

Water Softening Methods

Water Softening Methods

- ❖ Zeolite (Permutit process)
- ❖ Ion-exchange
- ❖ Mixed bed ion-exchange
- ❖ Reverse Osmosis

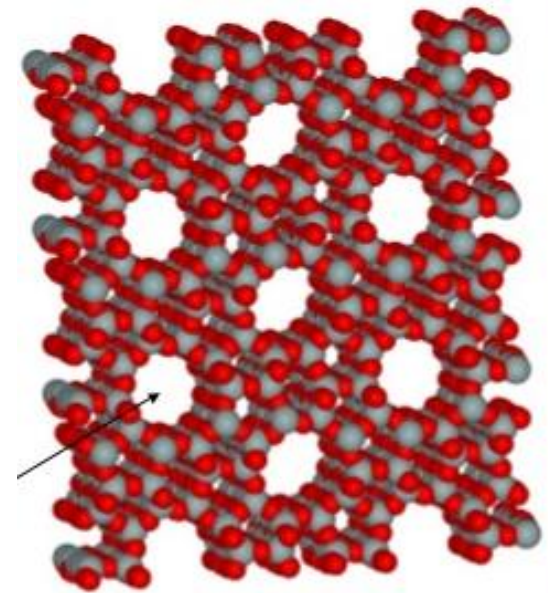
Permutit or Zeolite Process

- Zeolite is **hydrated sodium aluminium silicate** having a general formula, **$\text{Na}_2\text{OAl}_2\text{O}_3 \cdot x\text{SiO}_2 \cdot y\text{H}_2\text{O}$** .
- It exchanges Na^+ ions for Ca^{2+} and Mg^{2+} ions.
- Common Zeolite is $\text{Na}_2\text{OAl}_2\text{O}_3 \cdot 3\text{SiO}_2 \cdot 2\text{H}_2\text{O}$ known as natrolith.
- Other gluconites, green sand (iron potassium phyllosilicate with characteristic green colour, a mineral containing Glauconite)etc. are used for water softening.
- Artificial zeolite used for water softening is Permutit.
- These are porous, glassy particles having higher softening capacity compared to green sand.
- They are prepared by heating china clay (hydrated aluminium silicate), feldspar (KAlSi_3O_8 - $\text{NaAlSi}_3\text{O}_8$ – $\text{CaAl}_2\text{Si}_2\text{O}_8$) are a group of rock-forming tectosilicate minerals which make up as much as 60% of the earth's crust) and soda ash (Na_2CO_3)

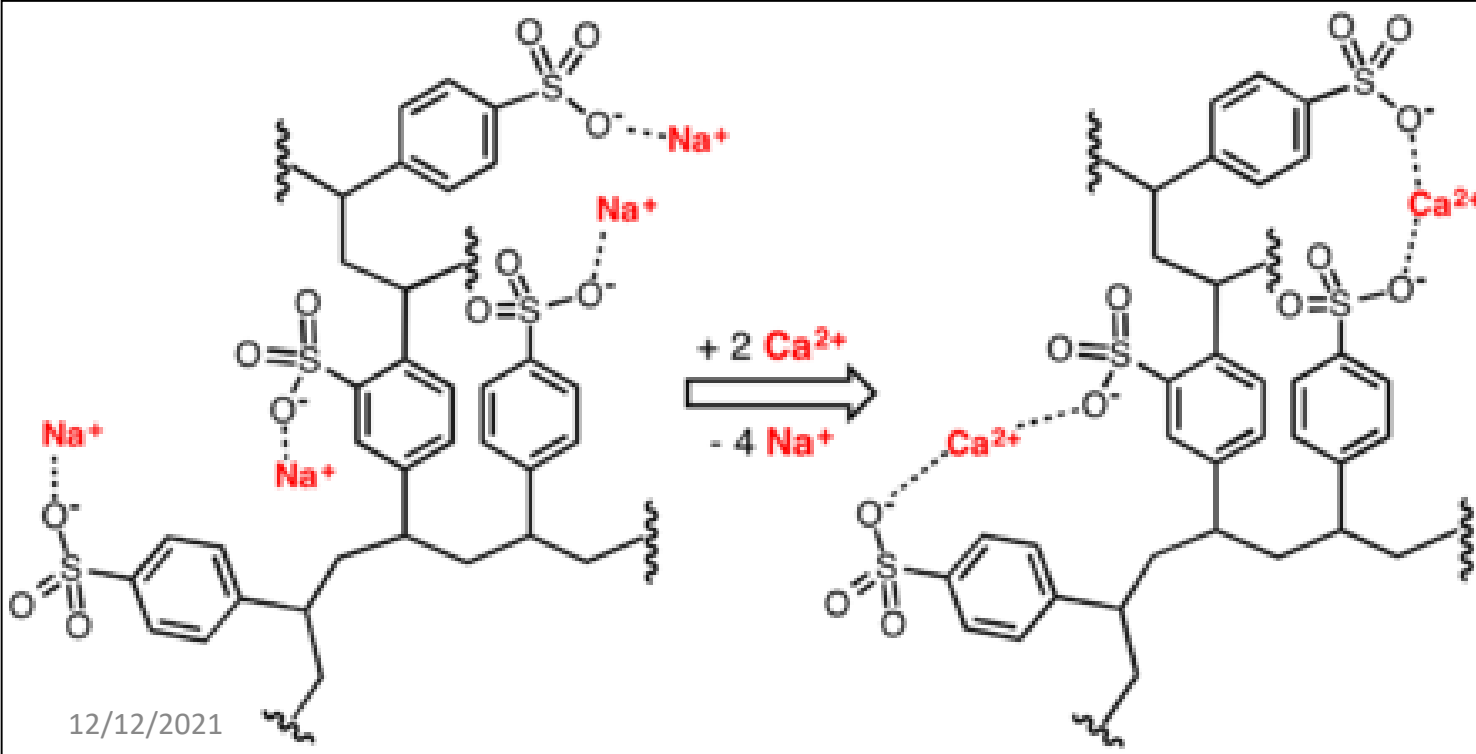
Natural Zeolites:

1. Natrolite - $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 4\text{SiO}_2 \cdot 2\text{H}_2\text{O}$
2. Laumontite - $\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 4\text{SiO}_2 \cdot 4\text{H}_2\text{O}$
3. Harmotome - $(\text{BaO} \cdot \text{K}_2\text{O}) \cdot \text{Al}_2\text{O}_3 \cdot 5\text{SiO}_2 \cdot 5\text{H}_2\text{O}$

