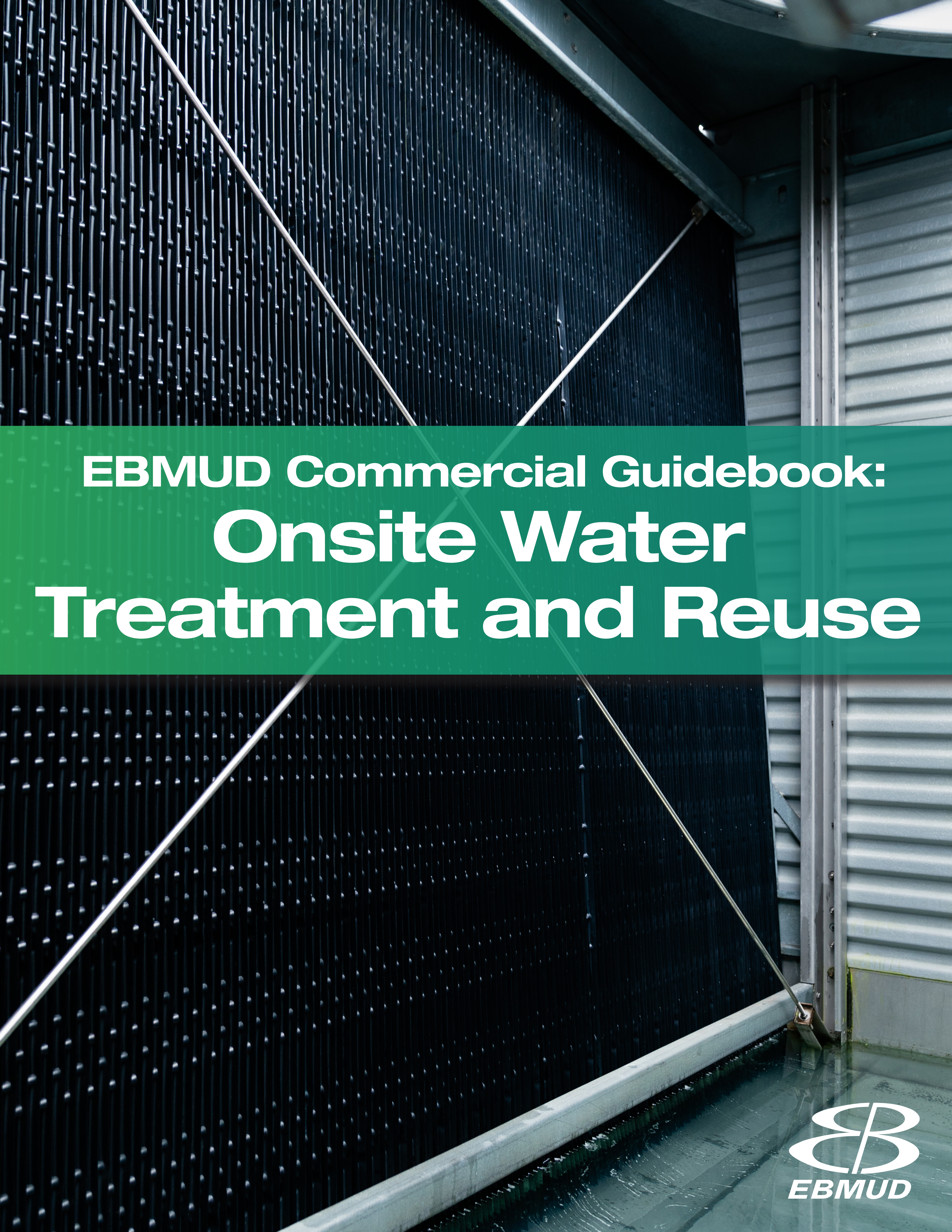
EBMUD Commercial Guidebook:

Onsite Water Treatment and Reuse



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ONSITE WATER TREATMENT AND REUSE

Onsite water treatment is used in many commercial operations, including food services, laundries, laboratories, pharmacies, and car washes. The type of treatment depends upon the application and the required water purity. Where applicable, water treatment and subsequent reuse can also be a useful tool in the water conservation arsenal, keeping the same volume of water on-site for multiple uses.

