

Chemical quality of water in dairy industry

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Introduction

- Water is a basic renewable natural resource upon which the survival and well being of living organisms depend.
- The food industry uses large quantities of water.
- In addition to use in the growing of the raw products, water is used for generating steam, cleaning, peeling, grading, and conveying products, as a heat exchange medium in heating and cooling operations, for cleaning plant and equipment, for condensing vapors, for the fire protection, sanitizing, drinking, humidification, as an ingredient in the finished products and as a means of waste disposal.

Effect of Hard Water



- To successfully fulfill this versatile role in food industry, water must be in adequate supply, safer and of high quality.
- Moreover due to the globalization and implementation of WHO and ISO concepts the quality of raw as well as finished products has become very important.
- Management of water in food industry consists of three components:
 - i) Quality at entry level
 - ii) Water conservation
 - iii) Waste management.

Types of Water

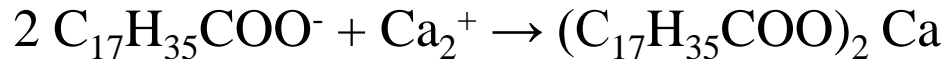
- Generally **water is classified** into two categories
 - i) Hard water and
 - ii) Soft water.
- **Water hardness** is basically due to the **presence of di- cations including Ca^{2+} and Mg^{2+}** . These ions enter a water supply by leaching from minerals.
- **Water hardness** is further of **two types**:
 - i) Temporary hardness and
 - ii) Permanent hardness.
- **Temporary hardness** is caused by the **carbonates and bicarbonates of calcium and magnesium**. This can easily be removed by boiling of water.
- On the other hand, **presence of sulfates and chlorides of calcium and magnesium** are responsible for **permanent hardness** of water.
- This kind of hardness is **not removed by simple boiling** but requires some **complex operations**.
- The **combined effect of temporary and permanent hardness is called as total hardness** of the water.

- Temporary hardness and permanent hardness are also known as **carbonate hardness** and **non- carbonate hardness**, respectively.
- Conventionally **hardness** is expressed in terms of **ppm of calcium carbonate**.
- In industry, the **major problem** caused by **hard water** is the **deposition** of scales in and on the pipes which can clog plumbing and interfere with heat exchangers.
- These **scale**, are composed mainly of **calcium carbonate** (CaCO_3), **magnesium hydroxide** [$\text{Mg}(\text{OH})_2$], and **calcium sulfate** (CaSO_4).
- Calcium and magnesium carbonates tend to precipitate out as hard deposits to the surfaces of pipes and heat exchanger surfaces.
- This is principally caused by **thermal decomposition of bicarbonate ions** but also happens to some extent even in the absence of such ions.
- **In boilers**, the deposits act as an insulation that **impairs the flow of heat into water**, **reducing the heating efficiency** and allowing the metal boiler components to **overheat**. In a pressurized system, this can lead to **failure of the boiler**.

- The following equilibrium reaction describes the formation of calcium carbonate scales



- Hard water, form white precipitate (scum) with soap solutions, instead of producing lather.
- This effect arises because the di- cations destroy the surfactant properties of the soap by forming a solid precipitate. A major component of such scum is calcium stearate.



The Indian standards for water quality tolerances for processed food industry

Bacteriological tolerances

Sl No.	Characteristics	Tolerances
1	Coliform bacteria, MPN index per 100 ml	<1
2	Standard plate count, per ml, (max)	50*
3	Proteolytic and lipolytic organisms combined count per ml (max)	5

*Not applicable in the case of cooling water and of hot water supplied in dairy industry.