- Capable of exchanging its Na ions



Porous Structure of zeolite



Permutit or Zeolite Process

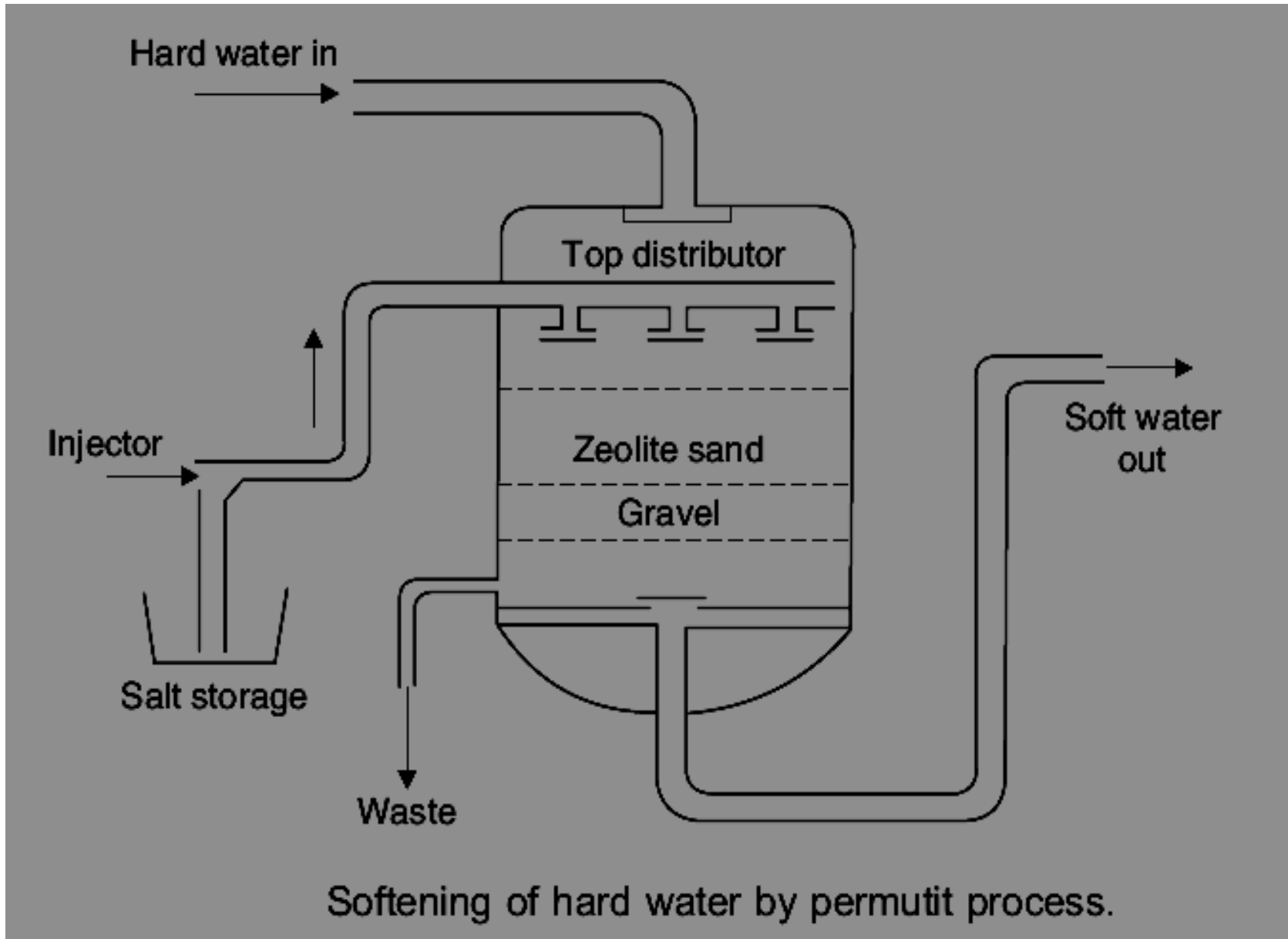
- o Method of softening:

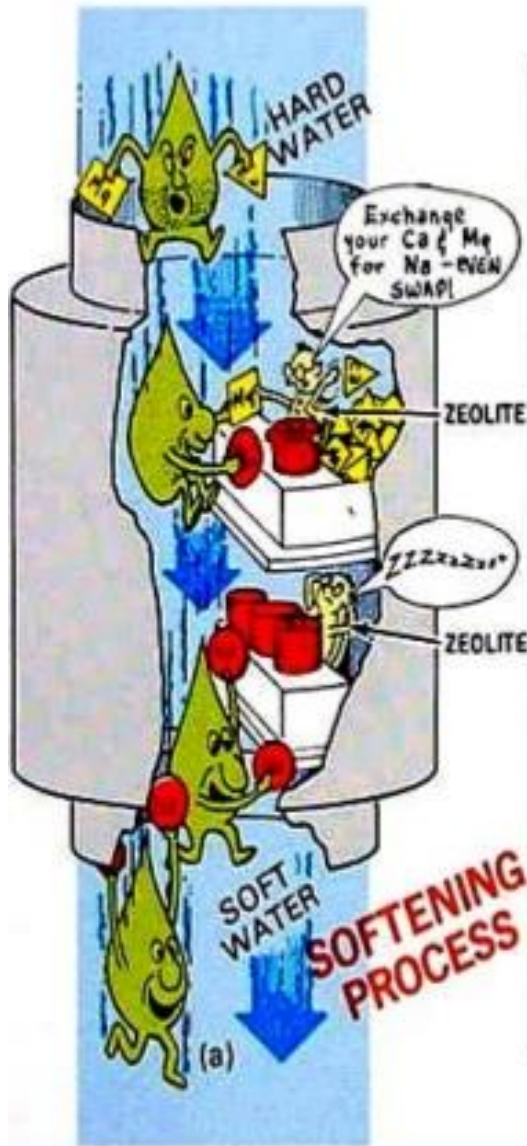


- o Regeneration of Zeolite:



Brine solution





Zeolite Process

○ Advantages:

- Residual hardness of water is about 10 ppm only
- Equipment is small and easy to handle
- Time required for softening of water is small
- No sludge formation and the process is clean
- Zeolite can be regenerated easily using brine solution
- Any type of hardness can be removed without any modifications to the process

○ Disadvantages:

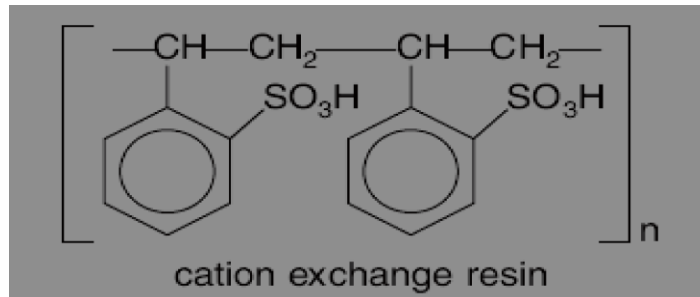
- Coloured water or water containing suspended impurities cannot be used without filtration
- Water containing acidic pH cannot be used for softening since acid will destroy zeolite.