Water treatment in the CII sector ranges from simple cartridge filtration to sophisticated systems that produce extremely pure water. For example, ice machines often have cartridge sediment and carbon filters installed on the make-up water, so the ice is free of particles and chlorine taste. Some laboratories and the pharmaceutical and electronics industries also require "ultrapure water." This type of ultra-purified water has had all but a few parts per billion of minerals, organics, and other substances removed through a train of treatment, including membrane filtration, carbon filtration, softening, reverse osmosis, and strong acid/base ion exchange, followed by microfiltration and ultraviolet-light disinfection.

Water-Savings Potential

The most accessible water treatment conservation opportunity is questioning the need for additional treatment in the first place.

If treatment is deemed necessary and can be performed in a cost-effective manner, choose methods that need the least amount of cleaning and backwash or that have reject streams.

All membrane processes, for example, produce a reject stream, which in the case of nanofiltration and reverse osmosis might be reusable. Table 8-1 compares various treatments found in commercial operations.

Different CII end uses require different water purity levels. As an example, the following lists the eight grades of water used in the manufacture of drug products[2]:

- Non-potable
- Potable (drinkable) water
- USP* purified water
- USP water for injection (WFI)
- USP sterile water for injection
- LUSP sterile water for inhalation
- USP bacteriostatic water for injection
- USP sterile water for irrigation

*The USP designation means that the water is the subject of an official monograph in the current US PHARMACOPEIA with various specifications for each type

Water Chemistry and Quality Relationships

There are some basic water quality considerations common to most commercial, institutional and industrial operations.

There are many reasons why water treatment may be needed. These include:

- Dissolved Salts
- Alkalinity, pH, Bicarbonate, etc.
- Hardness
- Iron and Manganese
- Organics
- Particulates
- Silica
- Biological Species

The cosmetics company L'Oreal provides an example of on-site water treatment and reuse.

Over 50% of L'Oréal's factories have on-site wastewater treatment plants, which are essential for recycling. At L'Oréal's manufacturing sites, recycled water is used for cleaning cosmetics production equipment. Depending on the site, up to 50% of the treated wastewater is linked back to the utilities. All incoming and used water is treated on site prior to being used for other purposes.[1]

1 *https://www.wbcsd.org/Programs/Food-and-Nature/Water/Resources/Case-studies/Recycling-and-reuse-of-treated-industrial-wastewater-in-cosmetics-operations*

2 *https://www.fda.gov/inspections-compliance-enforcement-and-criminal-investigations/inspection-technical-guides/water-pharmaceutical-use*

Common water quality terms:

Mesh size: The number of holes per square inch in a membrane

Micron: A thousandth of a millimeter (the size of the holes in a filter that will pass a particle that is a micron or larger)

pH scale: The measurement of how acidic or basic water is (water is acidic if the pH is lower than 7.0 and basic above 7.0)

Hardness: The amount of dissolved calcium and magnesium in water[3]

The remainder of this section describes common treatment processes to achieve the quality of water needed for the intended end use. Specialized industrial treatment processes are beyond the scope of this chapter.

Description of End Use

Each treatment technology offers unique opportunities for water conservation, as described below:

Sediment filtration is one of the most common treatment techniques. Swimming pools, water feeds to commercial ice machines, cooling tower side-streams, drinking water, and water-using medical equipment are examples where sediment filters are found. They remove particles down to a few microns in size. The two basic designs use disposable cartridges or granular filter media, but many other types of filters can be used.