Tolerances for radioactivity

Sl. No.	Characteristics	Tolerances
i)	Alpha emitters, $\mu\text{Ci/ml}$, Max	10^9
ii)	Beta emitters, $\mu\text{Ci/ml}$, Max	10^8

Physical and Chemical tolerances (BIS, 1981)

Sl no	Characteristics	Tolerance
1	Colour	20
2	Turbidity	10
3	Odour	None
4	pH	6.5 – 9.2
5	Total solids (mg/l. max)	1000
6	Total hardness (as CaCO ₃), (mg/l. max)	600
7	Sulphate (as SO ₄), (mg/l. max)	200
8	Fluoride (mg/l, max)	1.5
9	Copper (mg/l, max)	1
10	Lead (mg/l, max)	0.1
11	Zinc (mg/l, max)	15.0
12	Arsenic (mg/l, max)	0.2
13	Nitrate (mg/l, max)	20
14	Cadmium (mg/l, max)	0.1
15	Mercury (mg/l, max)	0.001

SOFTENING OF HARD WATER

- Food processors **almost always treat at least some of the water** used in the plants, even if they are supplied by a municipal system.
- This is due to the **special requirements for use in boilers, cooling towers and similar equipment.**
- Treatment may be done **to control corrosion and formation of scale on equipment, to remove turbidity caused by solids, to eliminate staining, odor and flavor problems, and to assure safety.**
- Designing a water treatment system for a food plant must be considered on an individual plant basis.

Turbidity-Solids Removed

- Turbidity results from suspended particles in water. The particles may range in size from 10^4 millimicrons in diameter for fine sand to colloidal suspensions with particle sizes from 1 to 200 millimicrons.
- Silt with a particle diameter of about 10^4 millimicrons tends to settle out as sediment in inactive form. To produce clear water, removal of particles in colloidal suspension is usually necessary.
- Since colloidal suspensions are relatively stable, a coagulant is used to cause aggregation of particles of sufficiently high density to promote settling out for clarification.
- Inorganic chemicals commonly used as coagulants are Ferric sulfate, Ferrous sulfate, Filter alum, Sodium aluminate.
- Rapid settling increases the efficiency of clarification, which can often be improved with the addition of a filter aid. Filter aids are chemicals which speed floc formation and settling.

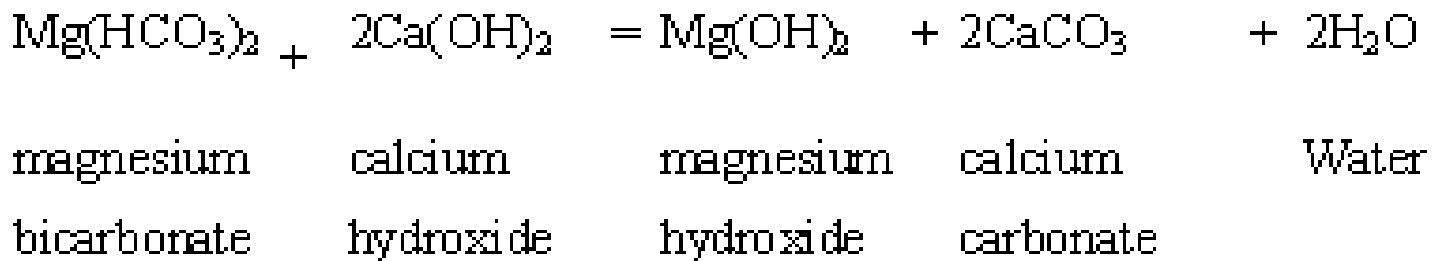
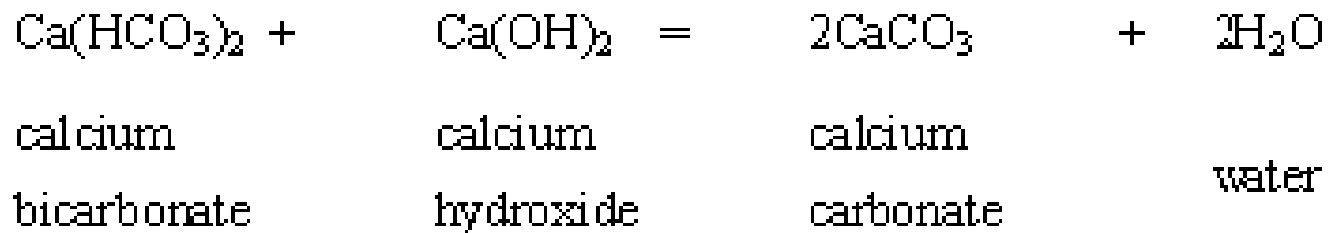
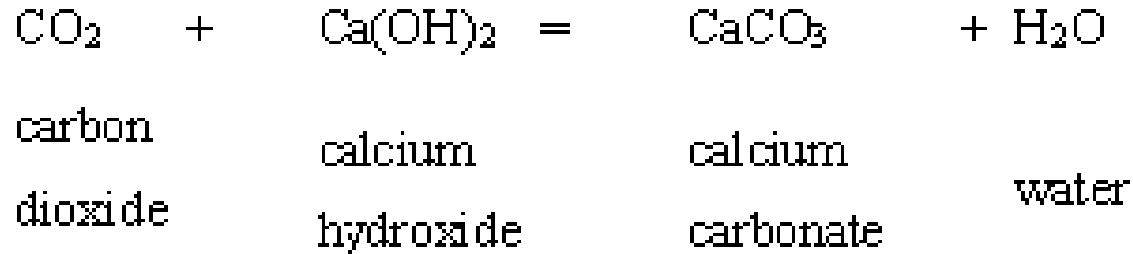
Softening

