

Natubhai V. Patel College of Pure & Applied Sciences
S. Y. B.Sc. Semester-4
Industrial chemistry/ IC (Vocational)
US04CICV01/US04CICH02: Chemical Plant Utilities
UNIT – 1

WATER

To select a site for the location of a factory, water supply is one of the factors to be considered. Besides the quantity of water, the nature, and amount of impurities present in the water are also important. Therefore, in selection of site for a factory following factors have to be considered:

- Quantity and Quality of water available,
- Effect of impurities on the process and
- Quantity of water needed.

Sources of water are river, lake (surface water) and well (underground water).

Common impurities present in natural water

Dissolved minerals: These are carbonates, bicarbonates, sulphates and chlorides of calcium, magnesium, sodium and potassium.

Dissolved gases: mainly air and Carbon dioxide

Suspended matter: consists of mineral matter, giving turbid or muddy water, Organic matter may also be present.

Microscopic matter: of plant and bacterial life giving colour, taste and odour.

From above, class 1, 2 and 3 form chief problem for industries and 3 & 4 for municipal supplies.

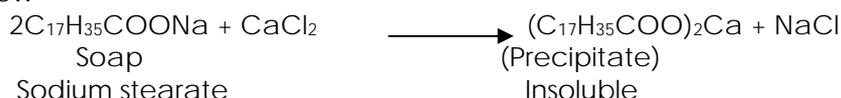
Hardness of water

Hard Water: A sample of water that reacts with soap to form a white scum and does not produce lather is known as hard water.

Soft Water: A sample of water that reacts with soap to form stable lather easily is known as soft water.

Calcium and magnesium salts are present as bicarbonates, sulphates and also as chlorides and cause hardness.

The difficulty in producing lather arises because of the fact that soaps are sodium and potassium salts of higher fatty acids and are soluble in water but when soap is used in water containing calcium and magnesium salts, insoluble soaps of calcium and magnesium are formed and precipitate, thus destroying the soaps. A typical reaction may be illustrated as follow



Such precipitate is not formed with the newer detergents, which are sulphonates of long chain alcohols.

Calcium and magnesium salts are not the only salts that cause hardness. They are mentioned because they are most commonly present. Generally, all soluble salts of heavy metals cause hardness because they form precipitate with soap.

Temporary hardness or Carbonate hardness

Hardness due to the bicarbonates of calcium and magnesium is called temporary hardness. The bicarbonates of calcium and magnesium are decomposed by boiling the water when carbonates are formed which are less soluble.

Permanent or noncarbonate hardness

Hardness due to sulphates and chlorides of calcium and magnesium is known as permanent hardness. This hardness cannot be removed by boiling of water.

Determination of Hardness

There are two methods

(1) Clark's method OR Soap method

In this sample test, 70 ml. of water is taken in a 300ml bottle. A standard soap solution is added from a burette and the bottle is shaken. The volume of soap required to produce lather stable for 5 minutes is noted and hardness is calculated. After some experience fairly

accurate results can be obtained.

It is estimated that if about 2 kg. Of common soap is added to 100 litres of water of hardness 100 mg.-litre, it would get precipitated by the salts present in the water. Lather would be produced only if more than this amount of soap is used.

(2)Complexometric method OR EDTA (Versenate solution) method:

This method gives more accurate results than previous method.

Fixed amount of water with indicator erichrome black T (Sodium 1-(1-hydroxy-2-naphthylazo)-6-nitro-2-naphtyl-4-sulphonate) is taken into the flask. Buffer solution of pH=10 is added to the flask because in acidic solution indicator (EBT) will polymerize to red-brown product. So to prevent this, buffer solution is added.