Ion-Exchange Process

- Ion-exchange resins are cross linked long chain polymers with microporous structure
- Functional groups present are responsible for ion-exchange properties
- Acidic functional groups (-COOH, -SO₃H etc.) exchange H⁺ for cations &
- Basic functional groups (-NH₂, =NH etc.) exchange OH⁻ for anions.

A. Cation-exchange Resins(RH⁺):

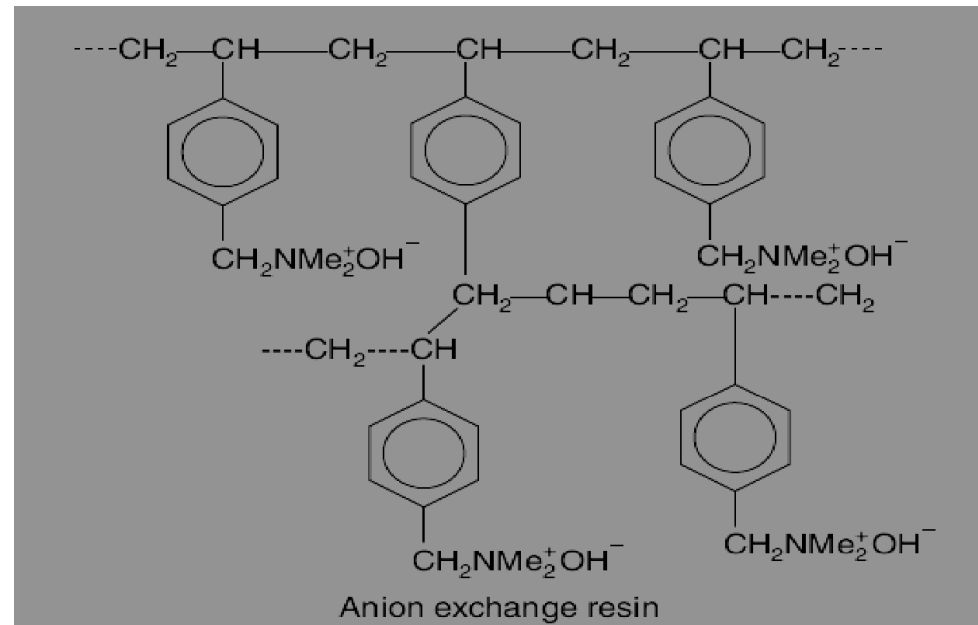
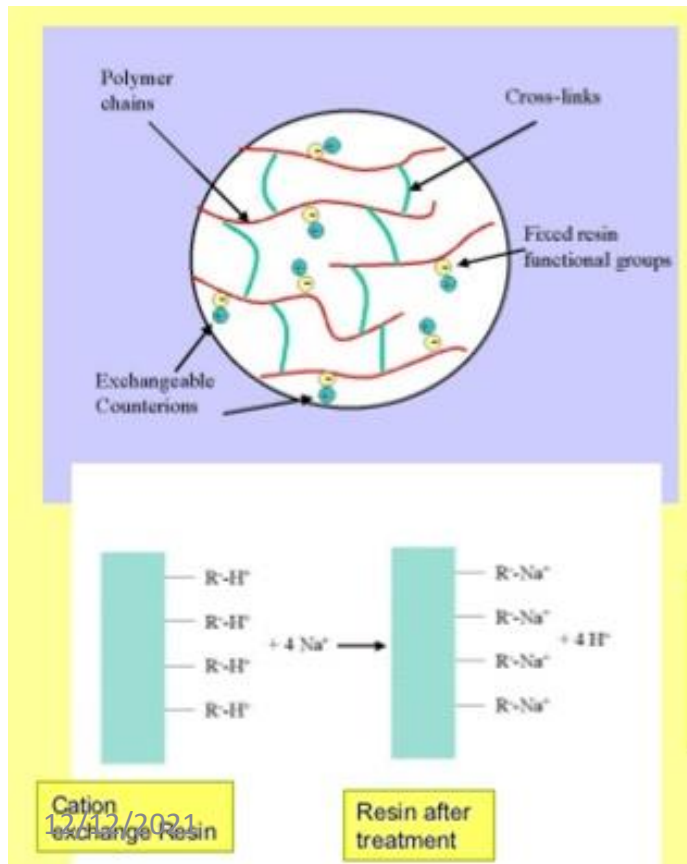
- Styrene divinyl benzene copolymers
- When sulphonated, capable of exchange H⁺



Ion-Exchange Process

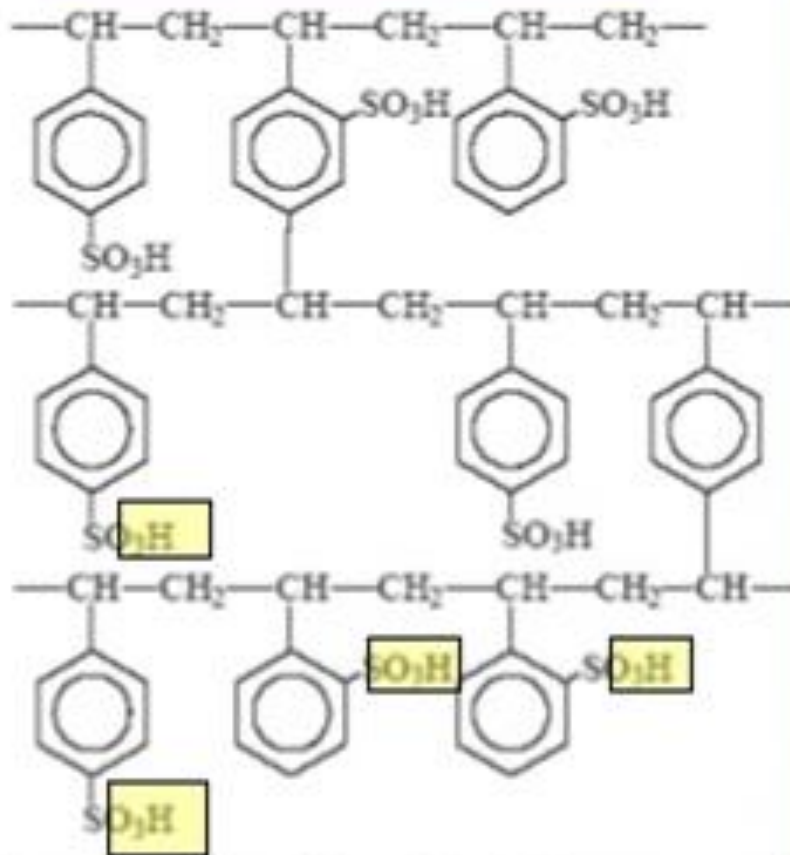
B. Anion-exchange resins (R'OH):