Softening of water is done to remove the hardness of water due to minerals. Different methods for water softening are as:

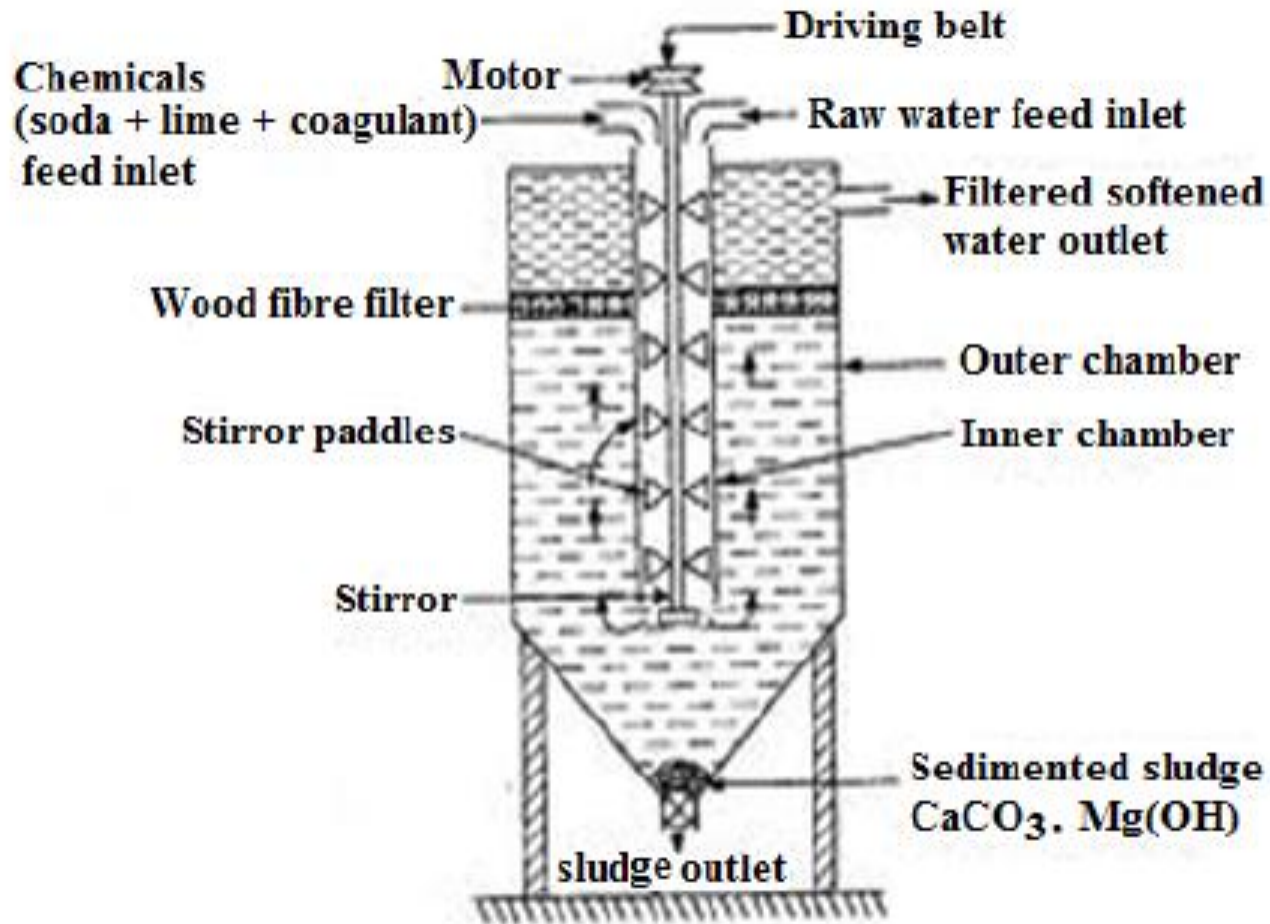
1. Cold lime method

- Many municipal water treatment plants use the cold lime softening method.
- In this process, calcium oxide (CaO) is added to the hard water to form calcium hydroxide, which reacts with magnesium and calcium bicarbonates and free CO_2 to form insoluble calcium carbonate and magnesium hydroxide.
- Magnesium hydroxide is a good flocculating agent which aids in precipitating the calcium carbonate particles.
- This treatment will usually result in water with about 70 to 85 ppm of calcium (4 to 5 grains per gallon) when discharged from the final filtration unit.
- Sand and gravel filters are commonly used for removing the precipitated salts by the cold lime softening method.

Process is based on the following reaction:

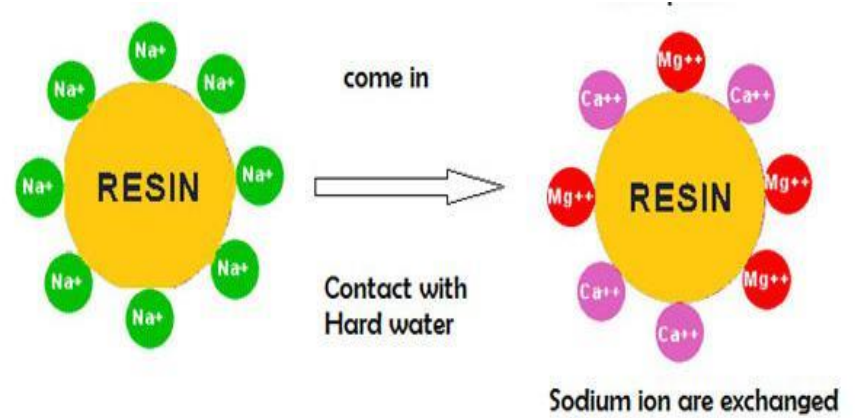
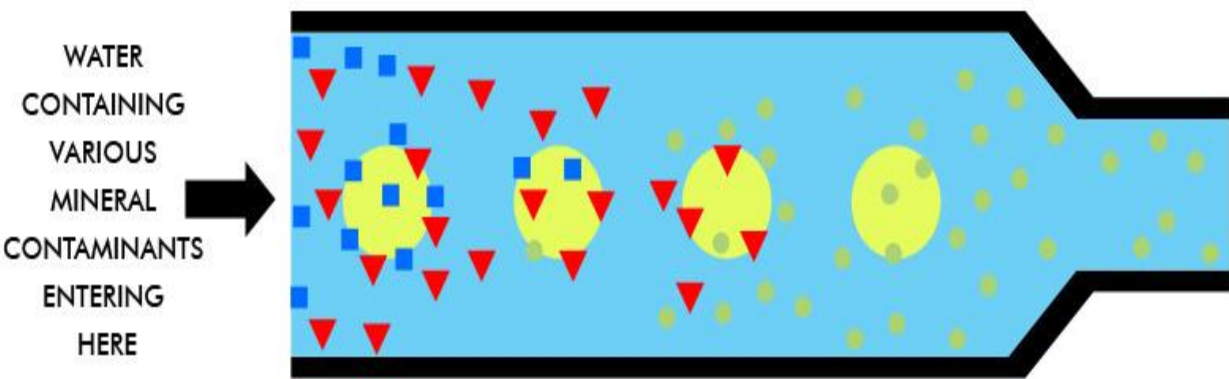
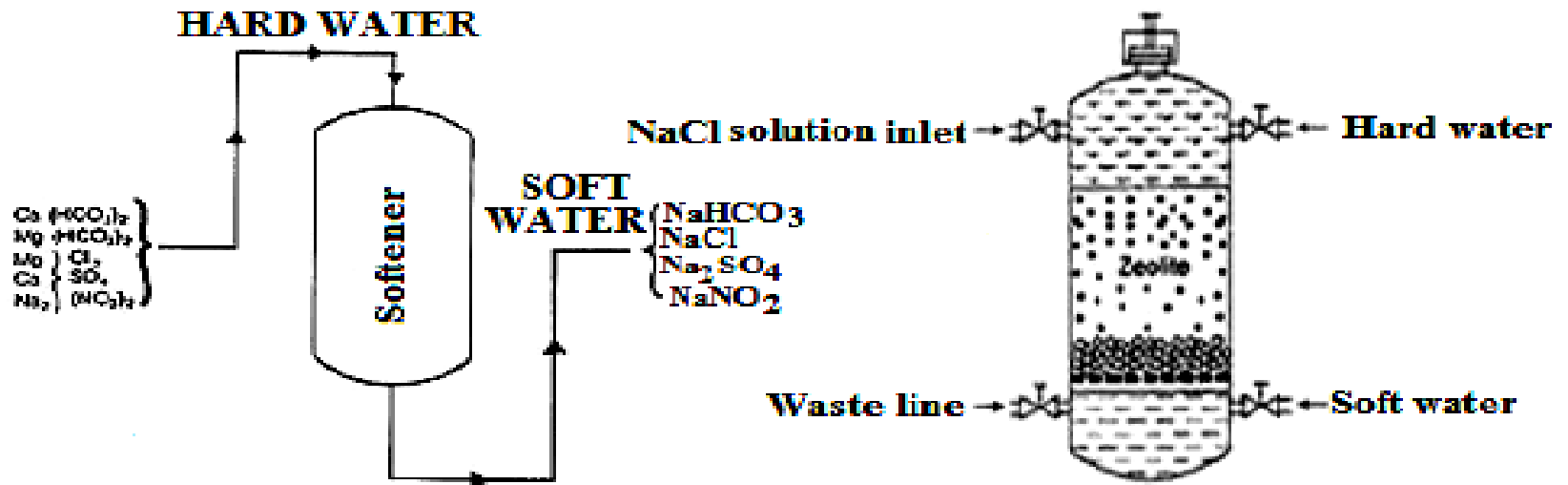


Continuous cold lime water softener



Base exchange softening method

- Most food plants has find the base-exchange process to be a more practical and controllable method for softening the water for cleaning and other uses.
- The **materials used** in the ion-exchange are **natural or synthetic zeolites** which often **are hydrous silicate or styrene based resins**.
- In the sodium cation exchange, sodium from the zeolite or resin displaces an equivalent quantity of calcium and magnesium in the water as it passes through the bed.
- Sodium zeolite softening is the most widely applied use of ion exchange.
- In zeolite softening, water containing scale-forming ions, such as calcium and magnesium, passes through a resin bed containing SAC (Strong Acid Cation) resin in the sodium form.
- SAC resins derive their functionality from sulfonic acid groups (HSO_3^-).