The solution becomes light red in colours. If EDTA (Ethylene diamine tetra acetic acid) is added to such a solution, the calcium and magnesium ions will form complex with EDTA. When the formation of complex with the free ions is completed. EDTA extracts the ions from dye and solution turns blue. This is the end point. Hardness is calculated in parts per million (ppm) from the reading obtained and ml. of water taken.

$$\begin{aligned} \text{Total hardness (X)} &= \frac{\text{Burette reading} \times 10^6}{\text{ml. of water taken}} \\ &= X \text{ ppm} \end{aligned}$$

Degree of Hardness

The weight of all the substances are expressed in terms of a weight equivalent to the weight of CaCO₃. For example 162 parts by weight of Ca(HCO₃)₂ would react with the same amount of soap as 100 parts by weight of CaCO₃. Therefore, the weight of Ca(HCO₃)₂ is multiplied by 100/162 to give weight in terms of CaCO₃. Similarly, weights of CaSO₄, CaCl₂, MgSO₄, Mg(HCO₃)₂ and MgCl₂ actually present are converted in terms of weight of CaCO₃ by multiplying by

$$\frac{100}{136} \quad \frac{100}{111} \quad \frac{100}{120} \quad \frac{100}{146} \quad \frac{100}{95} \quad \text{respectively,}$$

In water treatment only, those impurities which give rise to certain troubles are eliminated or kept within certain limits.

Major boiler troubles

Boiler troubles arising out of the use of unsuitable water, may be classified as

1. Carry over
2. Corrosion
3. scale formation
4. Caustic embrittlement
5. Turbine deposits

1. Carry over

As steam emerges from the surface of the water, it is associated with tiny droplets of water. Such steam is called wet steam. The droplets may carry with them suspended matter besides the dissolved matter present in the boiler water. Such carryover of water by steam along with suspended and the dissolved solids is called carry over.

It is mainly due to priming and foaming.

Priming

It is such rapid or violent boiling of water occurring in the boiler that water is carried into the steam outlet in the form of spray.

Priming because of

- Very high water level
- presence of excessive foam filling the steam space
- high steam velocity
- sudden steam demand leading to sudden boiling
- faulty boiler design

Priming is controlled by

- Keeping the water level as low as possible. Slight lowering of water level greatly reduces priming
- Avoid sudden steam demands, (by suddenly taking out a quantity of steam from boiler, the pressure in the boiler is reduced, the boiling point of water is reduced and

- super heated water is suddenly converted into steam
- minimizing foaming

Foaming

It is the formation of small but stable bubbles above the surface of water. These are carried over along with steam, leading to excessive priming.

Foam formation takes place when the concentration of solid in the surface layer is different from that in the mass of the liquid. This means that the solid must change the surface tension of water and promote foaming. Presence of fatty oil may form soap with the alkalinity. Soap greatly reduces surface tension of water.

Foaming can be controlled by the use of anti-foaming chemicals. e.g. Castor oil, which spreads on the surface of the water. This oil is used for low-pressure boilers. Only satisfactory way for foaming is blow down, i.e. removal of concentrated boiler water and replacing it by fresh feed water.

Carry over is undesirable because

- A considerable amount of heat is wasted by the removal of hot boiler water (i.e. in case of blow down).
- Water reduces superheat of steam in the super heaters.
- water takes along with it grit which strikes on the surface at high velocity and damages the walls
- Water contains large amount of dissolved solids which gradually get deposited and restrict the passage in the pipelines, causing corrosion and insulation,
- Water entering the steam engine cylinder causes serious trouble because of its incompressibility and inability to escape quickly through the steam parts.
- Foaming of water makes it difficult to know the exact level of water in the gauge glass.

2. Corrosion

It is one of the most serious problems caused by the use of unsuitable water. Boiler tubes, drums, economizers, super heaters and condensers are the most affected parts. The corrosion problem extends even to parts, which are not directly in contact with boiler water because gases like O₂ and CO₂ are released during heating of water.

These gases have corrosive effects corrosion is because of:

- Dissolved oxygen
- Mineral acids
- Dissolved CO₂
- Galvanic cell formation

Dissolved Oxygen

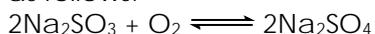
Dissolved oxygen in water is mainly responsible for corrosion in boilers. Dissolved O₂ in presence of moisture and at high temperature readily attacks iron. At high pressure, O₂ will dissolve more and high temperature reduces O₂ content. Solubility of O₂ in pure water is more than in the impure water.

Dissolved oxygen can be removed by

(a) Mechanical deaerator: Various types of deaerators have been designed. In a cylindrical chamber, water falls through perforated plates or is sprayed, so that larger surface is exposed. The deaerator is connected to a vacuum line, which sucks out the gases.

(b)Pre-heating: Solubility of a gas decreases with rise in temperature. Air begins to be expelled at temperature of about 65°C and is completely removed at the boiling point. Water is sprayed in a cylindrical equipment and steam moving in opposite direction. Steam heats and carries away the gases, which have been liberated.

