Water Chemistry

Water pollutant & their method of Removal:
↓
Introduction of harmful material into water bodies.

Methods of Removal:

① Sedimentation: / settling / Clarification
Based on gravity to remove suspended solid from water.

② Coagulation and Flocculation:

③ Filtration:
Removing small particles from water by passing it through a porous medium.

④ Water Disinfection :⇒
- Chlorination Ozonation

⑤ Reverse Osmosis: water purification process that uses a partially permeable memb. to separate ions.

⑥ Adsorption:

⑦ Advanced oxidation processes - chemical treatment — remove organic material in water & wastewater by oxidn through reacn.

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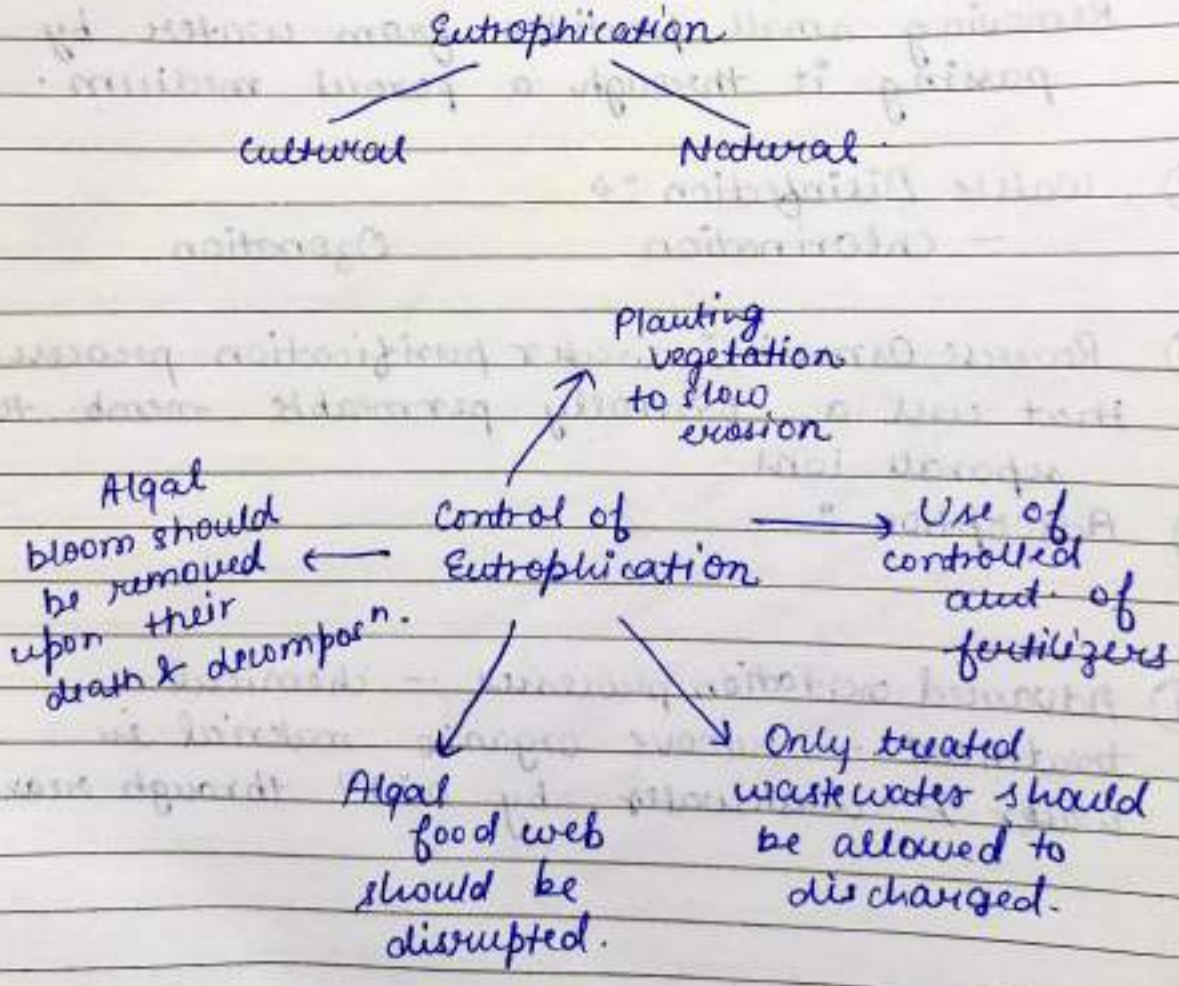
Eutrophication :

The addition of waste containing nutrients, mainly nitrates & phosphates - enriches the water body. Nutrients act as fertilizers & cause population explosion of water microscopic plants like algae & others like duck weed etc. This is called eutrophication.

