Topic Notes

**Water Hardness**

• Hard water does not easily form a lather with soap and is caused by the presence of Mg(2+) ions or Ca(2+) ions.

• Calcium for teeth and bones, nicer taste and good for brewing and tanning

• Produces scum, wastes soaps and blocks pipes, leaves scale on kettles and boilers.

• Most soaps contain sodium stearate, when soap is added to hard water it forms a grey insoluble compound called scum.

This is calcium stearate. • Ca(2+) + 2C17H35COO -----> (C17H35COO)2Ca (scum)

• Hard water wastes a lot of soap, Modern detergents are now used for washing clothes because they don’t contain soap and are not affected by hard water.

• Temporary hardness can be removed by boiling water. Temporary hardness arises from rain falling and dissolving carbon dioxide to form a slightly acidic solution of carbonic acid. Limestone or calcium carbonate reacts with this to form calcium hydrogen carbonate.

Temporary hardness is really a dilute solution of calcium hydrogen carbonate. Ca(2+) ions cause hardness here.

If water is heated a chemical reaction occurs that removes the Ca(2+) ions from the water. (Below)

Ca(HCO3)2 --> CaCO3 (insoluble) +CO2 + H20

• The insoluble calcium carbonate is the fur or scale that builds up in kettles and boilers.

• Mg(2+) ions often come from dolomite rock.

• Permanent hardness cannot be removed by boiling and is caused by the presence of calcium sulfate or magnesium sulfate.

**Removing permanent hardness**

• Distillation: This involves boiling the water and cooling the vapour. All dissolved solids and liquids are removed here but it is not feasible to be carried out on a large scale.

• Washing soda: The carbonate ions in the washing soda react with the calcium ions in the water and precipitates them out as calcium carbonate. Commonly used in bath salts to help lather form more easily.

• Ion Exchange resin: Man made materials which swap the ions that cause hardness for the ions that don’t. Cation exchange resin exchanges the positive ions in the water for Na+ ions.

Ca2+ + Na2R -----> CaR + 2Na+ , so the calcium ions remain in the resin. Eventually the resin needs to be regenerated by passing it through a solution of sodium chloride.

• In some cases all ions must be removed - deionized water. This involves passing water through a deionizer with ANION and CATION exchange resin. (mixed bed resin). Anion exchange resin removes the negative ions and replaces them with OH- ions. The cation exchange resin replaces positive ions with H+ ions.

Water Treatment

1. Screening: passing water through wire mesh to remove any floating debris like plastic bags, twigs and so on.
2. Flocculation: A flocculating agent is added which is normally Aluminium Sulfate (Al2(SO4)3). This causes suspended solids to coagulate or stick together to form large particles which settle out in settlement stage. A flocculant is a chemical added to water to coagulate suspended particles.
3. Settlement: The water is passed into settlement tanks, here it flows into the bottom and rises up very slowly so maximum settlement can occur. Over 90% particles are removed here and the water is then collected in channels.
4. Filtration: The water from settlement tanks is passed through large beds of sand which remove any remaining suspended solids. It is supported by a layer of gravel and these layers are cleaned regularly. The sand acts like a sieve or filter and removes any suspended solids.
5. Chlorination: A small amount of chlorine (0.2-0.5ppm) is added to the water to sterilize it or get rid of any harmful micro organisms. If too much is added it can taste unpleasant so it is regularly monitored by a bacteriological examination of water.
6. Fluoridation: By law, councils and associations must add small amounts of fluorine to the water, fluorine compounds commonly added are sodium fluoride, hexafluorosilicic acid. The fluoride ion helps reduce dental decay by strengthening teeth enamel.
7. pH adjustment: Some water authorities may need to alter pH before distributing water to homes and factories, pH may be raised by Calcium hydroxide or by sodium carbonate and lowered by CO2 or dilute sulfuric acid.

**Water Pollution**

* Pollution is the release of substances into the environment that damage the environment.
* Solubility of O2 in water is quite low and it depends on the temperature of the water, remember O2 is a non polar molecule and water is a polar molecule so that’s why solubility is low.
* It is vital for aquatic life. The more hot the water, the less solubility.
* When organic waste is discharged into a water way micro-organisms bloom use up the oxygen dissolved in water to produce CO2 and water. Dissolved oxygen level drops. Fish die. If it drops to 0, anaerobic bacteria take over and H2S will provide a foul smell of the river.

