Disadvantages of hard water

Problems of Hard water

In Domestic

- Washing & bathing
- Cooking
- Drinking

In Industries

- Paper industry
- Textile industry
- Sugar industry
- In concrete making
- In steam generation boiler

Problems of hard water - Domestic use

a) Washing:

- Hard water, when used for washing purposes, does not lather freely with soap.
- It produces sticky precipitates of calcium and magnesium soaps.
- Similar problem exists in bathing.

Problems of hard water - Domestic use

b) Cooking:

- Due to the presence of dissolved hardness producing salts the boiling point of water is elevated.
- Consequently more fuel and time are required for cooking.

Colligative Property – Boiling point elevation

$$\Delta T_b = T_b - T_b^* = \left(\frac{RT_b^{*2}}{\Delta Hvap}\right) \chi_{Solute}$$

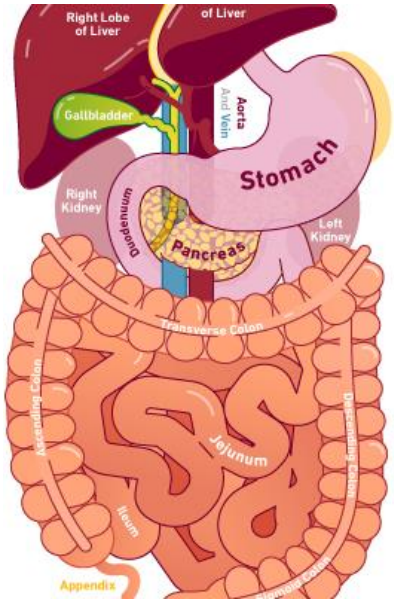
ΔT_b	= Boiling point elevation
T_b	= Boiling point of solution
T_b^*	= Boling point of pure solvent
$\Delta Hvap$	= Enthalpy of vapourisation
χ_{Solute}	= molarity of solute

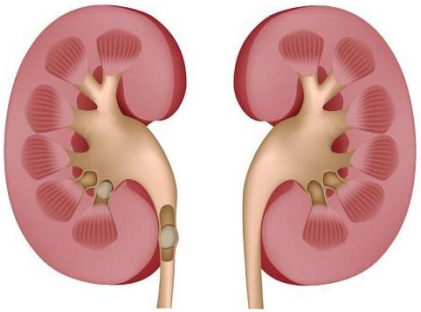
- Boiling point elevation is directly proportional to the molarity of the solute
- Each mole of solute particles raises the boiling point of 1 kg of water by 0.51 °C

Problems of hard water - Domestic use

c) Drinking:

- Hard water causes bad effect on our digestive system.
- The possibility of forming calcium oxalate crystals in urinary tracks is increased (Kidney stones).





KIDNEY STONES AND HARD WATER

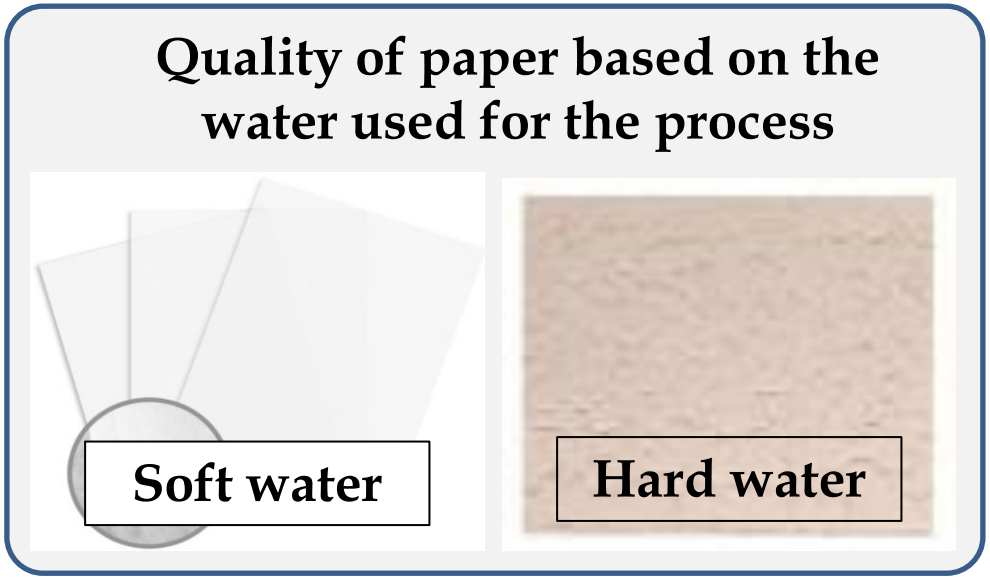
Disadvantages of hard water in industries