(c)Chemical treatment: for complete removal of O₂ chemical treatment is required. This is done by adding a reducing agent, sodium sulphite being commonly used, which reacts as follows:



Ferrous sulphate is also used. It gives precipitate of Fe(OH)₂ which is oxidized to Fe(OH)₃.

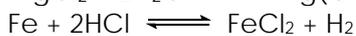
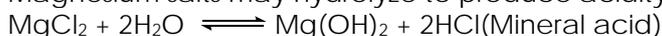
In high-pressure boiler, even traces of O₂ are undesirable hydrazine is added in such amounts that after reacting as under, residual hydrazine is about 0.02 mg/litre.



Thus no solid is added to the boiler. Hydrazine should be handled carefully; usually its solutions are used.

Mineral acids: Natural waters are alkaline. Waters in the mining areas are often acidic. In industrial areas the water may become acidic because of acidic industrial waste discharge into the water.

Magnesium salts may hydrolyze to produce acidity as follows:



Thus small amount of MgCl_2 will cause corrosion of a large amount of iron by producing HCl. Boiler water should have a pH value of about 10.5 so that acid may not attack iron.

Carbon dioxide: Water contains some dissolved CO_2 . If bicarbonates are present in the water, on heating they will decompose and produce more CO_2 . CO_2 with water gives carbonic acid, H_2CO_3 , which has a corrosive effect. Local corrosion caused by CO_2 is called pitting.



CO_2 can be removed by addition of limestone.



CO_2 can also be removed by NH_3 but NH_3 is corrosive to copper and its alloys, therefore amines are used.

Galvanic cells: Galvanic cells which iron forms with some of the boiler fittings made of other materials or with impurities, which cause corrosion. Zn is more electropositive than iron hence it is anodic to iron and gets dissolved first and iron is saved.

3. Scale Formation

Water containing impurities is fed into the boiler and pure water is removed in the form of steam leaving behind the impurities.

Some of the deposits stick to the metal surface and are known as scale. If they are in the form of soft and muddy deposits, which can be removed easily, are known as sludges.

Scale formation takes place because of salt like $\text{Ca}(\text{HCO}_3)_2$ which gives off CO_2 and insoluble CaCO_3 is precipitated on boiler surface giving the scale.

Some salts having lower solubility at high temperature cause crystallization, e.g. CaSO_4 crystallizes out on the surface at high temperature.

Silicate of Calcium and magnesium or other silicates deposited cause trouble because they are poor thermal conductor.

Disadvantages of Scale Formation

Waste of Fuel: The scales are bad conductors of heat, therefore they act as an insulator on the surface. This results in reduction in the heat transfer rate hence large quantity of fuel is required to maintain the rate of heat transfer.

Overheating of the boiler tubes: This is explained by following figure

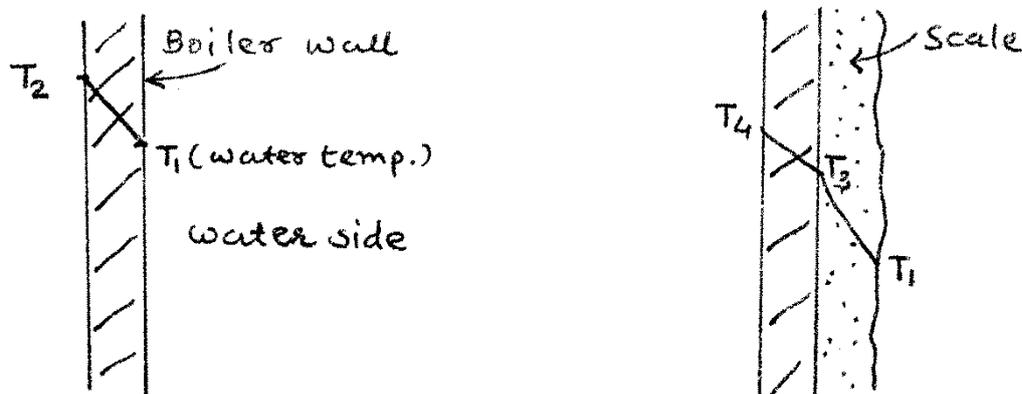


Figure:1 Insulating effect of scales

Figure on left shows a section of the boiler tube metal which is; completely free from scales. In this case, in order to heat the boiler water T_1° the metal surface towards the source of heat is heated to T_2° because of the temperature drop across the metal.