Abundant of algae — Algal Bloom.



DO

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Concept of DO :→

Dissolved oxygen is a measure of how much oxygen is dissolved in the water - the amount of oxygen available to living aquatic organisms.

The amount of dissolved oxygen in a stream or lake can tell us a lot about its water quality.

The amount of oxygen in water depends on factors such as :

Temperature
Pressure
Salinity

Also: Bio is Trophic Biotic int.

Concentration and solubility :

→ The amt of O_2 dissolved in water is most often expressed in terms of milligrams per litre of water (mg/L)

→ DO conc. are sometimes expressed as % of saturation. If the DO of the water is at the saturation conc., then it is said to be 100 % saturated.

→ This saturation conc. is known as the solubility of O_2, which is the amount of O_2 that water can hold.

Solubility of O_2 changes with temperature, salinity and pressure.

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→ Solubility of O_2 changes with temp°, salinity and pressure.
Solubility of O_2 in water ↑es, as temp° ↓es → cold water can hold more O_2.

For eg: Cold water at 5°C (12.8 mg/L) holds about 55% more DO than warm water at 25°C (8.3 mg/L)

Reason: Bcz temp° of water varies with the seasons, DO levels tends to be higher in the cooler months because the solubility of O_2 is higher in cold water.

→ In summer, water levels tend to be lower and the air is warmer, which leads to warmer water and lower DO levels.

The salinity of water also affects the solubility of O_2, such that sea water can hold about 20% less O_2 than fresh water.

DO solubility changes with temperature and salinity.

→ Pressure also affects the solubility of O_2. The water pressure at a certain depth depends on the height of the water column above it, so pressure ↑es with depth.

→ Water at greater pressure can hold more O_2, meaning that the solubility of O_2 ↑es at greater depths.

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For eg: water at 4 m (13.1 ft) depth can hold about 40% more O_2 than water at the surface.

Still water tends to have lower DO values than rapidly moving water

DO and aquatic life :⇒
Animals that feed on the bottom of a water body, where DO levels tend to be lower, can typically tolerate lower DO levels that animals that dwells near the surface.

Fish able to survive at 5 mg/L or higher

Hypoxia is a condition where DO is low enough to threaten aquatic animal species (less)

DO < 1-2 mg/L → Hypoxic

Environmental impacts on DO :⇒
DO levels in water bodies can be impacted by a no. of different environmental problems.

① For eg: run off associated with clearcutting or agricultural wastes can carry excessive organic material into water bodies, which can result in the depletion of O_2 as material is decomposed.

② Another problem is excessive nutrients which can enter water bodies through run off and results in Algal Blooms → a process known as eutrophication.

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Algal blooms can block light from reaching aquatic plants, and dead algae provide a source of organic matter that can deplete DO levels when it decomposes.

③ Riparian vegetation (plants that live along the banks of a stream or river) protects the DO of streams by providing shade that helps keep the water cool.

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When this vegitation is removed, however, the temp. of the water can rise, causing a corresponding drop in DO levels.

④ When water is withdrawn or stored for drinking water, irrigation, or industrial use, especially during dry months, the water level in streams can decrease, making them especially susceptible to temperature fluctuations and warming.

Resulting rise in DO can harm aquatic life in these water bodies

⑤ When water is used for industrial cooling processes and then discharged back into a stream, its temp. is often higher than the water in the stream, resulting in warming of the stream and a decrease in its DO.

Concept of BOD: Biochemical Oxygen Demand.

BOD is known to be the standard amount of oxygen needed for degradation by microorganism.

or

BOD

Amount of DO needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample.

⇒ BOD value is most commonly expressed in milligrams of oxygen consumed per litre of sample during 5 days of incubation at 20°C and is often used as a surrogate of the degree of organic pollution of water.

Sources of BOD:

Sources of BOD include leaves and woody debris, dead plants and animals, animal manure, effluents from pulp and paper mills, wastewater treatment plants, feedlots, and food-processing plants, and urban storm water runoff.