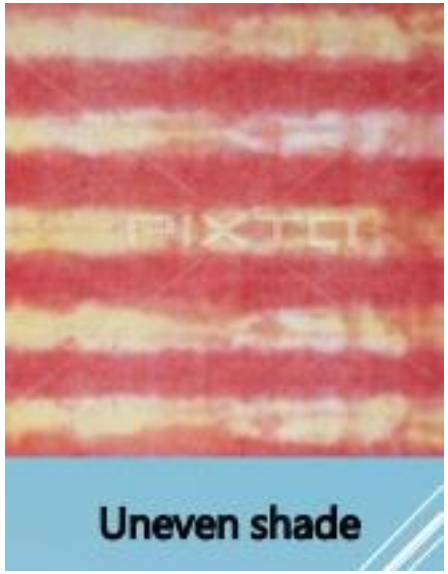
Paper Industry:

- The presence of calcium and magnesium has impact on the properties and quality of paper and their products

Textile industry:

- Ca^{2+} and Mg^{2+} ions of hard water react with dye molecules and precipitate the dye.
- During dyeing process, calcium and magnesium salts present in water make the quality of the shades very poor.





Disadvantages of hard water in industries

Sugar industry:

- If nitrates, sulphates of calcium and magnesium are present, they cause hindrance to crystallization of sugar

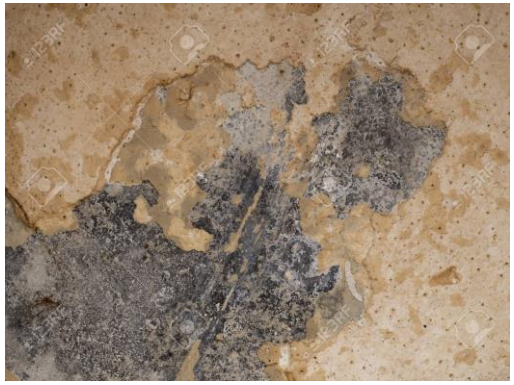
Concrete making:

- Water containing chlorides and sulphates, if used for concrete making, affects the hydration of the cement and the final strength of the hardened concrete.

In steam generation boilers:

- If the hard water is fed directly to the boilers, which led to the many problems such as "Formation of scales which corrodes the boiler, wastage of fuel, etc."

Sugar crystals



Concrete wall

Effect of Hard water on steam boilers

1. Sludge and Scale formation
2. Priming & Foaming
3. Caustic embrittlement
4. Boiler corrosion

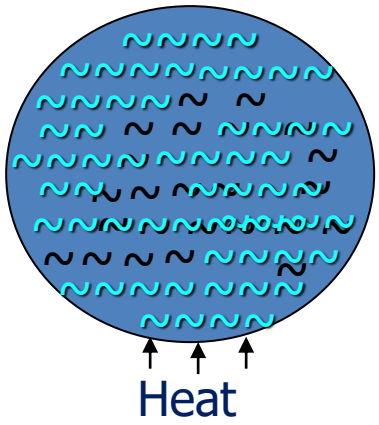
- How it forms
- Disadvantages
- Prevention

Effect of Hard water on steam boilers

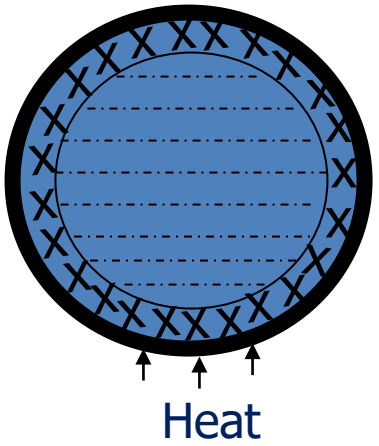
1. Sludge and Scale formation:

- Continuous evaporation of water takes places and concentration of dissolved salts (present in hard water) gets increased.
- At saturation point, it forms precipitates on the inner walls of the boiler
- **Sludges** : If loose & slimy precipitate formed
- **Scale** : If sticky, hard & adherent coat formed