Types of sediment filters include:

- Strainers
- Particulate Filtration
- Micro and Ultra Filtration

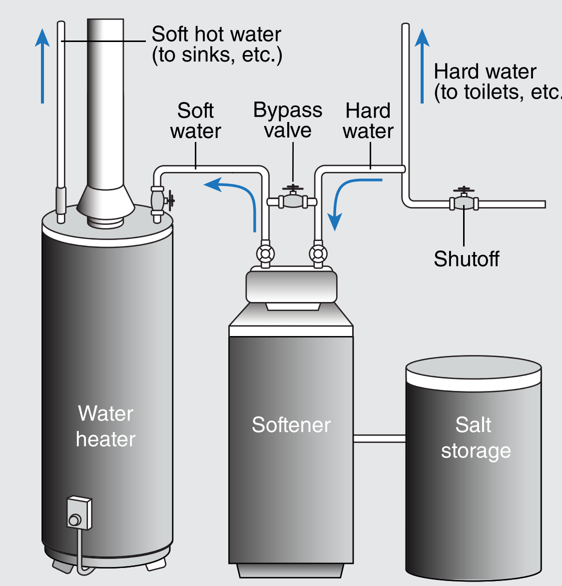
By their nature, cartridge filters are usually not designed for very large flows. Sample uses include pre-filters for ice machines, smaller medical equipment, and smaller swimming pools and spas. A filter's main objective is to remove debris, small particles and sediment from the water it is filtering. Other types of filters can filter out chlorine or other contaminants. Filter material varies from tightly wound fibers to ceramics, fused powdered-metals, or other materials. Such filters are left in place until the sediment buildup causes a predetermined increased pressure drop across the filter, at which time the filter is replaced, backwashed, or removed and cleaned for reuse.

The second type of sediment filter is often found where larger volumes of water must be processed or higher levels of sediment must be removed. These include granular media such as sand, coated media (DE, cellulose, and perlite), and mixed-bed filters. All of these must be backwashed. The backwash water is generally discharged to the sanitary sewer. In some larger applications, however, the sediment can be allowed to settle out and the clarified water can be reintroduced at the head of the filtration process. Common applications include swimming pools, industrial water treatment, and side-stream filtration for cooling towers.

Carbon filtration removes chlorine, taste, odor, and a variety of organic and heavy metal compounds from water by adsorption. Activated carbon, which has an enormous surface area per unit volume, attaches to the unwanted materials and holds them on its surfaces. Restaurants and food service providers for hospitals and other institutional operations often use activated carbon for drinking water and ice machine feed water. It is also used in the beverage industry for taste and odor control.

Activated carbon is also used to remove pollutants in the metal-finishing industry and other operations where pretreatment to remove metals or organics is needed. These systems can employ either disposable cartridges or packed columns, where the activated carbon can be removed and sent for recharge. With both cartridge and packed column systems, water simply passes through the carbon medium until its adsorptive capacity is used up.

Water Softening System



3 https://www.usgs.gov/special-topics/water-science-school/science/hardness-water

TABLE 8-1: Commercial Water Treatment Examples

	SEDIMENT FILTRATION	CARBON FILTRATION	SOFTENING & ION EXCHANGE	MEMBRANE PROCESS	DISTILLATION	DISINFECTION	OTHER
All Food Service	X	X	X	X			X
All Laundry & Dry Cleaning	X		X				
Hospital & Laboratory	X	X	X	X	X	X	X
Car Wash	X		X	X			
Beverage Manufacturing	X	X	X	X		X	
Metal Plating	X	X	X	X			X
Cooling Tower & Boiler	X		X	X		X	X
Pool, Spa, & Water Feature	X					X	
Office & Non-process	X	X	X			X	X