⇒ Higher BOD indicates more oxygen is required, signifying lower water quality.

⇒ Low BOD means less oxygen is being removed from water, so the water is usually more pure.

⇒ Nitrates and phosphates in a body of water can contribute to high BOD levels.

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Nitrates and phosphates are plant nutrients and can cause plant life and algae to grow quickly.
When plants grow quickly, they also die quickly.
This contributes to the organic waste in the water, which is then decomposed by bacteria resulting in a high BOD level.

Is Biochemical oxygen demand different from Biological oxygen demand ... ??

Biochemical oxygen demand measures the molecular oxygen utilized for the biochemical degradation of organic material (carbon aerous demand) and .... the oxygen used to oxidize inorganic material such as sulfides and ferrous ion.

It also may measure the amount of oxygen used to oxidize reduce forms of nitrogen. (nitrogenous demand).
Biological oxygen demand only addresses the oxygen used by the bacteria to degrade organic substances.

Items	BOD standards (mg/L)
Most pristine rivers	→ <1
Moderately polluted rivers	→ 2-8
Ordinary domestic sewage	→ 150-200
Municipal sewage efficiently treated	→ <20

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- Any effluent to be discharged into natural bodies of water should have BOD less than 30 mg/L.
- Drinking water usually has a BOD of less than 1 mg/L.
- But when BOD value reaches 5 mg/L, the water is doubtful in purity.

BOD level (in ppm)	Water quality
1-2	Very good: There will not be much organic waste present in the water supply.
3-5	Fair: Moderately clean
6-9	Poor: somewhat polluted. Indicates organic matter is present and bacteria are decomposing this waste
100 or greater	Very poor: very polluted. Contains organic waste

Factors affecting BOD.....

Temperature:

→ Elevated temp. loses the level of DO of water harming aquatic organisms like fish, amphibians and other.

→ High temperature limits oxygen dispersion into deeper waters, contributing to anaerobic conditions.

→ This can lead to feed bacterial levels when there is ample food supply.

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→ Higher water temperature Yes plant growth rates.
→ This results in a shorter lifespan and species overpopulation causing an "algae bloom" which reduces oxygen levels.

Eutrophication :

- Eutrophication occurs due to oversupply of nutrients, which causes explosive growth of plants and algae.
- When such organisms die, consume the oxygen in the body of water, thereby creating the state of hypoxia.
- Phosphate adheres tightly to soil, so it is mainly transported by erosion.

Environmental significance :⇒

→ BOD measures the amount of oxygen utilized by microorganisms for the process of decomposition of the organic matters in the water bodies.
→ It symbolizes the amount of organic pollution present in an aquatic ecosystem.
→ Also regulates the chemical oxidation of inorganic matter.
→ Determines the amount of organic matter present in soils, sewages, sediment, garbage, sludge etc.
→ Detects the rate of respiration in living beings.
→ A High Blood Oxygen Demand level means the amt of dissolved oxygen available for other marine organisms such as fish is low.

COD

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Concept of COD :

COD is the total amount of oxygen required to chemically oxidize the bio degradable and non-biodegradable organic matter.

* Always ↑er than the BOD value.

COD values were very much lower than that of 5th day BOD.

It indicated that potassium permanganate was not very effective in oxidizing all the organic matter present.

After that other oxidizing agents like ceric sulphate, potassium iodate and potassium di-chromate were also used.

Potassium di chromate was found to be most effective due to completely oxidize all organic matter - Relatively cheap - Easy to purify.

Advantages :

→ COD result are available much sooner than BOD test results.

→ COD test requires fewer manipulations of the sample.

→ COD test oxidizes a coide range of chemical compounds.

→ It can be standardize more easily

Disadvantages :

→ Major disadvantage is that the results are not directly applicable to 5-day BOD results without correlation studies

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over a long period of time.

→ One more limitation of COD is it's inability to differentiate b/w biologically oxidizable and biologically inert organic matter.

Coagulation: (Rapid-mix stage)

- Coagulation is a process of aggregation or accumulation of colloidal particles to settle down as precipitate.
- Subs. like metals, their sulphides etc cannot be simply mixed with the dispersion medium to form a colloidal solution.
- Charges present on the colloidal sols determines their stability.
- Coagulant chemicals with charges opposite those of the suspended solids are added to the water to neutralize the negative charges on non-settlable solids (such as clay and color-producing organic substances).
- Once the charge is neutralised, the small suspended particles are capable of sticking together.