**Eutrophication**

* Eutrophication is the enrichment of water with nutrients which leads to the excessive growth of algae.
* These include the enrichment of water with plant nutrients, especially nitrate ions NO3(-) and Phosphate ions PO4(3-)As these levels rise many plants and floating algae explode in population. These algae are short lived and when they decay a heavy oxygen demand is placed on water. It is a green scum and many life forms are killed as a result of the drop in dissolved oxygen levels.

• Natural eutrophication - in lakes caused by gradual increase in nitrogen and phosphorous levels caused by sediments building up in the lake.

• Artificial eutrophication - sudden increase in nutrients caused by artificial fertilisers being washed into rivers and lakes or by domestic sewage or waste from intensive farming.

**BOD**

* Biochemical Oxygen Demand is the amount of dissolved oxygen consumed by biological action when a sample of water is kept at 20 degrees in the dark for 5 days.
* The B.O.D. is the difference in the 2 dissolved oxygen levels as this is the amount of dissolved oxygen that has been used by biological action during test. Unit: mg/L
* NOTE: rate at which micro-organisms use up oxygen depends on the temperature of the water, solubility of oxygen in water decreases as temperature of water increases.
* The higher the B.O.D. value the more polluted the water
* May be used to test level of pollution of effluents, however because of low solubility of oxygen in water effluents with B.O.D. greater than 9mg/L must be diluted by a fixed amount of well oxygenated water.
* This ensures that dissolved oxygen will 9 be present throughout the 5 day test and a measurable amount of oxygen at least 2 p.p.m. will be left after the 5 days.

**Heavy Metal Pollution**

Water pollution is also caused by release of toxic metal ions such as cadmium, lead and mercury ions. These are heavy metals or cumulative poisons that build up in the body upon continuous exposure. Caused by industrial effluents or dumping of batteries with these metals. (Minamata Bay Japan - mercury poisoning, mercury salts damage intestine and kidneys - birth defects and death).

* These ions are removed by precipitation e.g. Pb(2+) (soluble) + 2Cl- ----> PbCl2 (insoluble)

**Sewage Treatment**

**I. Primary Sewage Treatment: Mechanical process,** the sewage flows through steel bars to remove any floating debris like twigs, leaves, plastics etc... These could interfere with the equipment in the plant. Then it is passed through grit channels where items like pebble and grit settle and are removed periodically. Suspended particles settle out of the sewage when the flow of the liquid stops. Sewage then flows into large settling tanks where it stays for a few hours and the solids or suspended particles settle out at the bottom. These are removed at regular intervals to be disposed of on land or sea. Then the supernatant liquid is passed onto secondary treatment.

II. **Secondary Treatment: Biological process** whereby the levels of suspended and dissolved organic material is reduced.

Activated Sludge Process - Sewage is pumped into a large aeration tank where it provides nutrients for growing micro organisms called activated sludge. They digest the sewage and the liquid in the aeration tank is kept aerated by a mechanical rotor that continuously churns liquid and sludge with the air. Sometimes compressed air is bubbled through the tank. Prevents concentration of dissolved oxygen dropping too low. From here the sewage flows into settling tanks. Some is recycled back into aeration tanks to come into contact with fresh sewage. The sludge removed is rich in nutrients and may be used as a fertilizer or stored in sealed tanks for anaerobic bacteria to convert it to methane - used as fuel. Micro organisms are continually decomposing organic waste into compounds like CO2, nitrates and so on. After secondary treatment 95% of the B.O.D. from original sewage is removed.

This effluent may be discharged into nearby waterway after this, however it may still contain compounds of nitrogen and phosphorus. These are removed in tertiary treatment.

**III. Tertiary Treatment:** Involves the removal of nitrogen and phosphorus compounds from effluents. Nitrates are from organic materials in sewage and phosphates are from house hold detergents.

* Phosphates are removed via precipitation e.g. adding aluminium sulfate - aluminium phosphate precipitates or by adding iron (III) chloride to precipitate it as iron(III)phosphate.
* Nitrogenous compounds are difficult and expensive to remove, may be present via ammonia, nitrites, nitrates or organic compounds containing nitrogen. Remember nitrates and phosphates cause eutrophication.

**Instrumental analysis of water**

• pH meters

• Atomic Absorption Spectrometry - each element has its own unique atomic absorption spectrum, it detects and measures concentrations of heavy metals in water.

• Colorimetry - White light is passed through a colored solution and the color of the solution is then compared with the color of solutions of known concentrations of that substance.