- Styrene divinyl benzene copolymers or amine formaldehyde copolymers with NH_2 , QN^+ , QP^+ , QS^+ , groups.
- On alkali treatment, capable of exchange of OH^-



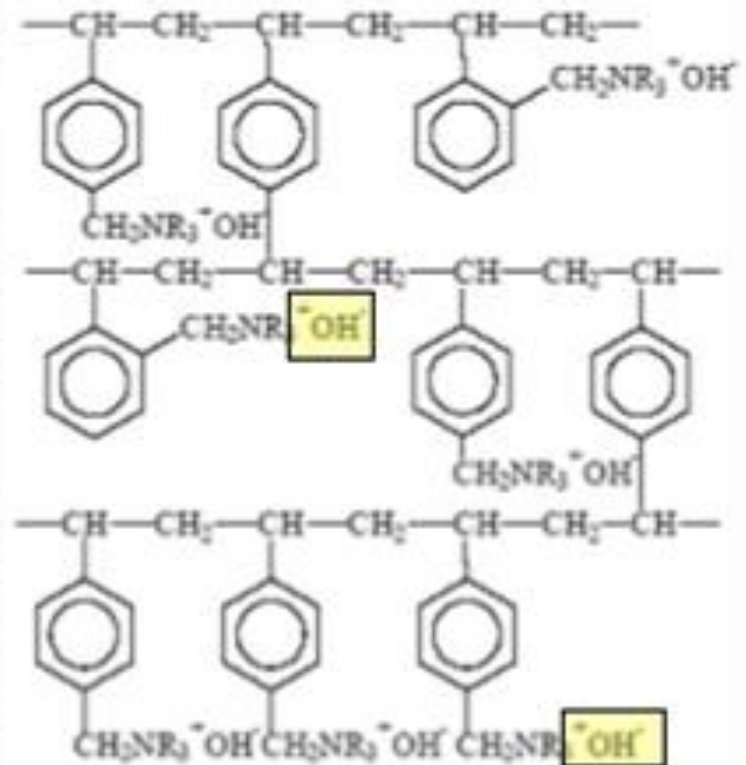
Structure of Cation and Anion exchange resins

Cation exchange resin



A strongly acidic sulphonated polystyrene cation exchange resin

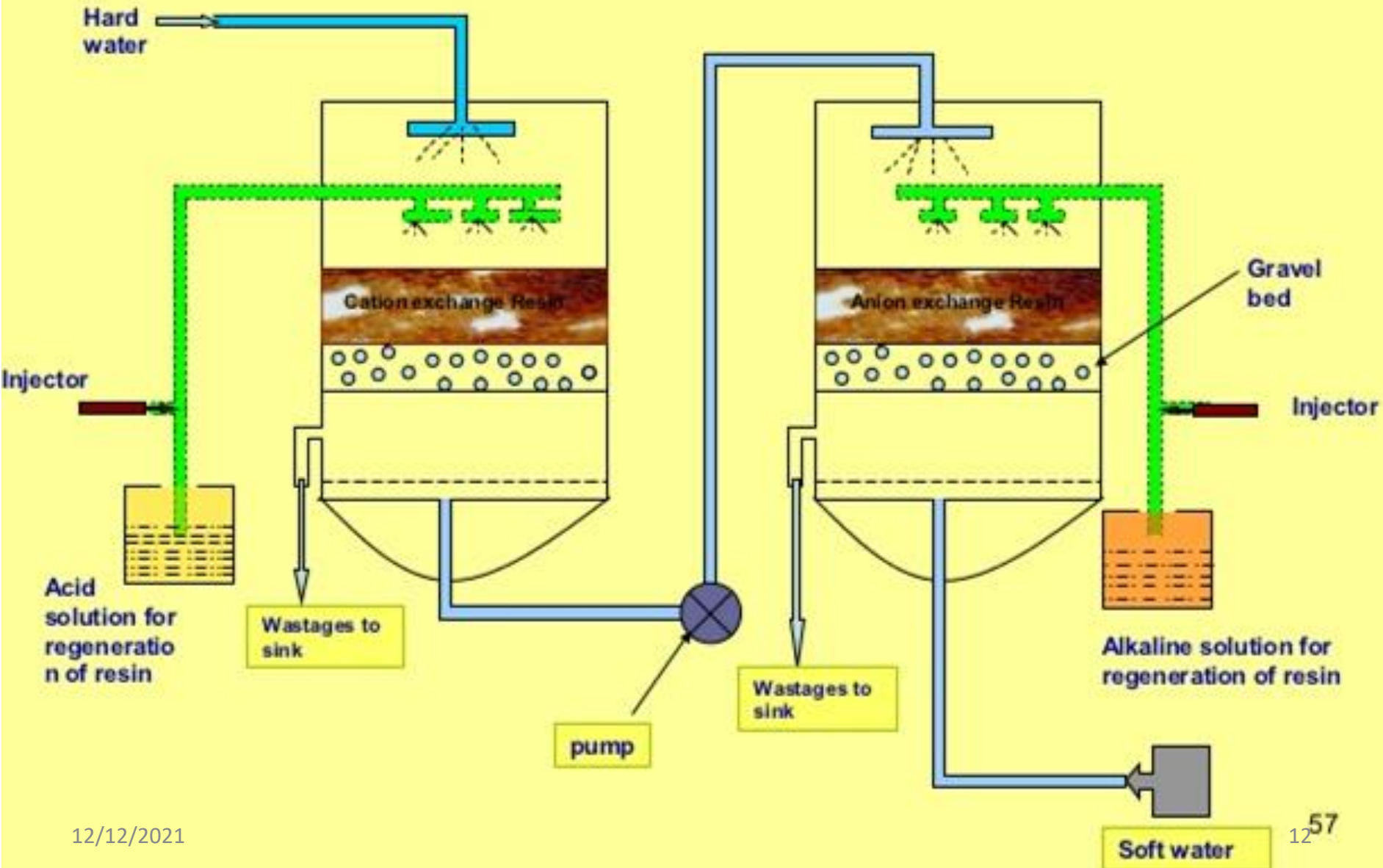
Anion exchange resin



A strongly basic quaternary ammonium anion exchange resin

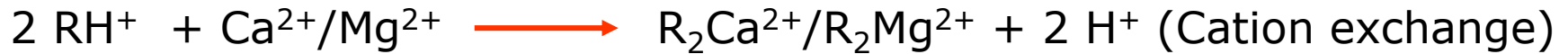
R = CH₃

Ion exchange purifier or softener

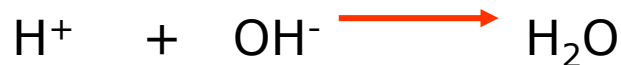


Ion-Exchange Process

The Process of Ion-exchange is:

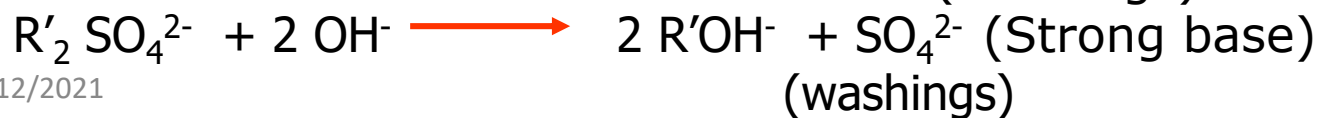
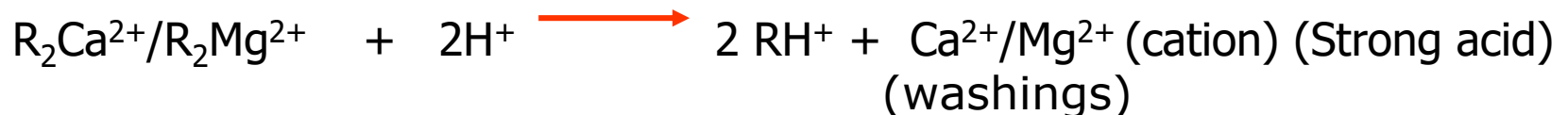


Finally,

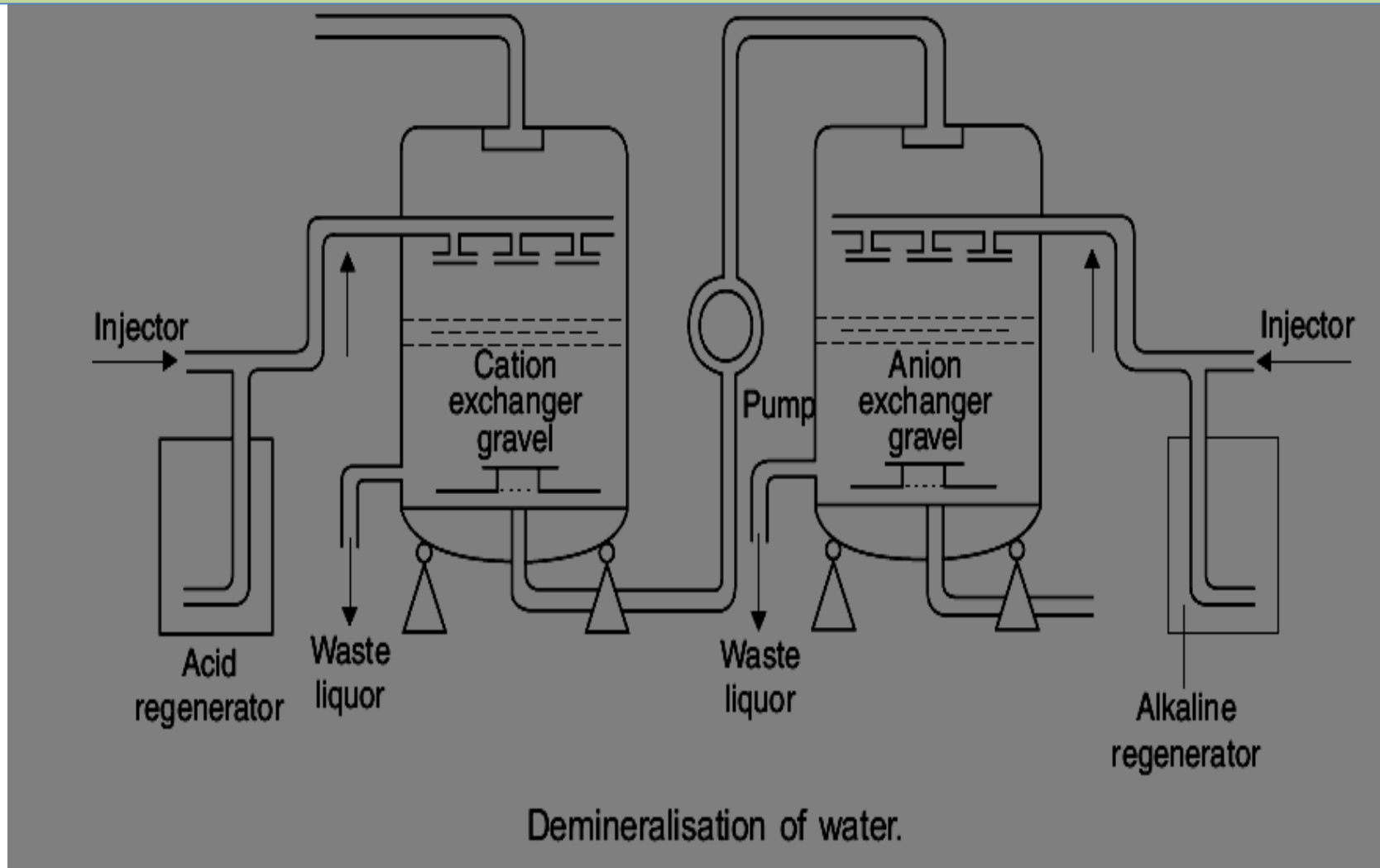


Regeneration of exhausted resins:

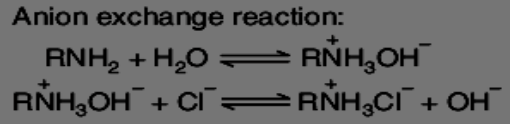
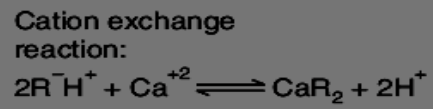
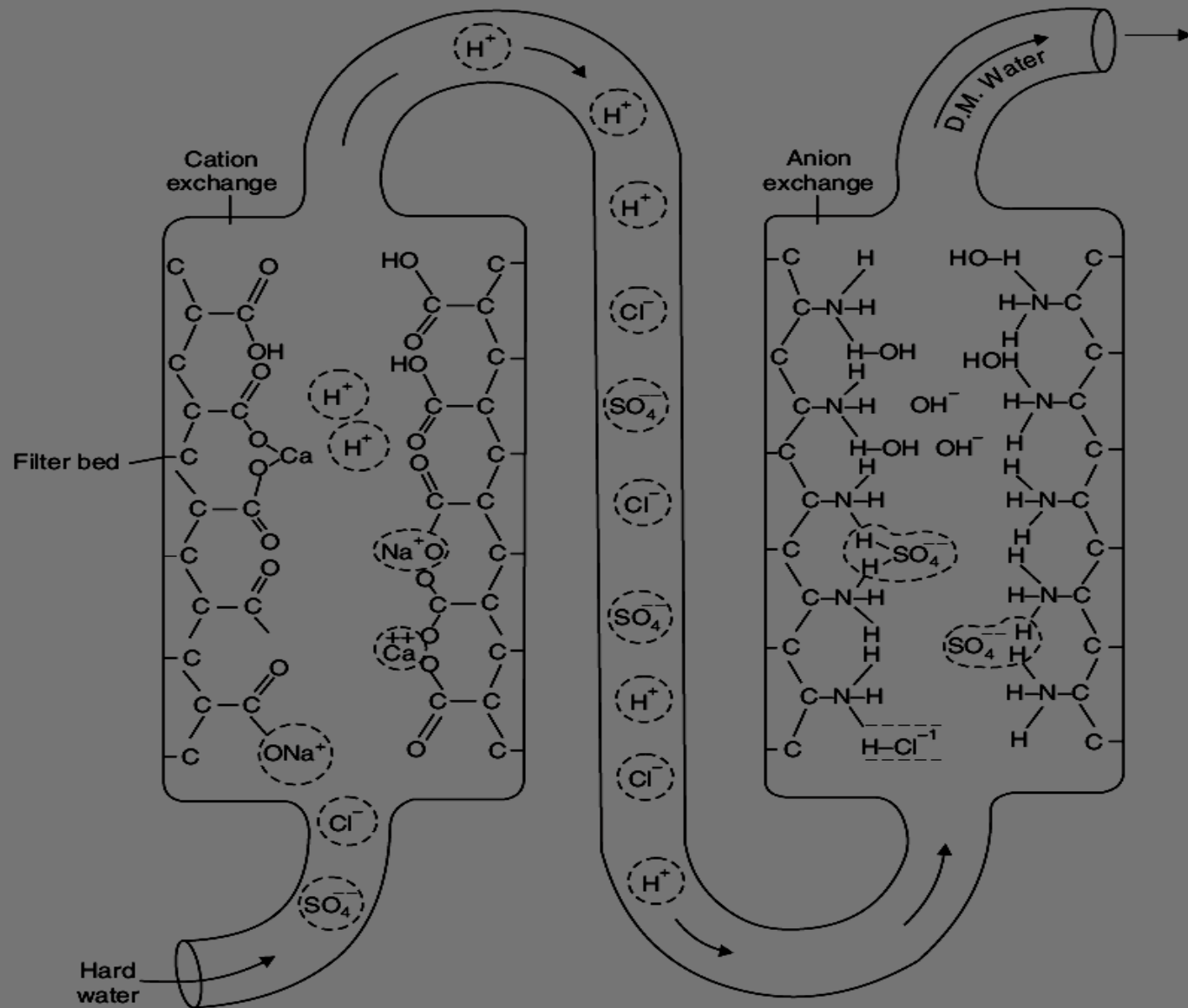
Saturated resins are regenerated:



Ion-Exchange Process



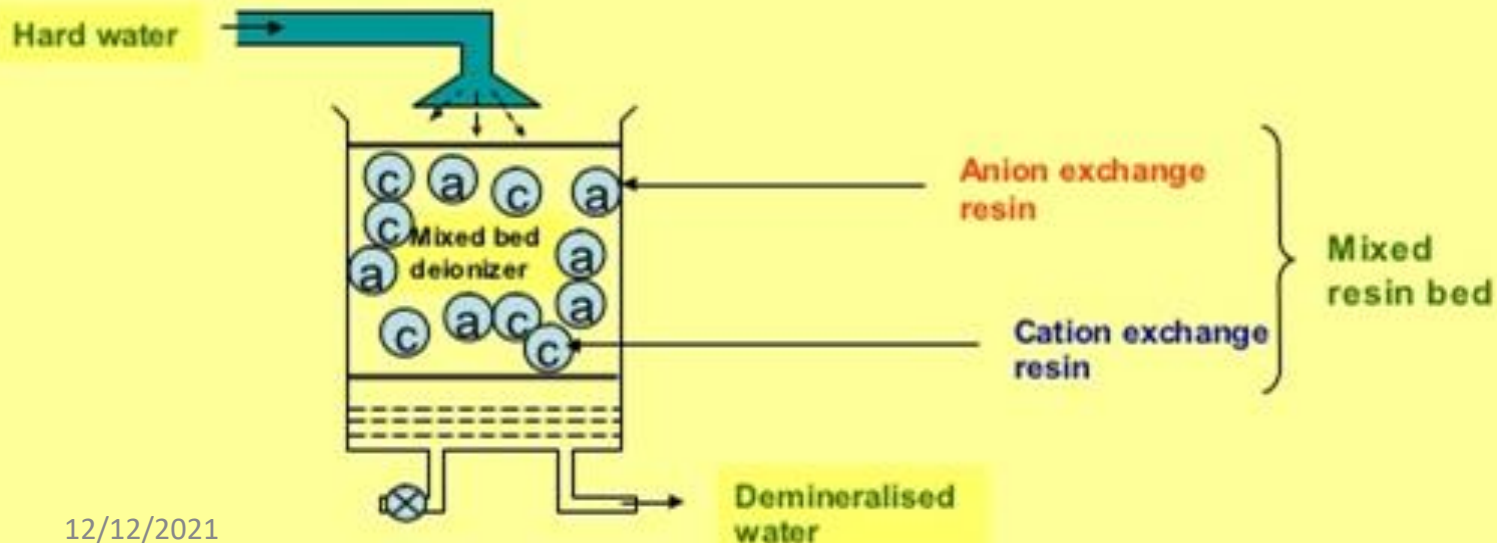
Note: Hard water should be first passed through the cation exchanger and then Anion exchanger to avoid hydroxides of Ca^{2+} and Mg^{2+} getting formed