→ Slightly larger particles are called microflocs and are not visible to the naked eye.

→ Water surrounding the newly formed microflocs should be clear.

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If not, coagulation, and some of the particles charge have not been neutralized. More coagulant chemicals may need to be added.

- A high-energy, rapid mix to properly disperse coagulant and promote particle collisions is needed to achieve good coagulation.
  → Over-mixing does not affect coagulation, but insufficient mixing will leave this step incomplete.
  → Contact time in the rapid-mix chamber is typically 1 to 3 minutes.

Flocculation: (slow-mix stage)

- Flocculation, a gentle mixing stage, uses the particles size from submicroscopic microfloc to visible suspended particles.
- Microfloc particles collide, causing them to bond to produce larger, visible flocs called pinflocs.
- Floc size continues to build with additional collisions and interaction with added inorganic polymers or organic polymers.
- Macroflocs are formed and high-molecular weight polymers, called coagulant aids, may be added to help bridge, bind and strengthen the floc, add weight, and increase setting rate.
- Once floc has reached it optimum size and strength, water is ready for sedimentation.

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- Design contact times for flocculation range from 15 or 20 min to an hour or more, an flocculation requires careful attention to the mixing velocity and amount of mix energy.
- To prevent floc from tearing apart or shearing, the mixing velocity and energy are usually tapered off as the size of floc rises.
  → Once floc are torn apart, it is difficult to get them to reform to their optimum size and strength.
  → The amount of operator control available in flocculation is highly dependent upon the type and design of the equipment.

- Once flocs are torn apard, it is difficult to get them to reform to their optimum size and strength.

- Conventional plants separate coagulation stage from flocculation stage. These stages are followed by sedimentation, and then filtration.
  → Conventional plants can have adjustable mixing speeds in both the rapid-mix & slow mix equipments.
  → Conventional plants have conservative retention times and rise rates. This usually results in requirements for large process basins and a large amount of land for the plant site.

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① Coagulants → Influent → Rapid mix 30 sec - 2 min Detention → Flocculation 20-45 min → Sedimentation 1-4 hrs → Filtration

② Lime → Influent → Rapid Mix 30 sec - 2 min Detention → Flocculation 20 - 45 min → Sedimentation 1 - 4 hrs → Filtration

pH range 9 - 10

Or alternate solid removal process

③ Lime → Influent → Flocculator clarifier → Recarbonation → Flocculator clarifier → Recarbonation → Filtration → Softened water

pH range 10 - 12

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Retention: (Detention) Retention time is the amount of time that water spends in a process.

Retention Time = $\frac{\text{Liquid volume of a basin (in gallons)}}{\text{Plant flow rate (gallons per min.)}}$

Sedimentation: (clarification)
It is the process of letting suspended material settle by gravity.

- Suspended materials may be particles, such as clay or silts, originally present in the source water.
- Suspended material or floc is typically created from materials in the water and chemicals used in coagulation or, in other treatment process such as lime softening.

Factors affecting sedimentation process :=>

1. Particle size :- The size and type of particles to be removed have a significant effect on the operation of the sedimentation tank.
   → Sand and silt can be removed very easily because of their density.
   → The velocity of the water-flow channel can be slowed to less than one foot

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per second and most of the sand and silt will be removed by simple gravitational forces.

→ In contrast, colloidal material (small particles that stay in suspension and make the water seem cloudy) will not settle until the material is coagulated and flocculated by adding a chemical, such as iron salt or aluminium sulfate.

② Water Temperature :⇒.
When water temp. ↓ses, the rate of settling becomes slower.
Result : As the water cools, detention time in the sedimentation tank must ↑se and the operators must make changes to the coagulant dosage to compensate for the decreased settling rate.

→ A water treatment plant has the highest flow demand in the summer when the temp. are highest and settling rates are the best.
⊙ When water is colder, the flow in the plant is at its lowest and, in most cases, detention time in the plant is ↑sed so floc has time to settle in the basins.

18 ×4 = 72 + 5 = 77

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(3) Currents :

→ Density currents are caused by the weight of solids, the conc. of solids and the temperature of the water.

→ Eddy currents are produced by the velocity and flow of the water coming into the basin and leaving the basin

→ Currents also tend to distribute floc unevenly throughout the basin, as a result, do settle at an even rate.