METHODS OF WATER TREATMENT

Recent years have experienced steady growth in the need for water purification. This need comes from all categories of users – commercial, industrial, institutional, municipal, OEM and residential. A broad range of applications and requirements for water quality has stimulated the water treatment industry to improve existing methods and to investigate and develop new water purification technologies.

Water treatment involves processes that alter the chemical composition or natural "behavior" of water. Primary water availability include surface or groundwater sources. Most municipal or public water comes from surface water such as lakes, reservoirs and rivers while private water supplies usually consist of groundwater pumped from wells.

Municipal or Utility Water Treatment

Today, most municipal water has been exposed to extensive treatment. Water treatment methods used by municipalities to meet local, state, national, or international standards vary, but the most common are categorized below.

Basket Strainer Pre-filtration

A coarse strainer including a removable basket screen with 50 to 100 mesh, is positioned at the intake point of surface water to remove larger particulate matter and to protect downstream equipment (e.g. pumps) from fouling which might lead to damage.

Illustration 6 - Basket Strainer Screen

Clarification

Clarification (Illustration 7) is a multi-stage process geared towards reducing turbidity and suspended matter. Steps include the addition of chemical coagulants (clotting agents), pH-adjusting reagent chemicals that react to form floc. Floc then settles using the force of gravity into settling tanks or is removed as the water percolates through gravity filters. The clarification process is designed to removes particles larger than 25 microns. Clarification is also used to get rid of naturally occurring iron and to remove colors, taste, and odor by adding strong oxidizing agents (e.g. chlorine). Where gravity filters are used, carbon slurries are sometimes added to aid in organic, color and odor removal.

Clarification can remove a high percentage of suspended solids at relatively low cost. However, clarification does not remove all types of suspended contamination and will removes no dissolved solids. The clarification process is approximate yet inexpensive. Thus water treated through clarification may still contain some suspended matter.