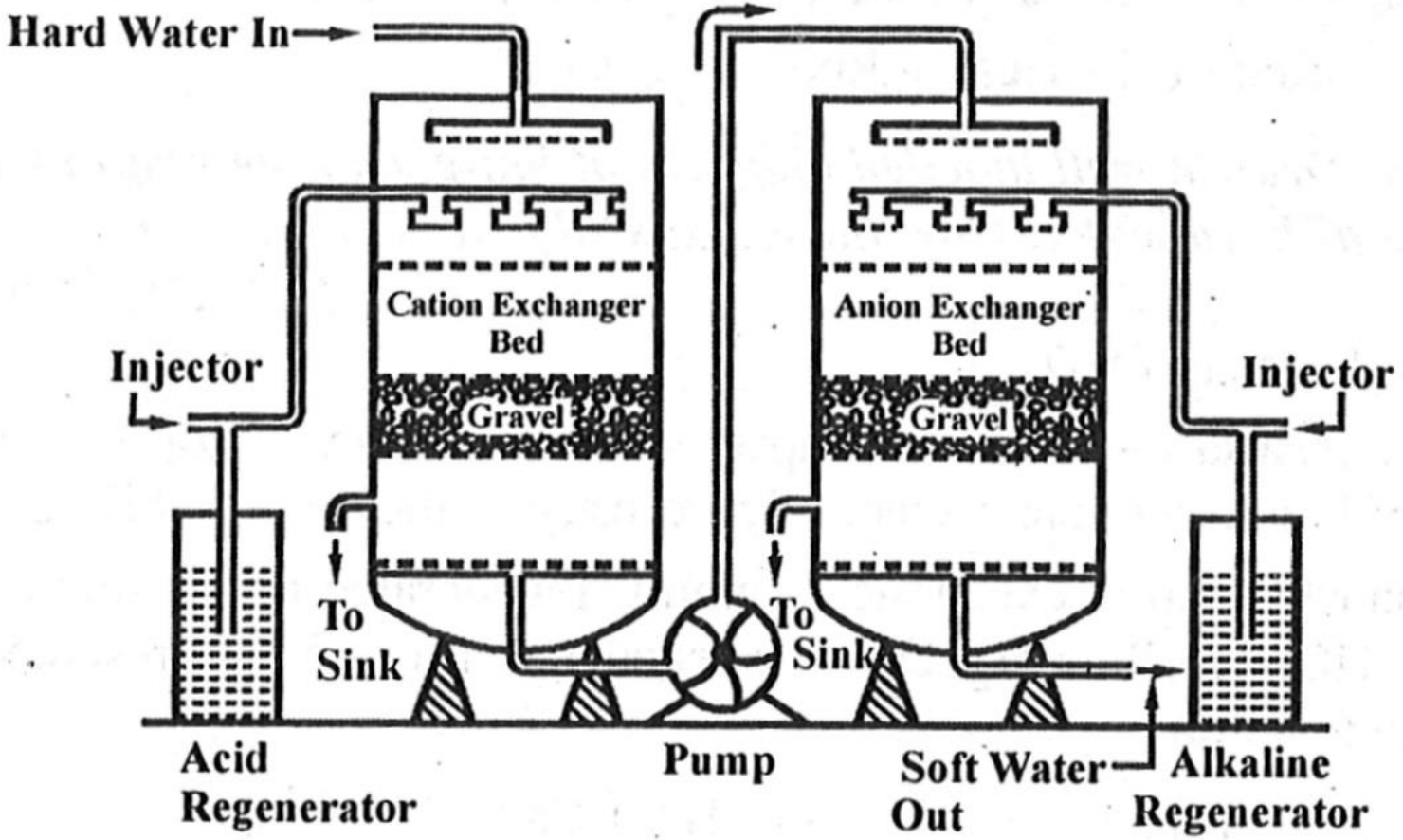
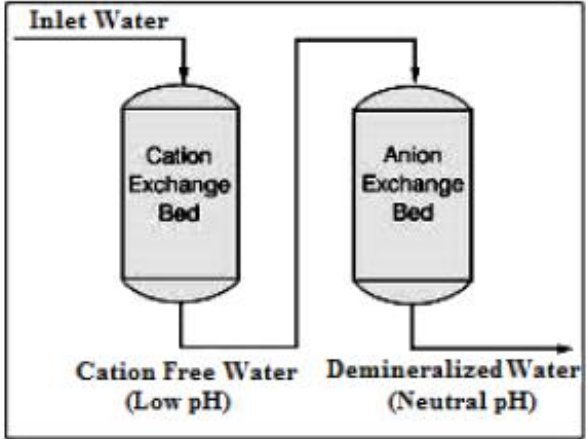
- In the resin, the hardness ions are exchanged with the sodium, and the sodium diffuses into the bulk water solution.
- The exchange reaction is reversible. When its capacity is exhausted, the resin can be regenerated with an excess of mineral acid.
- Strong acid cation exchangers function well at all pH ranges. The removal of hardness from water by a zeolite softening process is described by the following reaction:



In recent years the technology of ion exchange has advanced considerably and several excellent resins have been developed. For softening commonly used resins are of a sulfonated styrene divinylbenzene structure.

Demineralizing (Deionizing) water supplies

- Although softening water with a sodium cycle ion-exchanger is most commonly found in processing plants, there is also need for demineralized (deionized) water for special purposes, such as use in the beverage industry.
- Several variations may be found in demineralization systems depending on the analysis of the untreated water and the desired purity of the treated water.
- Systems for demineralizing water are basically of two types, multi-bed and mixed-bed.
- Mixed-bed units offer the advantage of less space required, and they will also produce high quality water.
- Multi-bed and mixed-bed ion ex-changers are sometimes sequenced into a system to produce very high quality demineralized water.

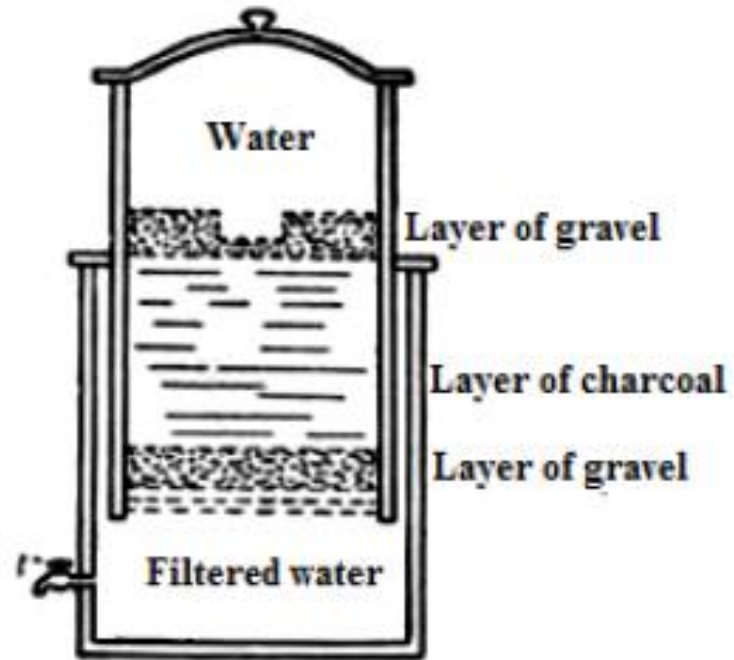


Filtration

- In many cases, water is filtered before softening or demineralizing. Depending upon the system and quality of water desired, the final step may be filtration.
- Large water treatment plants for municipalities will often use gravity type filters. However, food processing plants will usually find the enclosed pressure type filters more satisfactory.
- Water may be passed through a series of filters each with a different filter media to achieve a special purpose.
- For removal of particulate matter sand and gravel filter is effective. Where low silica is desired, nonsiliceous anthracite is used instead of sand.
- Food plants will find activated carbon filters useful for improving the taste and odor of certain water supplies. These filters absorb phenols, chlorine and similar compounds.

