Water Supply & Sanitary Engineering (DI05006021)

Unit 3: Treatment of Water
Lecture 13: Water Softening

GTU Diploma Engineering

Lecture Agenda

- What is Hardness?
- Causes and Types of Hardness
- Disadvantages of Hard Water
- Methods of Removing Temporary Hardness
- The Lime-Soda Process (Chemistry & Plant)
- The Zeolite (Ion Exchange) Process
- Comparison of Softening Methods

What is Water Hardness?

- Hardness is a characteristic of water that prevents the formation of lather with soap.
- It is primarily caused by the presence of multivalent metallic cations.
- The principal culprits are Calcium ($Ca2+$) and Magnesium ($Mg2+$) ions.
- Other minor contributors include Iron, Strontium, and Manganese.
- Hardness is usually expressed in terms of equivalent Calcium Carbonate (CaCO3) in mg/L.

Types of Hardness

- 1. Temporary Hardness (Carbonate Hardness):
- Caused by the carbonates and bicarbonates of Calcium and Magnesium.
- Easily removed by simple boiling.
- 2. Permanent Hardness (Non-Carbonate Hardness):
- Caused by sulfates, chlorides, and nitrates of Calcium and Magnesium.
- Cannot be removed by boiling; requires specific chemical treatment.
- Total Hardness = Temporary Hardness + Permanent Hardness.

Disadvantages of Hard Water

- Domestic Issues: Excessive soap consumption, clothes become stiff when washed, formation of sticky soap scum on bathroom fixtures.
- Industrial Issues: Forms hard scale inside boilers, severely reducing heat transfer efficiency and potentially causing boiler explosions.
- Plumbing: Scale buildup clogs hot water pipes and reduces the lifespan of water heaters.
- Food Industry: Can affect the taste of foods and beverages during commercial preparation.

Removal of Temporary Hardness

- 1. Boiling: Heat drives off CO_2, causing calcium bicarbonate to convert into insoluble calcium carbonate, which settles out.
- Reaction: $Ca(HCO_3)_2$ + Heat -¿ $CaCO_3$ (precipitate) + CO_2 + H_2O
- 2. Addition of Lime: For municipal scale, boiling is too expensive. We add hydrated lime ($Ca(OH)_2$).
- Reaction: $Ca(HCO_3)_2$ + $Ca(OH)_2$ -¿ $2CaCO_3$ (precipitate) + $2H_2O$
- The precipitate is then removed in a standard sedimentation tank.

Lime-Soda Process for Permanent Hardness

- To remove permanent hardness (sulfates/chlorides), both Lime (Ca(OH)2) and Soda Ash (Na2CO3) are added.
- Lime removes carbonate hardness and magnesium.
- Soda Ash removes the non-carbonate (permanent) calcium hardness.
- Reaction (Soda Ash): CaSO4 + Na2CO3 -¿ CaCO3 (precipitate) + Na2SO4 (soluble, non-hardness causing).
- Result: Heavy precipitates of CaCO3 and Mg(OH)2 are formed and settled out in clarifiers.

Features of the Lime-Soda Process

- Advantages:
- Very economical for large municipal supplies.
- Also removes iron, manganese, and reduces bacteria due to high pH.
- Disadvantages:
- Produces a massive volume of chemical sludge that is difficult to dispose of.
- Requires skilled supervision for precise chemical dosing.
- Can leave water unstable (scaling), requiring 'Recarbonation' (adding CO2) to stabilize pH.

The Zeolite (Ion Exchange) Process

- Zeolites are natural or synthetic resins that contain exchangeable Sodium (Na+) ions.
- Process: Hard water is passed through a bed of zeolite.
- Ion Exchange: The zeolite 'grabs' the Calcium (Ca2+) and Magnesium (Mg2+) from the water and releases Sodium (Na+) into the water in their place.
- Reaction: Na2Ze + Ca(HCO3)2 -¿ CaZe (exhausted resin) + 2NaHCO3
- Result: Water leaving the filter has zero hardness (contains only harmless sodium).

Regeneration of Zeolite

- Eventually, the zeolite bed runs out of sodium and is saturated with calcium/magnesium (exhausted).
- Regeneration: We wash the bed with a concentrated brine (NaCl / Salt) solution.
- The high concentration of sodium forces the reaction in reverse, driving the calcium off the resin and replacing it with sodium.
- Reaction: CaZe + 2NaCl -¿ Na2Ze (regenerated) + CaCl2 (waste washed to drain).
- The resin is ready to be used again.

Comparison: Lime-Soda vs. Zeolite

Concept 1	**Concept 2**

End Result: Zeolite achieves Zero hardness. Lime-Soda leaves about 50 mg/L (good for municipal).

Sludge: Lime-soda produces huge amounts of sludge. Zeolite produces no sludge (only a salty liquid waste).

Operation: Lime-soda is complex and requires daily dosing adjustments. Zeolite is simple and automated.

Cost: Lime-soda is cheaper for massive municipal plants treating highly hard water. Zeolite is favored for industry, hospitals, and homes.

Summary

- Hardness is caused by Calcium and Magnesium ions (temporary = carbonates, permanent = sulfates/chlorides).
- Lime-Soda process precipitates out hardness, producing sludge, suitable for municipalities.
- Zeolite process trades sodium for calcium, producing zero hardness, suitable for industry.
- Next Lecture: Miscellaneous treatments including Iron removal, RO, and addressing Taste/Odour.