The figure to the right represents surface with scale. Therefore, heating the water to T_1° the metal surface in the heat source side is heated to T_4° which is higher than T_2° C .

At high temperature metal becomes weak and cannot withstand high pressure. This becomes dangerous.

Prevention of Scale Formation

External treatment: It is given outside the boiler to remove the calcium and magnesium salts and silica from water which forms scale. For this, external equipment is needed which requires an investment.

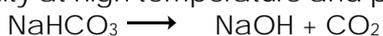
Internal treatment: Chemicals are added into the water entering the boiler, to convert the remaining salts into more insoluble salts that will be in form of nonstick sludge. This can be easily removed.

Blow down: In spite of giving external and internal treatment, concentration of impurities goes on increasing and practical solution is to make a blow down, i.e. remove the portion of the concentrated water which contains a large amount of dissolved matter. Along with it some sludge is also removed.

4. Caustic Embrittlement

Sometimes boiler failure is due to metal plate becoming brittle and cracks having been formed in the metal. This happens in areas which are under stress.

Alkali metal carbonates and bicarbonates present in water give rise to caustic alkalinity at high temperature and pressure,



Alkali metal Caustic

Bicarbonate

The concentration becomes greater near the rivets because of bad circulation of water and also the leaks through which steam escapes leaving behind water with a higher concentration of caustic alkalinity.

5. Turbine Deposits

To avoid or to minimize the turbine deposit, chemical analysis throughout the steam and water line is carried out. Chemicals are added properly and mixed properly. Operate demineralization plant properly to avoid the dissolved mineral matters.

Methods of boiler water treatment

The common treatments given to the boiler water to overcome from the troubles are described below

Preliminary treatments: may include simple treatments like sedimentation, coagulation and filtration. Details of these treatments are similar to those given under municipal water supply.

Pre-heating: It is heating feed water before enters the boiler. Very often blow down and low pressure steam is available. Hot fuel gas also is used for pre-heating. Water may be heated in a heat exchanger. The advantages of pre-heating are:

(a) Instead of feeding water at atmosphere temperature into the boiler, feed hot water in boiler. Thus save Fuel.

(b) A portion of temporary hardness maybe removed.



(c) Dissolved $\text{O}_2 + \text{CO}_2$ are removed.

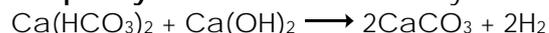
Initially at 65°C dissolved gases are removed from water and almost completely removed boiling. Thus removal of corrosive gases is advantageous.

(d) Use of hot water in chemical treatments such as lime-soda process, greatly helps in the process

Lime-Soda Process: It is used for feed water treatment for low and medium pressure boilers. Lime and soda convert the soluble impurities, into insoluble salts, which get precipitated and after settling they are filtered off.

Lime is generally 10% excess is added to water. Its advantages are

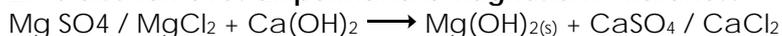
Temporary hardness is removed by the following reactions:



CaCO_3 & $\text{Mg}(\text{OH})_2$ are precipitated.

The removal of temporary hardness by lime does not introduce any soluble salt in water and reduce the total dissolve solids.

Lime also **removes all permanent magnesium - hardness**



An equivalent amount of permanent calcium hardness is introduced, which has to be removed by soda treatment. Here, there is no softening.

Lime also **removes free acids, CO_2 and H_2S**

Soda Treatment: It removes the remaining calcium permanent hardness.



Soda Process



Batch process

Continuous process

1. Batch Process: In this process chemicals are added in batches in water taken in tanks, agitated for necessary time and the precipitate allowed to settle and then filtered. Fresh water is again taken into the tank and the operation is repeated.

2. Continuous Process: Water together with lime and soda solutions enters a smaller tank continuously at a predetermined rate.