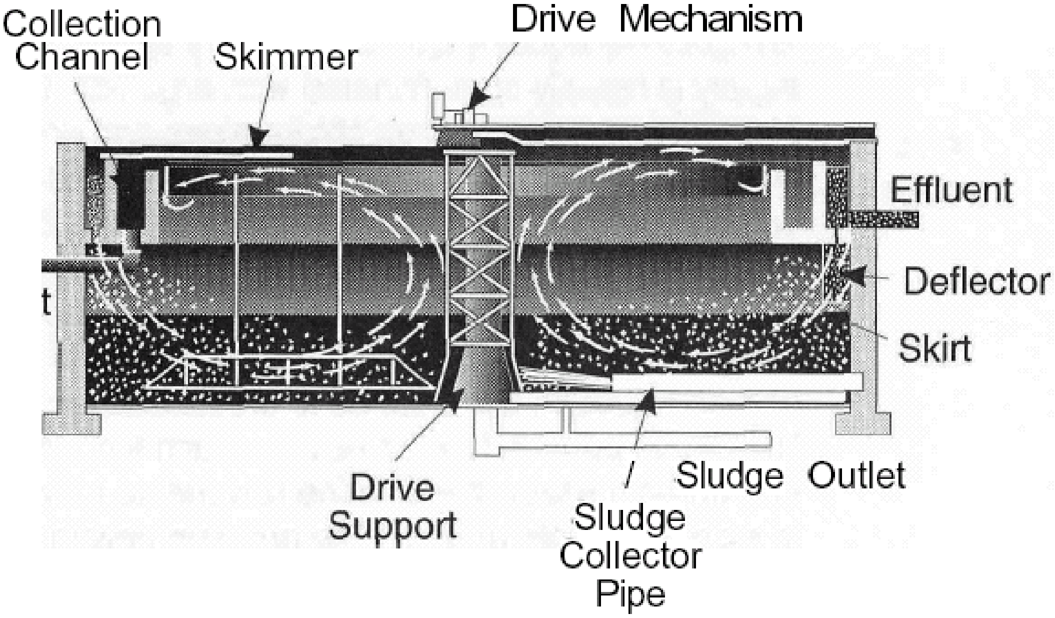


Figure 7 - Clarification *(Courtesy of Envirex)*

METHODS OF WATER PURIFICATION

In **Lime-Soda Treatment**, addition of lime (CaO) and soda ash (Na_2CO_3) reduces the level of calcium and magnesium and is referred to as "lime softening." The purpose of lime softening is to precipitate out hardness elements calcium and magnesium hydroxides, clarifying the water. The process is inexpensive but only marginally effective, usually producing water approaching 100-PPM (6-gpg) hardness. Another weakness of this process is the resulting high pH of the treated water, usually in the 8.5 to 10.0 range. Unless the pH is buffered to approximately 7.5 to 8.0, the water is usually unacceptable for general use.

Disinfecting is one of the most important steps to municipal water treatment. Commonly, chlorine gas (Cl_2) or liquid sodium hypochlorite ($NaClO_3$) is injected into the water supply after it has been clarified and/or softened. The chlorine then kills any bacteria. In order to maintain the bacterial "kill potential", an excessive amount of chlorine must be permeated into the supply to produce a residual amount. The chlorine level at remote distribution points is monitored with target levels usually about 0.2 to 0.5 PPM.

If the water supply is heavily contaminated with organic material, the chlorine may react to form chloramines and/or certain other chlorinated hydrocarbons like trihalo methanes (THM's), many of which are considered carcinogenic. In other cases, the chlorine can dissipate and no residual level is maintained at the point-of-use, allowing microbial growth to occur. To prevent this problem, most municipalities add ammonia or other nitrogenous compounds to create chloramines (NHgCl). The chloramine compounds formed have a much longer half-life, allowing a measurable chlorine residual to be maintained to extreme points-of-use. This then presents the problem of chloramines in the system.

pH Adjustment

Municipal waters must be pH adjusted to a pH of approximately 7.5 to 8.0 to prevent corrosion of water pipes, particularly to prevent dissolution of lead into the water supply. In the case of excessive alkalinity, the pH may be reduced by the addition of CO_2.

On-Site Treatment

After the water is delivered from the utility or the well, there are many on-site options for further treatment to meet specific water quality requirements.

Chemical Addition

Certain chemicals, membranes, ion exchange resins and other materials are sensitive to specific pH conditions. An example is to prevent acid corrosion in boiler feed water, the pH should be adjusted so it is 8.3 to 9.0.

To raise pH, the addition of soda ash or caustic soda is the least expensive. However, they are difficult to handle and fine tune, plus they add to the TDS.

To reduce pH, a buffering solution such as sulfuric acid (H_2SO_4) is injected into the flow using a chemically resistant metering pump (Illustration 8).

Illustration 8 - Chemically Resistant Pumps

Anti-scalants also known as dispersants are added when scaling may be expected due to concentration of specific ions in the stream. They disturb the scale formation, preventing crystallization.

Chelating, or binding agents are used to prevent the negative effects of hardness, preventing the deposition of Ca, Mg, Fe, Mn and Al.

Oxidizing agents have two distinct functions: as biocide, or to neutralize reducing agents.

Potassium permanganate ($KmnO_4$) is a strong oxidizing agent used in many bleaching applications. It will oxidize most organic compounds and is often relied upon to oxidize ferrous iron to ferric for precipitation and filtration.

Reducing agents, like sodium (meta) bisulfite ($Na_2S_2O_5$), are sometimes added to neutralize oxidizing agents like chlorine or ozone (O_3). In membrane and ion exchange systems, they prevent the degradation of membranes or resins, which may be sensitive to oxidizing agents. They are metered into solution and given a dwell time to complete the chemical reaction. Maintaining a residual amount of reducing agent extends their effect, for continues elimination of oxidizing agents.

