals may be added to the water to improve the treatment processes that occur later. These may include pH adjusters and coagulants. A variety of devices, such as baffles, and static mixers can be used to mix the water and distribute the chemicals evenly.

Flocculation: The chemically treated water is sent into a basin where the suspended particles can collide and form heavier particles called floc. Gentle agitation and appropriate detention times facilitate this process.

Sedimentation: The velocity of water is decreased so that suspended material (including flocculated particles) can settle out of the water stream by gravity. Once settled, the particles combine to form a sludge that is later removed from the clarified supernatant (the liquid removed from settled sludge) water.

How is filtration achieved?

Filtration is usually a combination of physical and chemical processes. Mechanical straining removes some particles by trapping them between the grains of the filter medium (such as sand). Adhesion is an equally important process by which suspended particles stick to the surface of filter grains or previously deposited material. Biological processes are also important in slow sand filters. These filters form a filter skin containing microorganisms that trap and break down algae, bacteria, and other organic matter before the water reaches the filter medium itself.

Comparing Filtration Systems:

Slow Sand Filtration

The filter consists of a bed of fine sand approximately 3 to 4 feet deep supported by a 1-foot layer of gravel and an underdrain system.

ADVANTAGES

Low cost, simple operation, reliable, and able to achieve greater than 99.9 percent Giardia cyst removal. It also does not require extensive active control by an operator.

LIMITATIONS

It is not suitable for water with high turbidity. Filter surface requires maintenance. Extensive land is required due to low-flow operation (0.03 to 0.10 gallons per minute per square foot [gal/min/ft^2] of filter bed area).

PROCESS

Filters are operated under continuous, submerged conditions maintained by adjusting a control valve located on the discharge line from the underdrain system. Biological processes and chemical/physical processes common to various types of filters occur at the surface of the filter bed. A biological slime or mat referred to as "schmutzdecke" forms on the surface of the bed, which traps small particles and degrades organic material present in the raw water. Slow sand filters do not require coagulation/flocculation and may not require sedimentation.

EQUIPMENT

Small plants are typically designed with cast-in-place concrete structures with wood or concrete slab covers. Piping is either cast iron or polyvinyl chloride (PVC). Flow meters are used to monitor the output for each filter. In climates subject to freezing temperatures, filters usually must be housed, and may require heating, lighting, and ventilation. Unhoused filters in cold climates develop an ice layer that prevents cleaning during winter months.

CHEMICALS

Water applied to slow sand filters is not prechlorinated because the chlorine can destroy organisms in the schmutzdecke.

Diatomaceous Earth Filtration

Diatomaceous earth filtration, also known as precoat or diatomite filtration, relies on a layer of diatomaceous earth approximately 1/8-inch thick placed on a septum or filter element. Septums may be placed in pressure vessels or operated under a vacuum in open vessels.

ADVANTAGES

The filters are simple to operate and effective in removing cysts, algae, and asbestos. They have been chosen for projects with limited initial capital, and for emergency or standby capacity to service large seasonal increases in demand.

LIMITATIONS

This filter is most suitable for water with low bacterial counts and low turbidity (less than 10 nephelometric turbidity units [NTU]). Coagulant and filter aids are required for effective virus removal. There is potential difficulty in maintaining complete and uniform thickness of diatomaceous earth on the filter septum.

PROCESS

Operation and maintenance of diatomaceous earth filters require: preparing slurries of filter body feed (diatomaceous earth) and precoat diatomaceous earth; adjusting body feed dosages for effective turbidity removal; periodic backwashing—every 1 to 4 days; disposing of spent filter cake; periodically inspecting the filter septum for cleanliness and damage; and verifying effluent quality.

EQUIPMENT

The minimum amount of filter precoat should be 0.2 pounds per square foot (lb/ft^2); and minimum thickness of the precoat should be increased from 1/8 to 1/5 inch to enhance Giardia cyst removal. In addition, minimum design criteria outlined in the Recommended Standards for Water Works (better known as 10 State Standards) should be met.

CHEMICALS

Use coagulant to coat the body feed to improve removal rates for viruses, bacteria, and turbidity.

Direct Filtration

Direct filtration systems are similar to conventional systems, but omit sedimentation.

ADVANTAGES

Effective direct filtration performance ranges from 90 to 99 percent for virus removal and from 10 to 99.99 percent for Giardia removal. The most effective direct filtration configurations for Giardia removal must include coagulation. Often used with steel pressure vessels to maintain the pressure in a water line to avoid repumping after filtration.

LIMITATIONS

Direct filtration is only applicable for systems with high quality and seasonally consistent influent supplies. The influent generally should have turbidity of less than 5 to 10 NTU and color of less than 20 to 30 units. (Water with 15 or more units of color causes aesthetic problems, such as staining.)

PROCESS

Direct filtration consists of several combinations of treatment processes. It always includes coagulation and filtration, and may require a flocculation tank or a pressure vessel after the coagulation addition.

EQUIPMENT

Dual- and mixed-media filters are used to effectively process higher influent turbidities without the use of sedimentation.

CHEMICALS

Typical coagulant dosages range from less than 1 to 30 milligrams per liter. Cationic polymers often successfully coagulate water supplies and assist direct filtration. Nonionic polymers are sometimes added to the filtration step to increase filter efficiency.