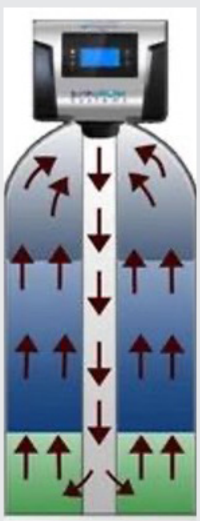
Water softening employs zeolites or ion exchange resins, where calcium and magnesium ions are exchanged for sodium or potassium ions. Softening removes hardness to control scale, improves water for washing, and prevents "hard water" spots. Recharge is done with a salt solution containing sodium or potassium cations, the most common being sodium chloride (table salt). Water is used in the recharging process to make up the brine solutions and to purge the softener of brine prior to being returned to service. All softener systems should be equipped with controllers that are activated based upon the volume treated, not on timers. They should either be adjusted for the hardness of the water supply or be equipped with a hardness controller that actually measures the hardness and volume treated, if the hardness of the feed water varies.

Softeners are commonly found where hardness interferes with water use or where scale formed by hard water could be detrimental. Laundries, car washes, boiler feed water, laboratory water, hot water systems for restaurants and food service establishments, and metal plating operations commonly employ softening. It is used occasionally for cooling tower feed water or in a process called side stream softening, which helps extend the usefulness of cooling tower water.

General Water Softening System Design Principles

There are certain design principles that are common to the previously mentioned technologies. First, the configuration of these devices is simply a vessel in which an ion exchange resin is located. It can be configured so that the water flows from the top down or the bottom up. The bottom-up flow pattern is reported to be more efficient, but excess sediment in the feed water will tend to clog the softener head unless a sediment filter is used before entering the softener.

Up flow configuration



Down flow configuration

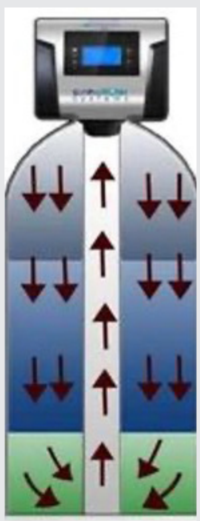


Image source: https://www.softenerparts.com/Upflow-vs-Downflow-Regeneration_c_389.html

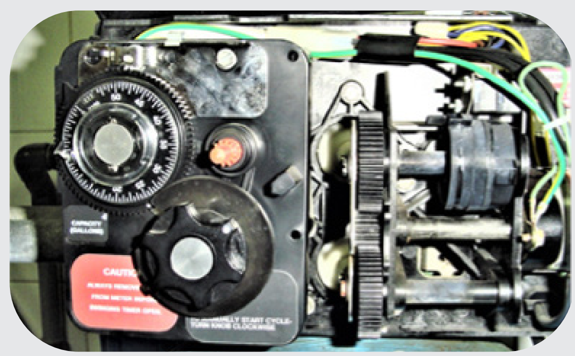
Methods used to know when to recharge the ion exchange resin:

1. **Timer control:** This is the oldest and most wasteful option. The system recharges the resin even when it does not need it. This wastes both water and chemicals.
2. **Flow meter:** The refill volume is pre-determined based on the water chemistry. When the resin has been exhausted based on the average volume of water that correlates to a specific water hardness, the recharge cycle will be triggered.
3. **Sensor-based control:** The most efficient method. The sensor measures the hardness, cation, or anion concentration and only recharges when the resin has been exhausted.

Deionization, a type of water softening, also employs exchange resins, but it is different from softening. Strong acid/base ion exchange resins, known as deionization resins, are used to produce extremely pure water for laboratory analysis, kidney dialysis, and feed water for a number of industrial processes. Water use is similar to that of recharging softening systems, but the ion removal systems operate similarly to ion exchange systems and have similar water use patterns. Ion exchange resins can also remove a variety of ionic contaminants, such as arsenic or fluoride.