The chemicals and water to be treated enter a bigger tank or chamber (see the figure). The second chamber is tall structure having a larger cross section at the top than at the bottom. As chemical reactions settle down, because towards the upper portion of chamber the velocity is less due to larger cross section, clear water is removed continuously from the top and sludge from the bottom. A part of sludge is recycled which helps in reuse of excess chemicals left behind in the sludge and also helps in precipitation by providing nuclei.

Cold Lime Soda Process: When the chemicals are added to water at atmospheric temperature, the process is known as cold lime soda process.

At this temperature precipitate is finely divided and do not settle easily, nor can it be easily filtered. Therefore it is necessary to add coagulants like alum, aluminium sulphate, sodium aluminate etc.

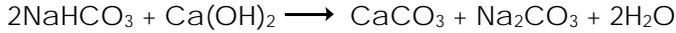
Coagulants get hydrolysed and form flocculent and gelations precipitated which entraps the finely divided particles and settle down readily or are easily filtered off. Ferrous sulphate and sodium aluminate are costlier than alum. Ferrous sulphate helps to remove oxygen and sodium aluminate helps the removal of silica and also oil.

Hot Lime soda Process: When this treatment is given at a higher temperature the process is known as hot lime soda process. Water is heated by waste steam or hot gases and calculated amount of chemicals is added as in cold process.

Advantages

- As reactions proceed, quickly at higher temperature, the reactions are completed in about 15 min., whereas in the cold process, several hours are needed. This greatly increases the capacity of the plant.
- Precipitate and sludges formed settle rapidly at higher temperature; hence coagulants are not needed.
- Filtration becomes easier because of the bigger size, of the particles and the reduced viscosity of solution at the higher temperature, hence the capacity of the filter is also increased.
- Residual hardness, i.e. hardness of softened water needs careful consideration. Solubility of calcium salts is very slightly higher at low temperature. More than this, the time taken for the completion of the reaction at a lower temperature is greater. In

the hot process the reaction time is less with the result that the hot process gives softer water. In some places, water is highly alkaline, and contains considerable amounts of sodium bicarbonates. On adding lime, calcium carbonate precipitates forming sodium carbonate.



In such a case, soda may not be heated for the removal of permanent hardness. As a matter of fact, cases are known where gypsum has to be added to remove soda so produced.

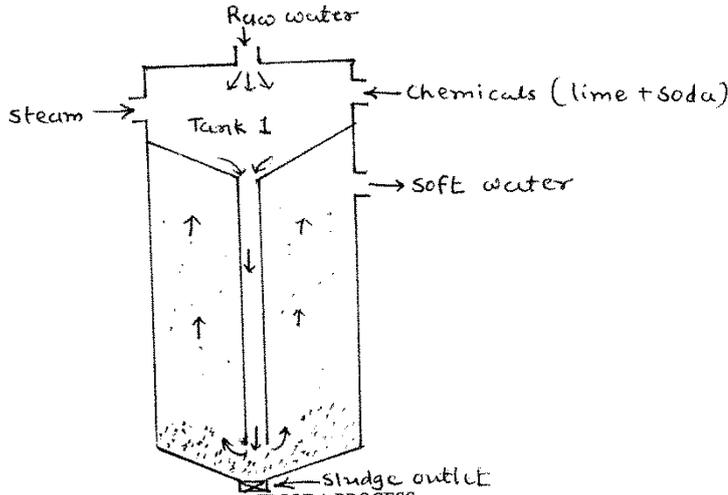


FIGURE: HOT LIME SODA PROCESS

Permutit or Zeolite Process

Zeolites are natural or synthetic complex compounds, consisting of hydrated sodium aluminium silicates approximately corresponding to the chemical formula $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 6\text{H}_2\text{O}$. Zeolites are insoluble.

They introduce Na^+ in place of Ca^{+2} and Mg^{+2} . As these exchange bases, they are also known as base exchangers.

If Na_2Z represents Zeolite, the reactions taking NaCl may be represented thus:



Zeolites are kept in cylinders, which act as filter beds. Hard water is passed through them. The hardness causing substances are retained as insoluble compounds according to the reactions given above. After use for some time the zeolite is converted into Calcium or magnesium zeolite and then it stop to soften water. At this stage it has to be regenerated by treatment with a conc. sodium chloride solution. When the original sodium zeolite is recovered



The Zeolite bed is again ready for use.