Mixed Bed Deionizer

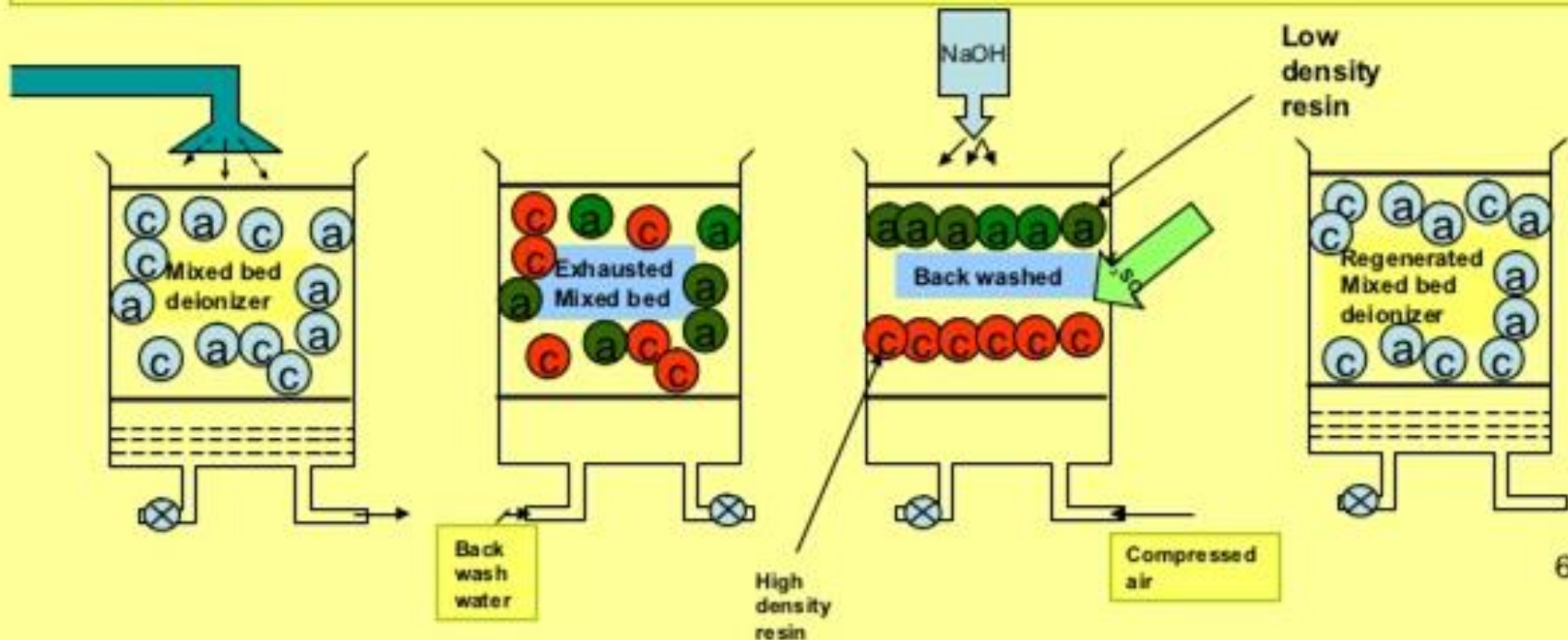
Description and process of mixed bed deionizer

1. It is a single cylindrical chamber containing a mixture of anion and cation exchange resins bed
2. When the hard water is passed through this bed slowly the cations and anions of the hard water comes in to contact with the two kind of resins many number of times
3. Hence, it is equivalent to passing the hard water many number of times through a series of cation and anion exchange resins.
4. The soft water from this method contains less than 1ppm of dissolved salts and hence more suitable for boilers



Regeneration of mixed bed deionizer

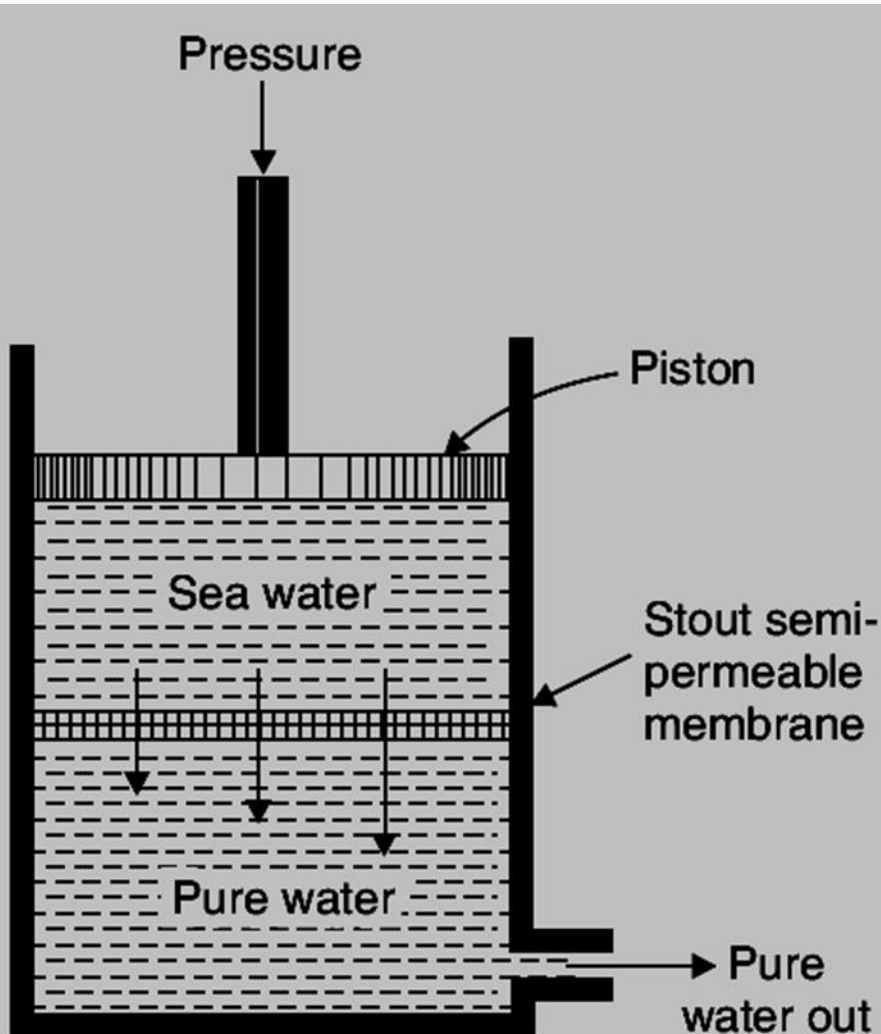
1. When the bed (resins) are exhausted or cease to soften the water, the mixed bed is back washed by forcing the water from the bottom in the upward direction
2. Then the light weight anion exchanger move to the top and forms a upper layer above the heavier cation exchanger
3. Then the anion exchanger is regenerated by passing caustic soda solution (NaOH) from the top and then rinsed with pure water
4. The lower cation exchanger bed is then washed with dil. H_2SO_4 solution and then rinsed.
5. The two beds are then mixed again by forcing compressed air to mix both and the resins are now ready for use