Timer Control

Flow Volume Control



Images source: HW (Bill) Hoffman & Associates, LLC

According to the U.S. Environmental Protection Agency, "Up to 10 percent of a laboratory's water consumption can be related to the multi-step process of generating deionized (DI) purified water through reverse osmosis (RO). Water savings can be achieved by carefully regulating purified water generation rates to meet laboratory demand and making sure that systems are sized accordingly. EPA's Environmental Science Center in Fort Meade, Maryland, saves approximately 1.5 million gallons of water and more than $5,000 in annual water costs by reducing DI/RO system operation from 24 hours per day to 12 hours per day."[4]

4 *https://www.epa.gov/greeningepa/water-management-plans-and-best-practices-epa*

Best Management Practices

- Do not use timers to regenerate systems
- Base recharge on either cumulative flow through the exchanger or on probes in the media that detect when to recharge
- For cation and anion exchange resins, follow the manufacturer's recommendations
- Do not over size the system
- The National Sanitation Federation provides the following additional advice:[5]

  "Actuation of regeneration of water softeners shall be by demand initiation. Water softeners shall be listed to NSF/ANSI Standard 44. Water softeners should have a rated salt efficiency exceeding 3,400 grains of total hardness exchange per pound of salt, based on sodium chloride equivalency, and shall not generate more than 5 gallons of water per 1,000 grains of hardness removed during the service cycle."

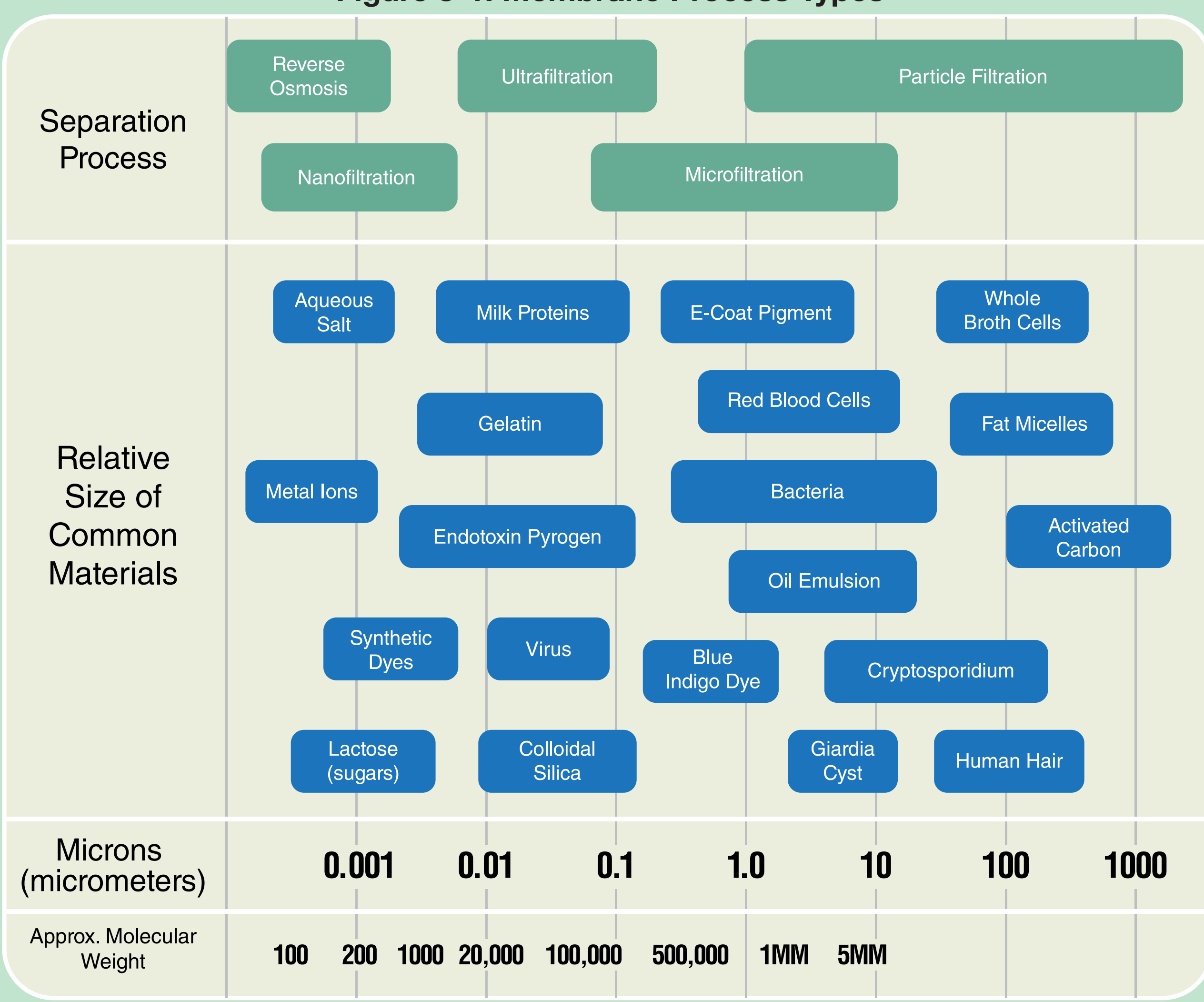
Membrane processes include several water treatment methods. A membrane, usually composed of a polymer material, is used to remove contaminates.