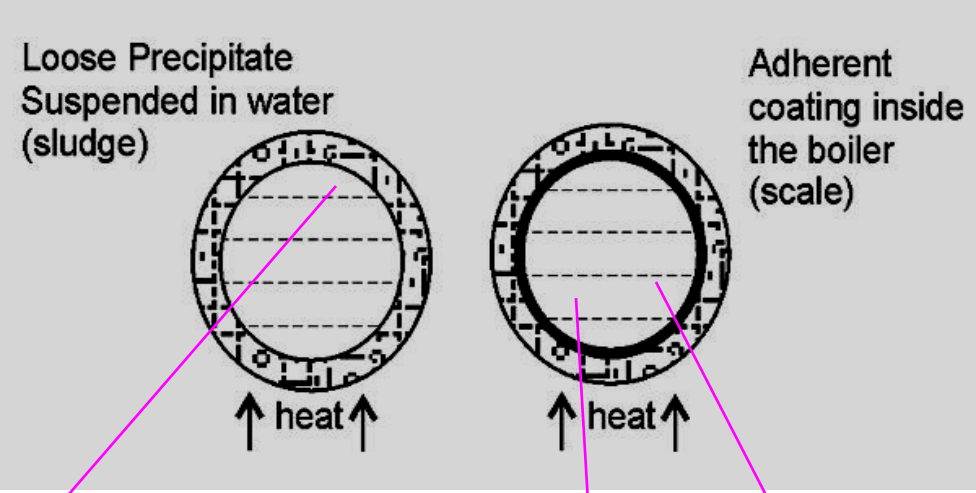
a) Sludges

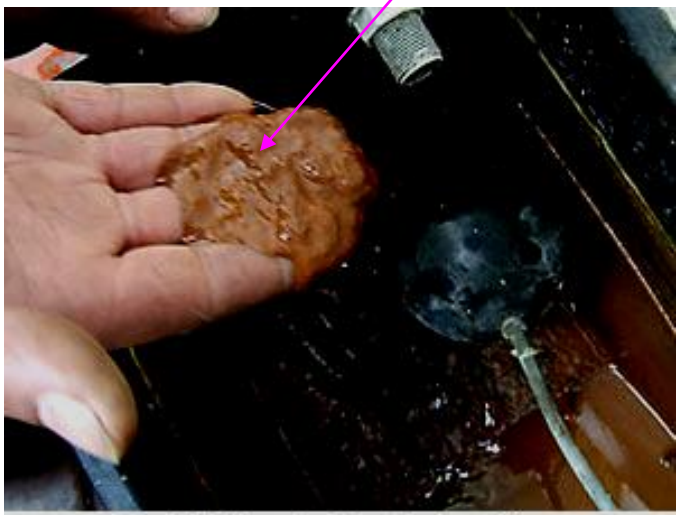


b) Scales

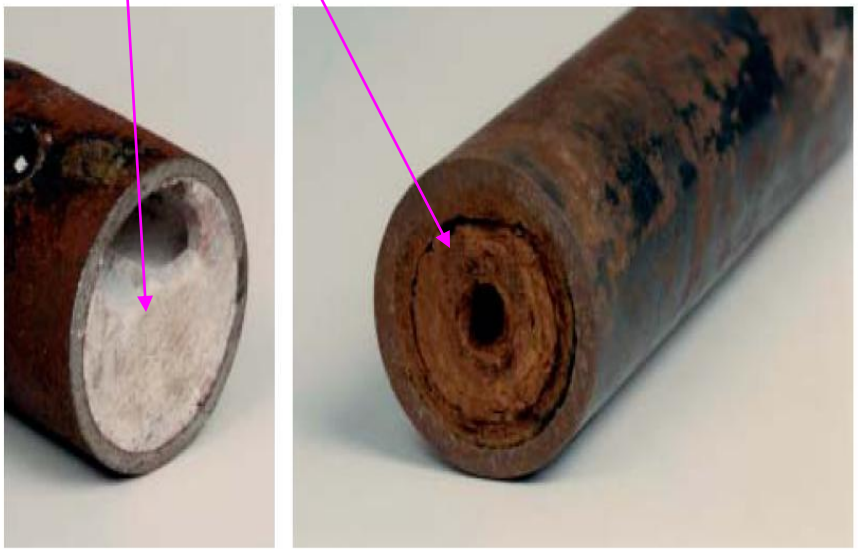


Examples of Sludge and Scale





Could this sludge be inside your central heating system?



Boiler scale on water side

Difference between Sludge & Scale

Sludge	Scale
Soft, loose & slimy precipitates	Hard deposits
Non-adherent deposits & can be easily scrapped off with a wire brush	Sick very firmly to the inner surface of boiler and are very difficult to remove
Formed by substances like $CaCl_2$, $MgCl_2$, $MgSO_4$ & $MgCO_3$	Formed by substances like $CaSO_4$, $Mg(OH)_2$, $CaCO_3$ & $CaSiO_3$
Formed generally at colder portions	Formed generally at heated portions of the boiler
Decrease the efficiency of boiler but are less dangerous	Decrease the efficiency of boiler and possesses the chances of explosions

(i) Sludge formation in boilers

- Sludge is a soft, loose and slimy precipitate formed within the boiler.
- Sludge can be easily scrapped off with the wire brush.
- It is formed comparatively colder portions of the boiler and collects in the bends where the flow rate is slow
- Sludges are formed by substances which have greater solubilities in hot water than in cold water, e.g., $MgCO_3$, $CaCl_2$, etc.