Advantages & Disadvantages of ion-exchange process

- Advantages:
 - Can be used for highly acid and highly alkaline water
 - Residual hardness of water is as low as 2 ppm.
 - Very good for treating water for high pressure boilers
- Disadvantages:
 - Expensive equipment and chemicals
 - Turbidity of water should be < 10 ppm. Otherwise output will reduce; turbidity needs to be coagulated before treatment.
 - Needs skilled labour

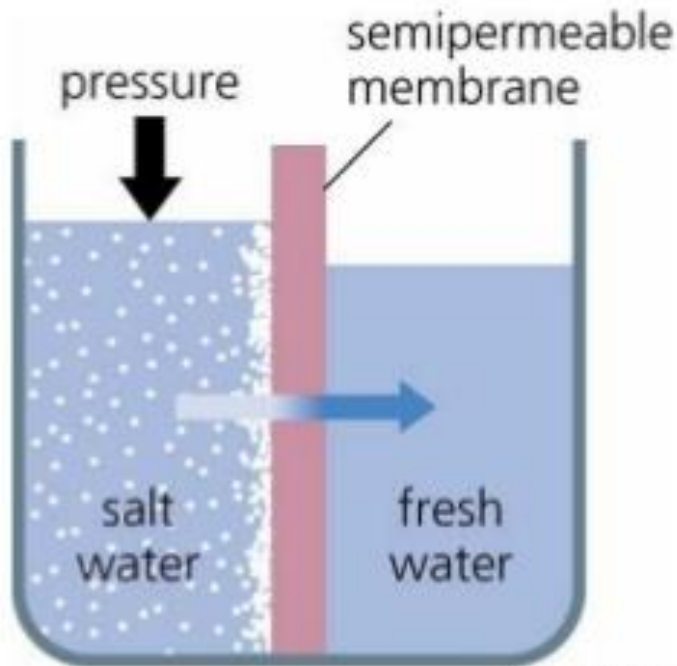
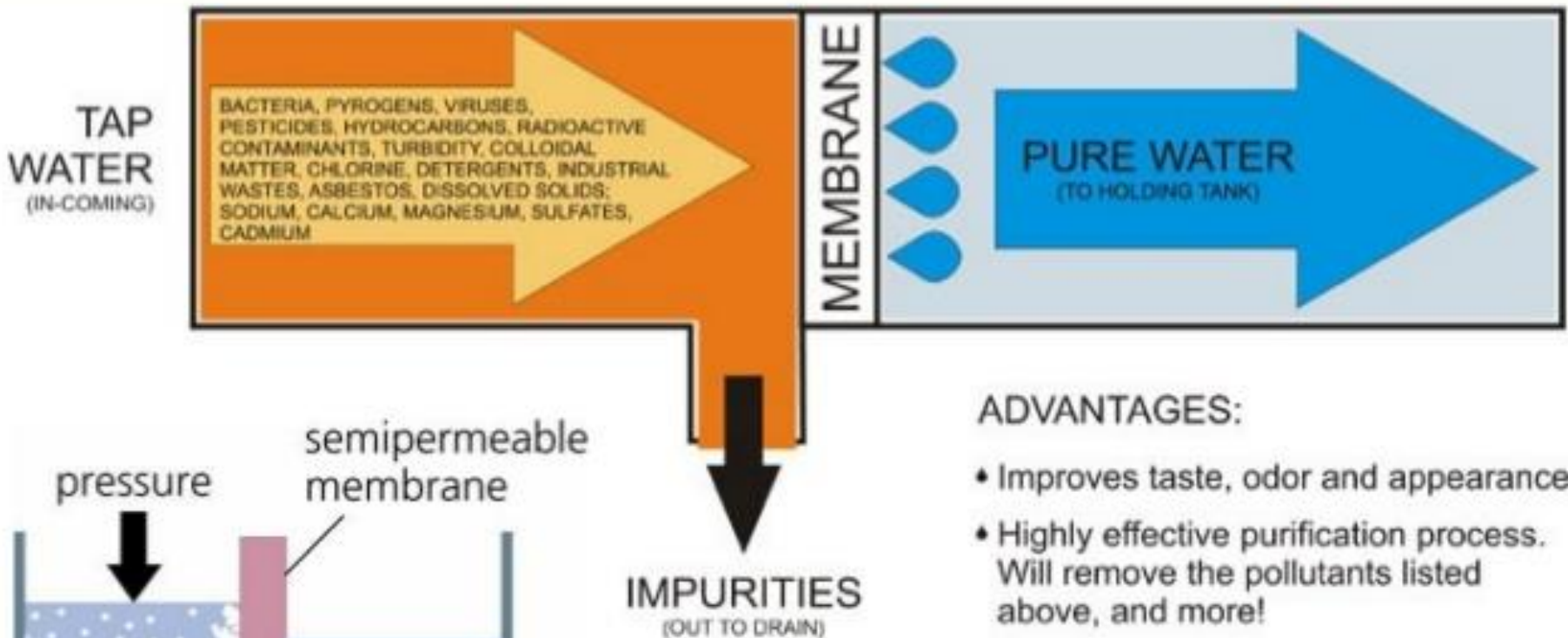
Reverse Osmosis



Reverse osmosis cell

- When two solutions of unequal concentrations are separated by a Semipermeable membrane, solvent will flow from lower conc. to higher conc.
- This phenomenon can be reversed (solvent flow reversed) by applying hydrostatic pressure on the concentrated side
- In reverse osmosis, pressure of 15-40 kg/cm² is applied to sea water.
- The water gets forced through the semipermeable membrane leaving behind the dissolved solids.

Reverse Osmosis



ADVANTAGES:

- Improves taste, odor and appearance
- Highly effective purification process. Will remove the pollutants listed above, and more!
- Consumes no energy
- Very convenient
- Flushes away pollutants, does not collect them
- Easy to keep clean
- Low production cost - gives you water of a guaranteed quality for pennies per gallon

Advantages of Reverse Osmosis

- Advantage is in removing ionic, non-ionic, colloidal and high molecular wt. organic matter.
- It removes colloidal silica (which is not removed during demineralisation)
- Cost is only the replacement cost of membranes (life is 2 years)
- Membrane replacement is fast and hence uninterrupted water supply can be ensured
- Because of the above reasons this process is being adopted for converting sea water into potable water and for high pressure boilers.