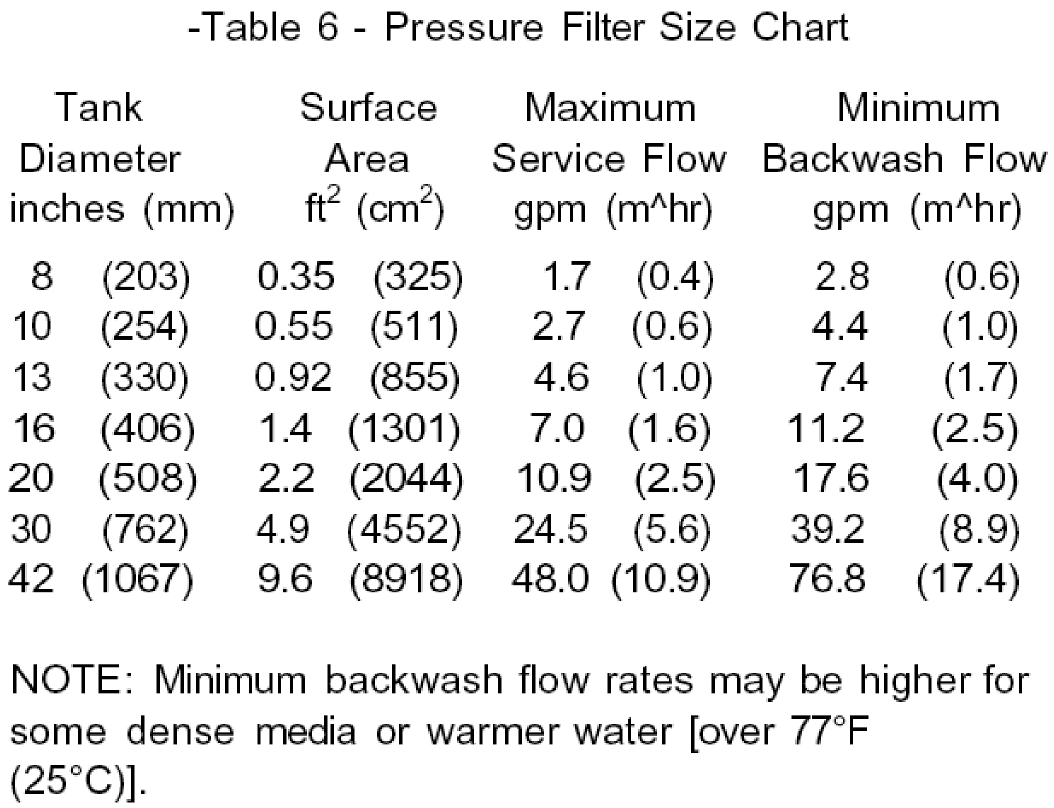
Tank-Type Pressure Filters

There are several types of mechanically identical pressure filters available, each performing a specific task. A typical filter consists of a housing tank, filter media directional valves and a controller to cycle the filter through its various stages - service, backwash and rinse.

The most critical aspect of pressure filter performance is the relationship of flow rate to filter media surface area. This relationship is the primary cause of failure or trouble in filter systems. The most common reason for a problem is that many filters are incorrectly specified for the job at hand. The nominal flow rate in the service cycle depends on surface area available, and should not exceed a nominal rate of 5 gallons per minute (gpm) per square foot (1.1 m^3hr per 0.01 m^2) of surface area, with at least a 30-inch filter bed depth. Surface area is determined by the simple equation for the area of a circle: $A = \prod r^2$, where A = the area of a circle, r = radius, and $\prod = 3.1416$.

This formula is also applied to determine minimum backwash flow rates. Backwash flow rates are a function of backwash water temperature, type, size, density of media, and the specific design of the pressure filter. Media with densities of 90-100 lb./cu. ft., require 10 to 12 gpm/sq. ft. of tank bed area. Less dense media may use lower backwash rates. Very cold water uses somewhat lower backwash rates, and warmer water requires higher rates. The table below expresses this relationship as a function of tank diameter. There are many types of filter media but all of them should follow the flow rate guidelines in Table 6.