All membrane processes have three things in common:

1. A feed stream
2. A retentate or waste stream
3. A product called permeate

The type of membrane process used depends upon the size or type of contaminant one wishes to remove, as illustrated by Figure 8-1.

Figure 8-1: Membrane Process Types



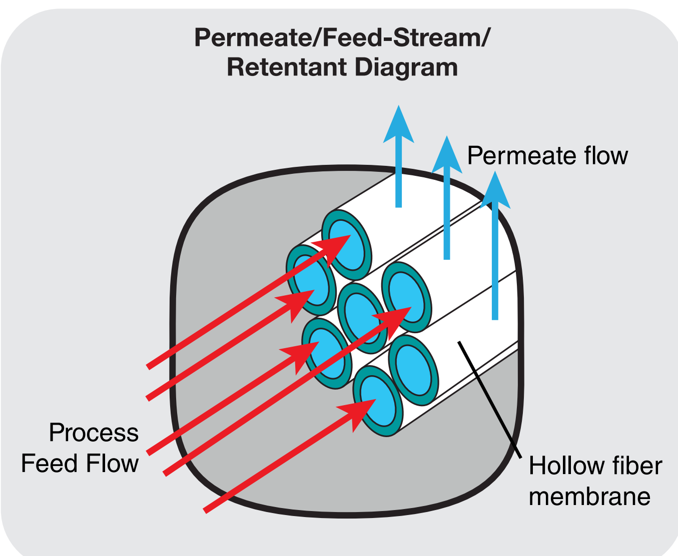
Note: 1 micron (micrometer) = 4×10^{-5} inches = 10^4 Angstrom units

5 *https://savetexaswater.org/bmp/commercial/doc/CI_BMP_Guide030413.docx*

Microfiltration employs membranes that remove particles of 0.1 to 10 microns in size or larger. It is used in municipal water treatment to remove bacterial and Giardia lamblia cysts, and Cryptosporidium oocysts. Water is forced through the membrane until the pressure drop reaches a set point. The filter is then backwashed. The membranes also require periodic chemical cleaning. Both the backwash and cleaning processes use water. Retentate (what is retained, for example by a filter or porous membrane) or waste volumes are usually a small percentage of the total feed volume. The retentate is often recirculated and only a small stream of “bleed water” is discharged as wastewater. Some ceramic filters can also filter in this range.

Ultrafiltration operates at higher pressures than microfiltration and removes materials that are much smaller, including viruses and proteins. It is often used to separate milk and whey. These filters must be backwashed and cleaned in a manner similar to microfiltration membranes.

The following diagram represents an ultrafiltration membrane, but could represent any of the four membrane processes.



Nanofiltration membranes have pore sizes midway between those of ultrafiltration and reverse osmosis. Nanofilters are often referred to as “softening” filters, since they are effective in removing multivalent cations such as calcium and magnesium.