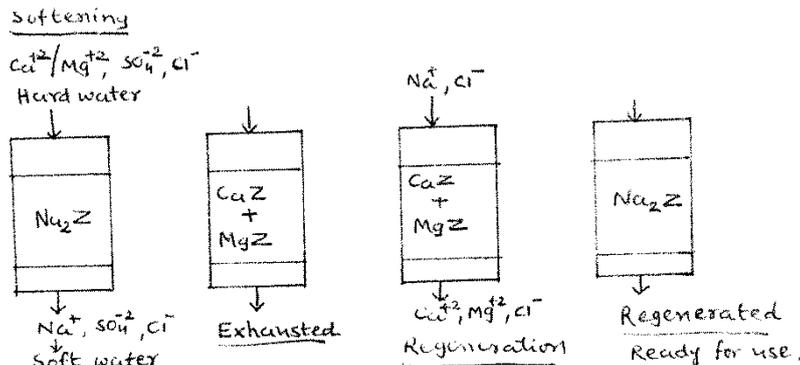
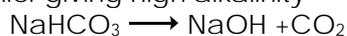


Figure: Water softening by Zeolite process.

Turbidity will clog the pores and restrict the flow, excess acidity alkalinity will attack the zeolite, therefore pH value should be around 7, iron or manganese salts will produce iron or manganese zeolites from which it cannot be easily regenerated. Therefore, these should be removed before passing water through zeolite bed. Hot water is not passed through zeolite bed because zeolite tends to dissolve in hot water.

The temporary hardness will give water containing NaHCO_3 which dissociates inside the boiler giving high alkalinity



Alkalinity causes caustic embrittlement. CO_2 with steam makes condensed water acidic, hence corrosive. Thus it is necessary to remove temporary hardness as far as possible before using zeolite.

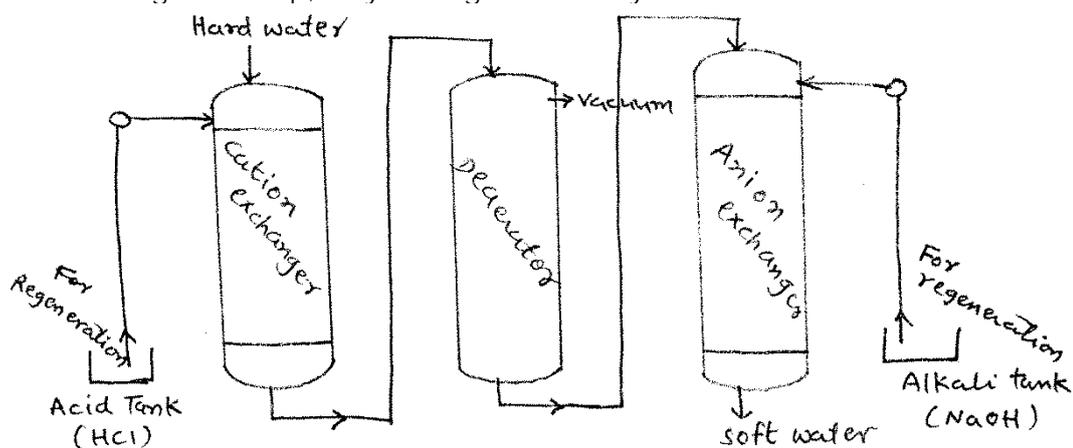
Advantages

- It removes the hardness completely.
- Equipment is a compact unit occupying a small space
- It automatically adjusts itself to different hardness and can be worked under pressure, therefore plant can be installed in the water supply line and avoid double pumping
- Impurities are not precipitated; there is no danger of sludge formation at a later stage.

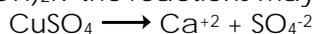
Deionizer or Demineralizers

Several organic substances - resins of complex chemical structures - which behave similar to the zeolites. By this process all the ions are removed. The cations are replaced by OH^- . Water to be treated in two cylinders containing the resins, one of which removes cations and other anions.

When resins get used up, they are regenerated by acid and alkali treatment

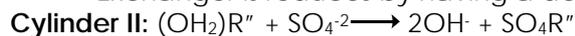


Suppose the first and second cylinders contain resins represented by the formulas $\text{H}_2\text{R}'$ and $(\text{OH})_2\text{R}''$ the reactions may be represented thus :



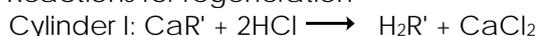
Water coming out from cation exchanger is highly acidic. Water from nature contains large amount of carbonates and bicarbonates. These ions like other anion can be removed by passing through union exchanger. CO_3^{-2} & HCO_3^- in presence of H^+ form H_2CO_3 (or $\text{H}_2\text{O} + \text{CO}_2$). The load on anion

Exchanger is reduces by having a deaerator which will remove CO_2 .