Sand filters using sand, diatomaceous earth (DE) or other filtration media are used to remove turbidity. Sand filters are able to process large volumes rather inexpensively. The location of the fine media on top of the coarse media causes the sand filter to clog quite quickly and the coarseness of sand allows many smaller impurities to pass through.



-Table 6 - Pressure Filter Size Chart

Tank Diameter inches (mm)	Surface Area ft^2 (cm^2)	Maximum Service Flow gpm (m^hr)	Minimum Backwash Flow gpm (m^hr)
8 (203)	0.35 (325)	1.7 (0.4)	2.8 (0.6)
10 (254)	0.55 (511)	2.7 (0.6)	4.4 (1.0)
13 (330)	0.92 (855)	4.6 (1.0)	7.4 (1.7)
16 (406)	1.4 (1301)	7.0 (1.6)	11.2 (2.5)
20 (508)	2.2 (2044)	10.9 (2.5)	17.6 (4.0)
30 (762)	4.9 (4552)	24.5 (5.6)	39.2 (8.9)
42 (1067)	9.6 (8918)	48.0 (10.9)	76.8 (17.4)

NOTE: Minimum backwash flow rates may be higher for some dense media or warmer water [over 77°F (25°C)].

Table 6 - Pressure Filter Size Chart

Neutralizing Filters usually consist of a calcium carbonate calcite medium (crushed limestone or marble) to neutralize low pH water.

Oxidizing filters use a medium treated with oxides of manganese as a source of oxygen to oxidize and precipitate iron, manganese, hydrogen sulfide, and others.

Activated carbon (AC) adsorbs low molecular weight organic material and reduces chlorine or other halogens from water, but does not remove any salts. It is similar to ion exchange resin in density and porosity. AC filters are one of the few low cost methods available to remove low molecular weight (<100 MW) organic material and chlorine.

AC filters may become a source for harboring and colonization of bacteria and pyrogenic materials. As a result, they must be changed periodically to avoid bacterial growth, but are not easily reactivated in the field. Accumulated solids require regular and frequent backwash of the filter units unless they are installed after reverse osmosis or ultra-filtration.

Multi-media Filters use progressively finer layers of filter media to trap increasingly smaller particles. The staggered arrangement of coarse media followed by fine enables the filter to run for extended periods of time before backwash is required. Multi-media filters can remove suspended solids to as low as 25 microns in size, but not dissolved solids. The top layer is a coarse anthracite coal followed by a layer of fine sand.

Pre-coat Filters

Using a media of diatomaceous earth, pre-coat filters remove very small particulate matter, including some bacteria. They are practical only for limited volume applications but are common for swimming pools, beverage plants, and small installations.

Cartridge Filters

Cartridge filters, once considered point-of-use (POU) water treatment method have broadened their utility due to recent breakthroughs in filter design, such as the development of melt-blown polymer filters. Cartridge filters are offered in two general types: depth and surface filters.

In depth cartridge filter, water flows through the cross-sectional wall of the filter where the particles are trapped throughout the complex openings in the media. The filter material may be made of cellulose, cotton, polypropylene or other synthetic or natural yarns.

Illustration 10 – Melt-Blown Plastic Depth Cartridge

Depth cartridge filters (Illustration 10) are disposable, cost-effective, and available in the particle range of 1 to 100 microns (nominal). Depth cartridges are not an absolute method of purification, since a small amount of particles within the micron range may pass into the solution being filtered. However, there are premium depth filters available that feature absolute micron particle entrapment.

The most important factor in determining the effectiveness of depth filters is the porosity throughout the cross-sectional wall. The best depth filters have progressively higher density toward the inside wall with lower density on the outside.

The effect of this "graded density" (Illustration 11) is to trap coarser particles toward the outside of the wall and the finer particles toward the inner wall. Graded-density filters have a higher dirt-holding capacity and longer effective filter life than depth filters with single-density construction.