- Filters with highly activated carbon require a special tank lining to protect the vessel from galvanic corrosion.
- Filter media are available for removing iron and manganese from water or to raise the pH of acidic water by removing carbon dioxide.
- The oxidizing filter medium which removes iron and manganese does so by forming an insoluble precipitate which collects on the bed.
- The precipitates are removed by periodic backwashing. Frequent regeneration of the bed with a solution of potassium permanganate restores the oxidizing capability for iron and manganese removal.
- A unit utilizing a rotary aerator and a bed of high luster anthracite coal as the filter media has the advantage of not requiring chemical treatment for regeneration.
- The unit appears useful for treating water with a high iron content and relatively low cost operation. Regular backwashing to expand the bed and remove the ferric precipitate is important as in any filter.

water filter



Reverse osmosis systems

- Reverse osmosis separates one component of a solution from another by placing the solution under pressure against a semi permeable membrane.
- Typically the pores of the semi permeable membranes used in reverse osmosis are 5 to 20 Angstrom units (5 to 20 x 10⁻⁸ cm) in diameter.
- Cellulose acetate is commonly used as a membrane.
- Reverse osmosis is a method of purifying water to a high degree, especially when used in conjunction with a pre- filter and an ion-exchanger.

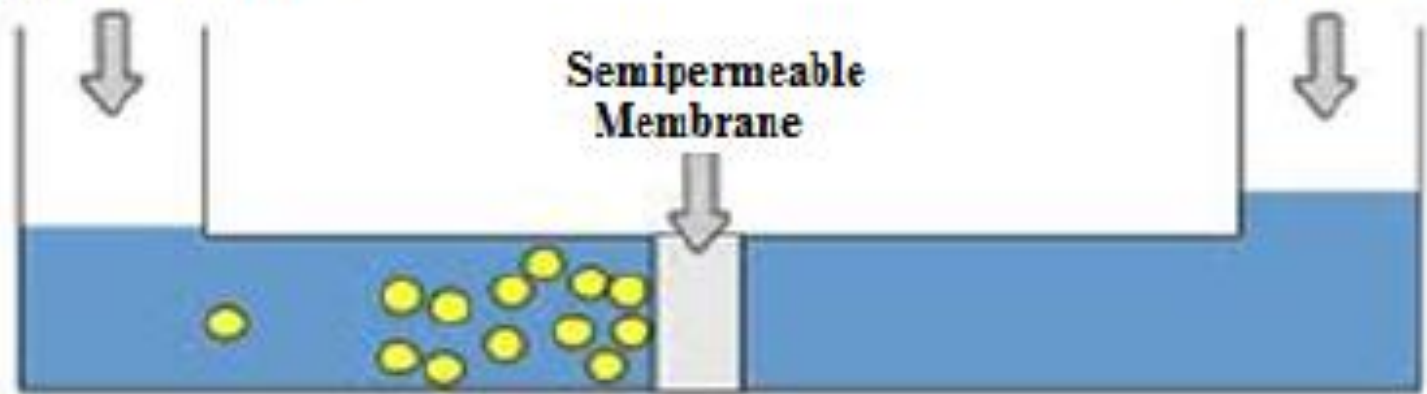
Advantages:

- Membrane life is normally 1 to 3 years,
- Low maintenance requirements,
- Pressure is the only energy requirement
- Membranes can be fitted for specific separations or where very high quality water is required.

Reverse Osmosis

Applied Pressure

Pure Water



Semipermeable Membrane

Direction of water Flow

Chlorination of Water Supplies

- Addition of small amounts of chlorine to water supplies acts as a safeguard against waterborne diseases.
- Food processing plants have increasingly been chlorinating water for plant use to improve sanitation.
- Chlorine may be added to water systems in food plants as a gas or as solution of chlorine compounds which are mainly hypo chlorites of sodium or calcium.
- Some plant operators have found chlorine dioxide to be very satisfactory where considerable organic matter is present, such as in recycled water systems.

Chlorine dose rates for specific purposes

Source/Purpose of Water	Dose rate (ppm)
Well	1-5
Surface	1-10
Cooling	3-5
Chilling	20
Washing	50

THANK YOU