H^+ and OH^- unite to form H_2O , thus not solid is added to water. When the plant does not soften any more, the first cylinder is regenerated by passing a dil. Solution through it and second cylinder by passing dilute alkali.

Reactions for regeneration



Mixed bed deionizers are also now available. The main disadvantage of process is the

equipment is costly and more expensive chemicals are needed for regeneration. If water contains turbidity or large amount of dissolved salts then the output is reduced.

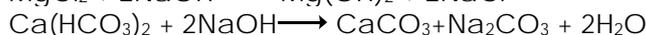
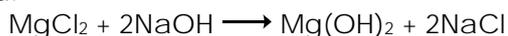
This process is very good for water for very high pressure boilers. For low pressure boiler, the equipment is rather costly and water may be treated more economically by other processes.

Feed water conditioning

It is treatment given to correct undesirable tendencies.

Phosphate treatment

In the lime- soda process, calcium is precipitated as CaCO_3 , which is quite insoluble. However a small amount remains in solution. This can be removed by sodium phosphate (Na_3PO_4) which precipitates the less soluble $\text{Ca}_3(\text{PO}_4)_2$, thus hardness is further reduced. For the best results, the pH value of water should not be less than 9.5. For this purpose NaOH is added.



Na_3PO_4 and NaOH precipitate magnesium as hydroxide and calcium as phosphate. These reagents are costlier than lime and soda.

Na_3PO_4 treatment also helps to control pH value of water. Na_3PO_4 gives alkaline reaction and can be used to increase the pH value.

This treatment is often given after lime-soda treatment. It has disadvantage of causing "after precipitation", that is gradual precipitation in pipes, equipment, etc.

Sodium aluminate treatment

Sodium aluminate precipitates calcium and magnesium as insoluble aluminates NaAlO_2 hydrolyses also, giving NaOH and $\text{Al}(\text{OH})_3$. NaOH so produced precipitates some of the magnesium as $\text{Mg}(\text{OH})_2$. Flocculent precipitates of $\text{Al}(\text{OH})_3$ and $\text{Mg}(\text{OH})_2$ are produced which remove finely suspended and colloidal impurities, including silica and oil droplets, which are ordinarily difficult to remove. Sodium aluminate is cheaply available from bauxite refineries.

Treatment for microbiological growth

The growth of greenish matter may be commonly observed in stagnant waters. Similar growth may take place in heat exchangers, condensers and cooling systems. They restrict the flow of water and also retard the heat transfer. Sometimes they may come out suddenly in large masses and clog the pipe or the pump. Algae and slime are present in such water.

Bacteria produce gas which can attack stainless steel and cause pitting.

Chlorine is very effective to remove algae and slime. CuSO_4 is more effective for algae than for slime. It cannot be used if pH value is above 8.5 as copper hydroxide will be precipitated. Chromates are used for corrosion control and for control of algae and slime.

Chloramine is also used. Bleaching powder mixed with NH_3 and when NH_3 and Cl_2 combine to Chloramine is formed which destroy the microbiological growth.

Fe and Mn Removal

These are present in small amounts in water in absence of dissolved O_2 . Fe and Mn give red and black precipitates, respectively, when water comes in contact with air. They are highly undesirable in water for dye and tanning industries and for laundries. They also give metallic taste to water. They are removed in forms of insoluble $\text{Fe}(\text{OH})_3$ & $\text{Mn}(\text{OH})_2$ by oxidation, followed by coagulation and filtration. The oxidation may be by blowing of air in water.

Silica Removal

About 5-8 mg/lit silica is present in natural water. After lime-soda process because of alkalinity of water, during filtration through sand bed Silica dissolves in water. Calcium and Magnesium silicates act as cements and bind together other particles into a hard scale.

Soluble silica is removed by the use of magnesium compounds like MgO. For high pressure boiler silica is removed by strongly basic anion exchangers.

