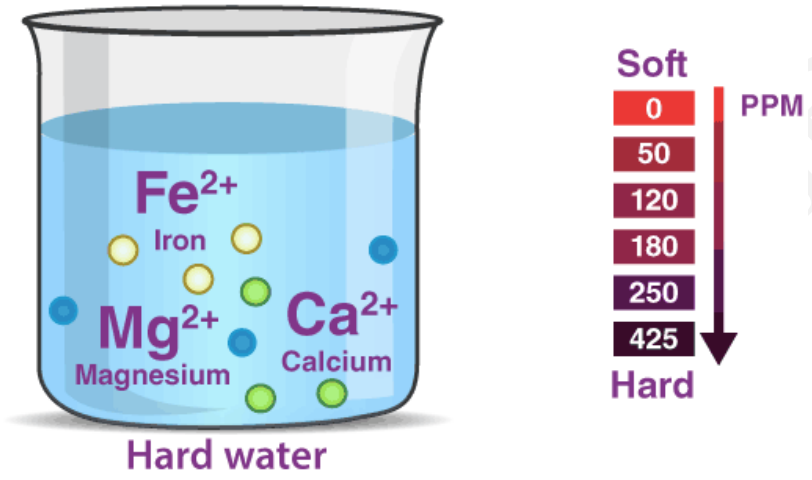
Water Hardness



Water Hardness

The simple definition of water hardness is the amount of dissolved calcium and magnesium in the water. Hard water is high in dissolved minerals, largely calcium and magnesium. You may have felt the effects of hard water, literally, the last time you washed your hands. Depending on the hardness of your water, after using soap to wash you may have felt like there was a film of residue left on your hands. In hard water, soap reacts with the calcium (which is relatively high in hard water) to form "soap scum". When using hard water, more soap or detergent is needed to get things clean, be it your hands, hair, or your laundry.

Water Hardness Scale

Description	Hardness (mg/l)
Extremely soft	0-45
Soft	46-90
Moderately Hard	91-130
Hard	131-170
Very hard	171-250
Excessively Hard	Over 250

Problems in Wet Processes Due to Hard Water

Process	Problems
Desizing	Deactivate enzymes
Scouring	Reacts with soap to form insoluble organic salts $CaSO_4+2RCOONa \rightarrow (RCOO)_2Ca \downarrow + Na_2SO_4$ $MgSO_4+2RCOONa \rightarrow (RCOO)_2Mg \downarrow + Na_2SO_4$
Bleaching	Causes loss of bleaching agent $2\ H_2O_2 \rightarrow 2\ H_2O + O_2$
Mercerizing	Reduce absorbency and luster of the fabric
Dyeing	Combine with dye stuffs, change their shade and make them insoluble
Printing	Break emulsion and change viscosity of printing paste
Finishing	Interfere with catalyst, cause resins & other additives to become non-reactive, break emulsion and deactivate soap

Methods of Water Softening

1) Soda lime process
2) Base Exchange/ Zeolite process
3) Demineralization

Soda Lime Process

- ✓ Soda lime is a process used in water treatment to remove **hardness** from water. This process is now **obsolete** but was **very useful for the treatment of large volumes** of hard water.
- ✓ Addition of **lime (CaO)** and **soda (Na_2CO_3)** to the hard water precipitates **calcium as the carbonate**, and **magnesium as its hydroxide**. The amounts of the two chemicals required are easily calculated from the analysis of the water and stoichiometry of the reactions.