Reverse osmosis (RO) removes salts from a water stream. It finds use wherever very pure water is needed, such as laboratories, medical uses including kidney dialysis, metal plating, boiler feed water, and other related applications. Typically, RO will reject 90 to 95 percent of the salts. RO is also used before strong acid/base deionization for the production of ultrapure water for laboratory, pharmaceutical, and microelectronics manufacturing operations.

Acoustic nanotube technology employs acoustics instead of pressure to direct water through small-diameter carbon nanotubes. The technology is based on an acoustically driven molecular screen integrated with carbon nanotubes that allow the passage of water molecules while blocking any larger molecules and contaminants. It consumes less power than traditional filtration systems and drives water away from contaminants instead of removing pollutants from water. The process also eliminates the need for flushing the filter system.

The primary applications of acoustic nanotube technology are municipal water plants, medical facilities, laboratories, distilleries, desalination plants, industrial facilities, wastewater treatment plants, and the consumer segment. The innovation is scalable with the integration of multiple filters, according to the filtration needs of users[6].

Photocatalytic water purification technology uses photocatalysts and ultraviolet (UV) rays to remove toxic substances from water. Photocatalysis can break down a range of organic materials, estrogens, pesticides, dyes, crude oil, and microbes such as viruses and chlorine-resistant pathogens, as well as inorganic compounds such as nitrous oxides. Photocatalytic water treatment systems are suitable for use in water and wastewater treatment facilities and can treat industrial wastewater polluted with high loads of organic substances or metals. This technology was developed by Panasonic[6].

Automatic Variable Filtration (AVF) technology is a simple process by where upward flow of influent is cleaned by downward flow of filter media. It eliminates the need for any additional process or freshwater for filter media cleaning. AVF systems are suitable for municipal drinking water and wastewater treatment, wastewater recycling and reuse, pre-filtration for membrane processes and desalination applications[7].

6, 6, 7 *https://www.water-technology.net/features/latest-water-purification-technologies-top-five/*

Best Management Practices for RO and Nanofiltration Systems

- Size equipment to meet the need
- Choose systems that maximize the percent of water that is recovered as product water
- Require that new systems achieve at least 75% product recovery
- RO and nanofiltration reject water should be captured and reused for irrigation, cooling tower makeup, and other appropriate uses wherever possible

Distillation is a process once common to make water for laboratory applications and is still found in many laboratories. Electric or gas stills are the most common still types. Production quantity depends upon the size of the still. Smaller stills often use once-through condenser water and can waste huge volumes of water to produce a single gallon of distillate. Small and medium size stills use air to cool the coils and have no discharge. These are the most water efficient stills. Some larger stills have reject streams to prevent scale buildup. These typically dump 15-25% of the water entering the still.

Best Management Practices for Distillation Systems

- Do not use systems that rely on once-through cooling
- Air cooled systems and systems that use the feed water for cooling should be used

Disinfection and related technologies can consume small amounts of water if chemicals are fed in a liquid or slurry form. Chemical disinfection technologies include use of chlorine compounds, ozone, and hydrogen peroxide, as well as pH control with acids and bases and the addition of antiscalants and sequestrates such as sodium hexametaphosphate. Ultraviolet light, heat, and extreme mechanical sheer are among other technologies in use.

The potential for water savings by choosing among disinfection technologies is not great; however, the potential to waste water in cleaning the equipment and storage vessels is a concern which can be abated by the use of waterless cleaning methods