Oil removal

Generally, natural waters are free from oil but small amounts are likely to come from the oils used for lubrication of the pumps.

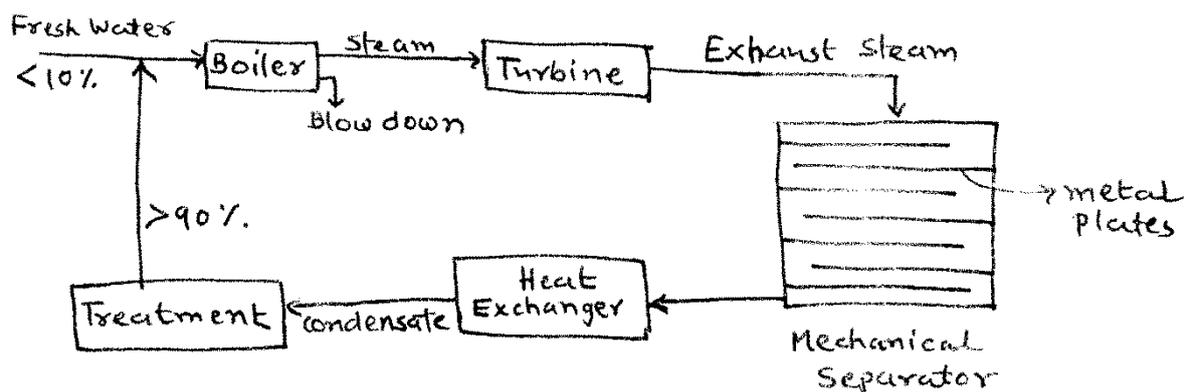


Figure: Oil removal by mechanical separator

For removal of oil the exhaust steam is passed through mechanical oil separators, which consists of a chamber with a number of metal plates. As the steam with droplets of oil passes over the plates, droplets of oil are retained on the metal surface. Thus most of the oil is removed. Sodium aluminate is added to the condensate, which removes the remaining oil.

If oil is vegetable or animal oil, it may get hydrolysed producing fatty acids, which may have corrosive action.

Fatty acids may combine with the alkalinity, producing soap, which forms sticky coating on the metal surface. These will attract other impurities and form thicker deposits.

O₂ removal

Write down about preheating, deaerater and reducing agents in this topic, which you previously studied.

Boiler compounds

The inorganic constituents of boiler compounds precipitate the scale forming salts and also help to control the corrosion. The organic constituents are characterized by high molecular weights. These form large particles, which are adsorbed on the metal surface and then prevent the formation of hard scale.

Boiler compounds are more expensive than the ingredients brought separately.

MUNICIPAL WATER SUPPLY

Municipalities draw their water from rivers, wells, and lakes. This water contains dissolved matter which in most cases is harmless for drinking. Municipalities have to supply potable water. i.e. water which is safe and good to drink.

The treatment most widely given include

- Sedimentation and coagulation
- Filtration
- Sterilization

(1) Sedimentation and Coagulation

Sedimentation means simple settling. It is the process by which the force of gravity acts on particles heavier than water and causes them to move downwards and settle.

For this purpose water is kept in huge tanks, called sedimentation tanks in which water moves very slowly. Time required for sedimentation depends on the weight, size and shape of particles and the viscosity and fractional resistance of water. Because viscosity varies with temperatures the settling rate varies in different seasons. Sedimentation requires 4-12 hours.

Generally, only 70% of suspended matter settles down by plain sedimentation.

Further removal of matter is done by addition of coagulants like, alum, ferrous sulphate, ferric chloride, sodium aluminate etc. Generally about 95% suspended matter is removed by coagulation.

Coagulation reactions are salt hydrolyses and produce a floc of the hydroxide e.g. $Al(OH)_3$ and $Fe(OH)_3$. The flocculent precipitate so produced has a large surface area and the floc removes the finally divided matter by adsorption or electrical attraction of oppositely charged particles, which quickly settle down.

Filtration

It is the process of passing a liquid containing suspended matter through a suitable porous material in such a manner as to effectively remove the suspended matter from liquid. Filters are of two types:

- Gravity filters
- Pressure filters

(a) Gravity Filters: Water flows through the bed by gravity. These filters are of two types:

- (i) Slow sand filters (ii) Rapid, sand filters