Packaged Filtration

Packaged filtration is simply all of the features of filtration—chemical addition, flocculation, sedimentation, filtration—mounted as a unit on a frame for simple hookup of pipes and services. It is most widely used to treat surface water supplies for removal of turbidity, color, and coliform organisms with filtration processes. Packaged filtration is often used to treat small community water supplies, as well as supplies in recreational areas, state parks, construction sites, ski areas, and military installations, among others.

ADVANTAGES

The four major advantages of package plants are their compact size, cost effectiveness, relative ease of operation, and design for unattended operation. (Some states require that an operator be in attendance at all times. Check your state regulations.)

LIMITATIONS

When the turbidity of the raw water varies a great deal, these package plants require a high level of operator attention and skill.

PROCESS

Package plants are most appropriate for plant sizes ranging from 0.025 to 6 million gallons per day. The most important factor to consider in selecting a package plant is the influent characteristics, such as temperature, turbidity, and color levels. Pilot tests might be necessary before a final system can be selected.

EQUIPMENT

Package plants are assembled in a factory, skid mounted, and transported to the treatment site, or they are transported as component units to the site and then assembled.

CHEMICALS

Chemical feed controls are especially important for plants without full-time operators or with variable influent characteristics. Even with these automated devices, however, the operator needs to be properly trained and well acquainted with the process and control system.

Membrane Filtration

A membrane is a thin layer of material capable of separating substances when a driving force is applied across the membrane.

ADVANTAGES

Membrane filtration can be an attractive option for small systems because of its small size and automated operation. Membrane processes are increasingly employed for removal of bacteria and other microorganisms, particulate material, and natural organic material, which can impart color, tastes, and odors to water.

LIMITATIONS

Fouling of the membranes is the major problem preventing widespread application of this technology.

PROCESS

Membrane filtration works by passing water at high pressure through a thin membrane in the form of hollow fiber or spiral-wound composite sheets. Organic and other contaminants are retained on the high-pressure side and frequently must be removed by reversing the flow and flushing the waste. Periodic chemical cleaning may be required to remove persistent contaminants. Membrane assemblies are contained in pressure vessels or cartridges.

EQUIPMENT

The membrane technologies are relatively simple to install and for groundwater sources that do not need pretreatment, the systems require little more than a feed pump, a cleaning pump, the membrane modules, and some holding tanks.

CHEMICALS

Periodic backflushing and occasional chemical cleaning is necessary to maintain the membrane or fibers.

Cartridge Filtration

Cartridge filters are considered an emerging technology suitable for removing microbes and turbidity in small systems.

ADVANTAGES

Cartridge filters are easy to operate and maintain, making them suitable for small systems with low-turbidity influent.

LIMITATIONS

Cartridge filtration systems require raw water with low turbidity. Polypropylene cartridges become fouled relatively quickly and must be replaced with new units. Although these filter systems are operationally simple, they are not automated and can require relatively large operating budgets.

PROCESS

Cartridge filtration uses a physical process—straining water through porous media. It can exclude particles 0.2 micrometers (µm) or smaller. The pore sizes that are suitable for producing potable water range from 0.2 to 1.0 µm. Roughing filters, for pretreatment prior to cartridge filtration, are sometimes necessary to remove larger suspended solids and prevent the rapid fouling of the cartridges. Roughing filters can be rapid sand filters, multimedia filters, fine mesh screens, or bag filters.

EQUIPMENT

A cartridge consists of ceramic or polypropylene filter elements fitted into pressurized housings.

CHEMICALS

A disinfectant is recommended to prevent surface-fouling microbial growth on the cartridge filters and to reduce microbial pass-through. Except for a disinfectant, no chemical additions are necessary. However, corrosive chemicals may be required for the periodic membrane cleaning process.

How does one select the appropriate filtration system?

First, review all raw water quality data to establish the requirements for the alternatives. Once the potential alternatives are selected, determine the necessity of pilot or bench-scale tests. If the desired performance of one or more of the alternatives is in doubt, testing is appropriate. (Testing is always useful if time and budget allow).

Otherwise, literature surveys, bench-scale studies, or pilot-test results can be used to derive each alternative's performance characteristics and design considerations. Following this initial selection, the basic process concerns for the various alternatives should be identified and evaluated, including:

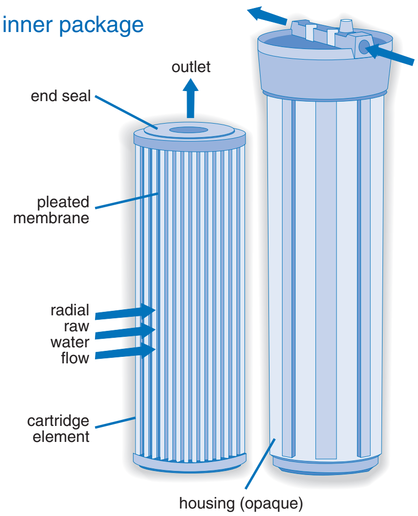
- turbidity removal performance,
- Giardia removal performance,
- color removal performance,
- cleaning cycle frequency,
- necessary chemicals/chemical dosages,
- applicable regulatory standards,
- required operational skills, and
- necessary sludge management.

Where can I find more information?

Information in this fact sheet was primarily obtained from two sources: Environmental Pollution Control Alternatives: Drinking Water Treatment for Small Communities, EPA/625/5-90/025; and Technologies for Upgrading Existing or Designing New Drinking Water Treatment Facilities, EPA/625/4-89/023. Both can be ordered free from the U.S. Environmental Protection Agency Office of Research and Development at (513) 569-7562.

Cartridge Filter

With replaceable inner package



Slow Sand Filter