Recommendations

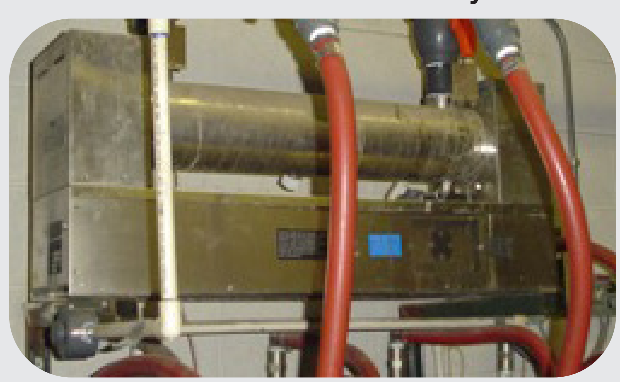
- For all filtration processes, require pressure gauges to determine when to backwash or change cartridges
- For all filtration processes, base backwash upon pressure differential
- For all ion exchange and softening processes, require recharge cycles to be set by volume of water treated or based upon conductivity controllers
- Use water treatment only when necessary
- Choose a reverse-osmosis or nanofiltration system with the lowest reject rate for its size
- Choose distillation equipment that recovers at least 85 percent of the feed water
- Evaluate opportunities to reuse backwash waste streams

Examples of Actual CII Water Treatment Systems

The following images provide examples of actual water treatment insulations in CII establishments.

"Bench-top" Ultra Pure Systems Commonly found in Laboratories

Ultra Violet Water Disinfection System



Images source: HW (Bill) Hoffman & Associates, LLC

Examples of Actual CII Water Treatment Systems (continued)

RO Filters at a Car Wash

Sand Filter for Olympic Size Swimming pool

Images sources: HW (Bill) Hoffman & Associates, LLC

Resources

1. Appliance Standards Awareness Project 2021
   https://appliance-standards.org/product/faucets#:~:text=In%202015%2C%20the%20California%20Energy,maximum%20flow%20rate%20for%20private
2. California Building Standards Commission
   https://www.dgs.ca.gov/BSC/Codes
3. California Energy Commission, California Code of Regulations Title 20, Sections 1601 Through 1608, Toilets, Urinals, and Faucets Regulations Effective January 1, 2016.
4. California Energy Commission, Appliance Efficiency Regulations - Title 20
   https://www.energy.ca.gov/rules-and-regulations/appliance-efficiency-regulations-title-20
5. California Green Building Standards Code—Part 11, Title 24, California Code of Regulations—known as CALGreen
   https://www.dgs.ca.gov/BSC/CALGreen
6. California Green Building Standards Code Chapter 5, Division 5.3
   https://codes.iccsafe.org/content/CAGBC2022P1/chapter-5-nonresidential-mandatory-measures#CAGBC2022P1_Ch05_SubCh5.3_Sec5.303
7. CalGreen Plumbing Fixture Requirements
   https://calgreenenergyservices.com/2019/11/30/calgreen-plumbing-fixture-requirements/
8. California Plumbing Code 2019
   https://up.codes/viewer/california/ca-plumbing-code-2019/chapter/4/plumbing-fixtures-and-fixture-fittings#411.0
9. John Koeller, P.E., Koeller & Company, Bill Gauley, P.Eng., Gauley Associates, Ltd., MaP Testing, Commercial Flushometers Toilet & Urinal List Downloads - May 4, 2021
   https://www.map-testing.com/downloads.html
10. National Conference of State Legislatures, Water-Efficient Plumbing Fixtures
    https://www.ncsl.org/research/environment-and-natural-resources/water-efficient-plumbing-fixtures635433474.aspx
11. Plumbing Supply.com, Showeroff® Metering Shower Systems
    https://www.plumbingsupply.com/metering-shower-systems.html
12. US EPA, WaterSense Commercial Toilets Specifications
    https://www.epa.gov/watersense/commercial-toilets#:~:text=WaterSense%20labeled%20flushometer%2Dvalve%20toilets,adequate%20flow%20to%20function%20effectively
13. US EPA, WaterSense, Case Studies for Commercial Buildings
    https://www.epa.gov/watersense/case-studies
14. US Department of Energy, Energy Cost Calculator for Urinals
    https://www.energy.gov/eere/femp/energy-cost-calculator-urinals#output

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