(i). Sludge formation in boilers

Disadvantage of sludge formation

- Sludges are poor conductor of heat, so they tend to waste a portion of heat.

- Excessive sludge formation disturbs the working of the boiler. It settle at the bends thereby causing blocking

Prevention of sludge formation

By using well softened water and by frequently blow down operation

(ii). Scales formation in boilers

Decomposition of calcium bicarbonate

- Scales are the main source of boiler troubles. Scale composed chiefly of calcium carbonate and is the main cause of scale formation in low-pressure boilers.

$$Ca(HCO_3)_2 \xrightarrow{\text{Heat}} CaCO_3\downarrow + H_2O + CO_2\uparrow$$

Scale

- But in high-pressure boilers, $CaCO_3$ is soluble.

$$CaCO_3 + H_2O \longrightarrow Ca(OH)_2 \text{ (Soluble)} + CO_2$$

(ii). Scales formation in boilers

Decomposition of calcium sulphate

- The solubility of calcium sulphate in water decreases with increase of temperature (because dissolution of $CaSO_4$ is an exothermic process).
- The solubility of $CaSO_4$ is 3,200 ppm at 15°C and it reduces to 55 ppm at 230°C and 27 ppm at 320°C
- $CaSO_4$ gets precipitated as hard scale on the heated portion of the boiler. This is the main cause of scales in high-pressure boilers.

(ii). Scales formation in boilers

Hydrolysis of magnesium salts

Dissolved magnesium salts undergo hydrolysis forming magnesium hydroxide precipitate which forms a soft type of scale

$$MgCl_2 + 2H_2O \longrightarrow Mg(OH)_2 + 2HCl$$

Presence of Silica

presence of silica in small quantities deposits as calcium silicate ($CaSiO_3$) or magnesium silicate ($MgSiO_3$). These deposits stick very firmly on the inner side of the boiler surface and are very difficult to remove

Disadvantage of scale formation

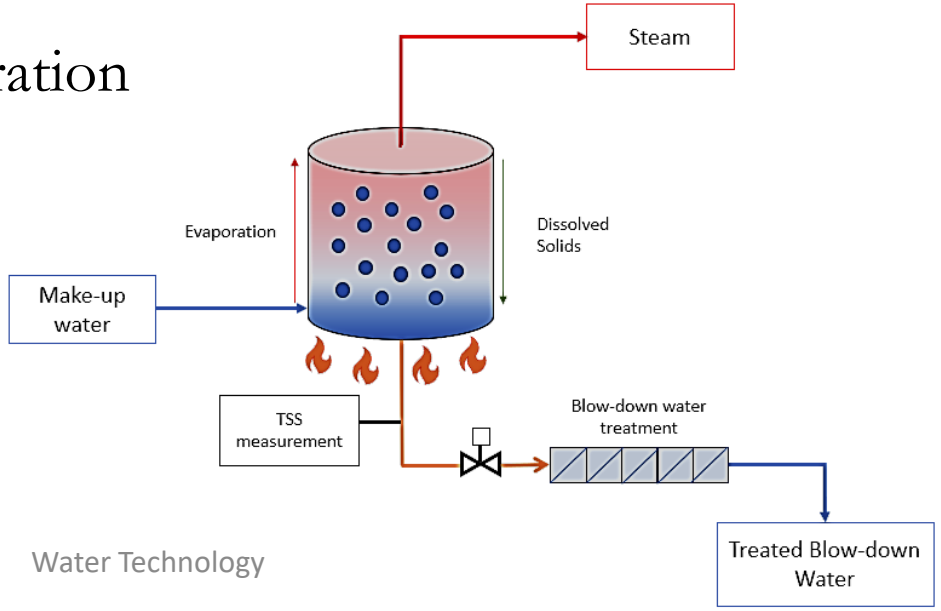
- Low thermal conductivity

Thickness of scale (mm)	0.325	0.625	1.25	2.5	12
Wastage of fuel	10%	15%	50%	80%	150%

- Lowering boiler safety
- Decrease in efficiency
- Danger of explosion

Removal of Scales

- By giving thermal Shock if they are brittle (heating the boiler and then suddenly cooling with cold water)
- If they are adherent and hard – dissolving them with help of chemicals.
  - Calcium carbonate scales can dissolved by using 5-10% HCl.
  - Calcium Sulphate scales can be dissolved by adding EDTA (ethylene diamine tetra acetic acid) with which they form soluble complex.
- Frequent blow down operation



Prevention of scale formation

(will be discussed in the next module)

- External Treatment
  - Removing hardness-producing constituents of water

- Internal Treatment
  - Colloidal Conditioning
  - Phosphate conditioning
  - Carbonate conditioning
  - Calgon conditioning
  - Treatment with sodium aluminate ($NaAlO_2$)