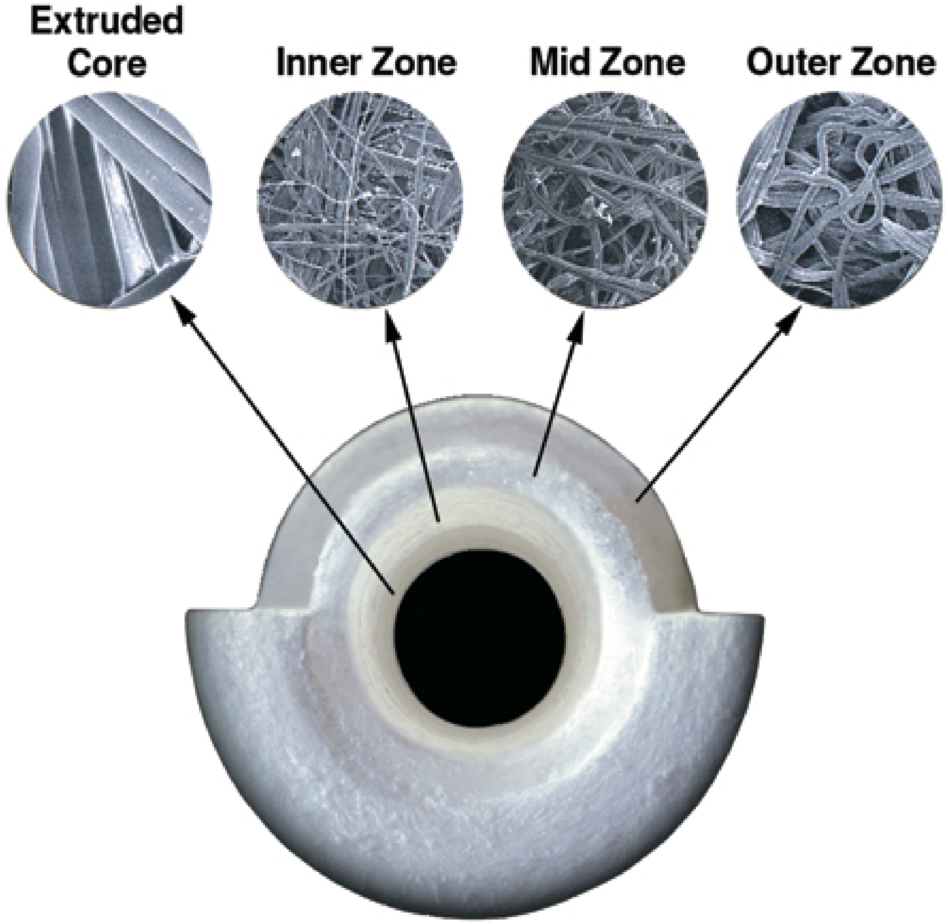


Illustration 11 - Graded Density Core / Melt-Blown Depth Cartridge

Surface filters such as pleated cartridge filters (Illustration 12) act as absolute particle filters, using a flat porous sheet media, either a membrane or specially treated non-woven material, to trap particles.

The media is pleated to increase usable surface area available. When used to trap larger particles of more than one micron, pleated filters are usually not cost-effective for water filtration. However, pleated membrane filters serve best as sub-micron particle or bacteria filters in the 0.1 to 1.0-micron range, and are often used to polish water in critical applications.

The sub-micron-pleated filters are available as re-usable or disposable, constructed with a polymer membrane. Newer cartridges also perform in the ultra-filtration range: 0.005 to 0.15 micron.

Illustration 12 - Surface Filtration / Pleated Filters in Harmsco Stainless Steel Filter Housing

Membrane cartridge filters are expensive relative to depth filters, and require replacement as the filter becomes covered with an impervious thin coating as the membrane surface is loaded with particulate matter. To avoid plugging of the pores, point-of-use ultra-filtration cartridges are built in a spiral-wound configuration. This allows a cross-flow mode of operation that helps to keep the surface clean. Point-of-use ultra-filtration cartridges are used to remove pyrogens and other larger molecular compounds from ultra-pure water.