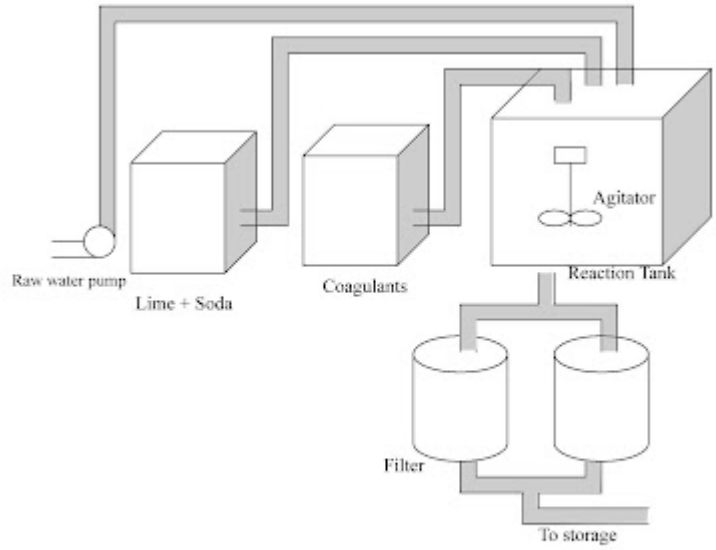


Figure 1: Soda lime water softening process

In this process, hydride lime and soda ash (Na_2CO_3) are used to remove hardness of water. For the removal of **temporary hardness**, **lime is used**.

$$Ca(HCO_3)_2 + Ca(OH)_2 = 2CaCO_3 + 2H_2O + CO_2$$

$$Mg(HCO_3)_2 + Ca(OH)_2 = MgCO_3 + CaCO_3 + 2H_2O$$

$MgCO_3$ is slightly soluble in water and is again hydrolyzed to produce more insoluble $Mg(OH)_2$.

$$MgCO_3 + Ca(OH)_2 \longrightarrow Mg(OH)_2 + CaCO_3$$

For the removal of permanent hardness, **soda ash** is used.

$$CaSO_4 + Na_2CO_3 = CaCO_3 + Na_2SO_4$$

$$MgCl_2 + Ca(OH)_2 = Mg(OH)_2 + CaCl_2$$

Base Exchange/Zeolite Process

Sodium alumino silicates minerals (zeolite)

- In this process hard water is treated with **base exchange complex or zeolite**. Zeolites are hydrated silicates of sodium or aluminium with general formula $(Na_2O)_x\ (Al_2O_3)y\ (SiO_2)z\ (H_2O)_n$.
- Zeolites are naturally occurring and base exchange complexes are artificially prepared.
- When zeolites are bought in contact with hard water the following reactions take place-

For temporary hardness:

$$Ca(HCO3)2 + Na2O.Z \longrightarrow CaO.Z + 2NaHCO3$$

$$Mg(HCO3)2 + Na2O.Z \longrightarrow MgO.Z + 2NaHCO3$$

For permanent hardness:

$$CaSO4 + Na2O.Z \longrightarrow CaO.Z + Na2SO4$$

$$MgSO4 + Na2O.Z \longrightarrow MgO.Z + Na2SO4$$

For regeneration of Zeolites:

$$CaO.Z + 2NaCl \longrightarrow Na2O.Z + CaCl2$$

Demineralization Process

It is a modern industrial water softening process. By this process, it is possible to remove hardness as well as remove of all dissolve salts i.e. $FeCO_3$, $CaCl_2$.

Demineralization process of water softening can be brought about in two ways:

1st step – Hydrogen cation exchange.

2nd step – Anion exchange

1st step – Hydrogen cation exchanger/1st resin bed :
In this process, sulphonated resin in hydrated form is used.
For water softening,

$$CaCl_2 + H_2R \longrightarrow CaR\downarrow + HCl$$

(Resin of hydrated form)

$$Ca(HCO_3)_2 + H_2R \longrightarrow CaR\downarrow + 2H_2O + 2CO_2$$

when resin is exhausted, For regeneration, less then of $2\%H_2SO_4$ is used

$$CaR + H_2SO_4 \longrightarrow CaSO_4 + H_2R$$

(Regenerated hydrogen cation exchanger)

2nd step – Anion exchanger : Amino resin is used as an anion exchanger & produced HCl is removed.

$$HCl + HOR_1 \longrightarrow ClR_1\downarrow + H_2O(\text{Soft water})$$

(Resin of Hydroxide form) Precipitation

For Regeneration reaction, 1% Solution of Caustic soda is used

$$ClR_1 + NaOH \longrightarrow NaCl + HOR_1 \text{ (Regenerated resin)}$$

The regeneration is performed by using alkali.