CE102:-

Page No.:
Date:

7/1/19

ENVIRONMENTAL ISSUES

- Explosion of Environmental, Scale:
  Issues

Spatial scales:-

Micro :- (10-100m), Middle (100-500m) } Local
Neighbourhood (500m-4km) }
Urban (4-100-1000km)
Continental (1000-10,000 km)
Global (>10,000 km)

- History of environmental contamination:-

1900:- Local epidemics attributed to bacterial siege.

- Typhoid:- Salmonella typhi
  Cholera:- Vibrio cholerae

- Apart from this, untreated sewage waste, organic carbon waste dumped into water also caused huge problem in the form of oxygen depletion in aquatic bodies.

Regulatory action:- Research in chemistry and microbiology contributed to sanitary engineering, leading to

- U.S.-Canada boundary waters treaty (1909)
- Local sewerage and sanitary regulations regarding organic waste disposal.

1950's :- Contamination and environmental issues arise at the regional scale

- Nitrogeneous and phosphorus based nutrients disposed in water, at suitably warm temperature forms algae. Unregulated disposal caused eutrophication due to algal blooms. This lead to death of aquatic life due to blockage of sunlight

- Also, toxic waters were observed due to formation of blue-green algae (cyanobacteria).

- Accidental spills, especially such as oil, again lead to aquatic pollution.

- Construction of dams and reservoirs to divert water between various basins lead to depletion of biodiversity.

- Release of industrial effluents such as heavy metal contamination (Arsenic, lead) lead to chronic disease exposure in humans also.

Scientific response - Study of limnology: study of all abiotic components present in water that have an effect on the biotic components in water
Consists of hydrobiology (phytoplankton, zooplankton, fish), chemistry and hydrology

Regulatory action - The great lakes water quality agreement (1972 and 1978)

Great lakes:-
Superior, Michigan, Huron, Erie and Ontario.

- Tertiary sewage treatment to take care of nutrients such as N and P.

- Phosphorus ban in detergents (sodium phosphate).
very essential component.

1970's :- Study at continental scale

- Acid rain formation:- NO_x and SO_x pollutants dispersed from factories into air, dissolved into water in the form of rain and pH of rain water went down affecting quality of soil drastically.

NO_x :- $NO + NO_2$, mostly released as NO, but largely converted to NO_2.

SO_x :- any sulphur oxide.
Apart from this, heavy metal oxides also dissolve in water (rain).

- Chernobyl nuclear disaster (1986):- Huge release of radioactive debris drifted through air even into other countries, leading to biological deformities and birth defects.

- Formation of exotic species:- Migration of locally large species into other areas following environmental degradation lead to minority species formation.

Soil and water pollution lead only to local and regional effects, but air pollution leads to widespread (continental) effect.

Scientific response:- Ecotoxicology,
Broadening of Environmental science:-
Limnology with ecotoxicology, economics, sociology, political science, meteorology (weather), medicine.

Regulatory action:-

- Zero discharge:- Concept of recycling and reusing, thus preventing any discharge of any kind of waste into the environment.

- Rio convention (1992):- Convention on biological diversity. The term biodiversity was coined. All the nations agreed to preserve the existing biodiversity either in the same area (in situ) or ex situ (by taking to another location).

- Montreal convention (1999):- Addressing the question of transporting and handling hazardous waste.

- SO_2 emission control target was set especially in thermal power plants, as they were the largest emitters by burning coal (10% is SO_2 emission of 100% coal).

- Conception of Sustainable development - Term coined by G.H. Brundtland in his report. Development by judicial usage of existing resources such that needs of present are met without compromising on needs of future.

Extent of impact :- Global level

- Generation of uncontrolled municipal solid waste and its unscientific disposal.

- Urban sprawl :- Haphazard growth of population in the outskirts of cities.

- Genetic defects.
- Population explosion leading to fast depletion of natural resources.
- Water shortage due to rapid industrial usage and consequent wastage.
- Ozone layer depletion due to CFC (Chloro fluoro carbons) released from various man made devices such as refrigerators.
- Global warming :- Rise in temperature due to thermal capture by greenhouse gases such as CO_2, methane, water vapour
- Depletion of fish stock and loss of biodiversity.

Regulatory action includes same procedures as that of continental level.

The environment is a continuum of systems involving similar processes in the temporal and spatial scale. Temporal is the micro scale and spatial is the macro, mega and global scales. thus, any change in micro scale is reflected onto the other scales as well.

ENVIRONMENTAL SYSTEMS:-

- Natural environmental system:- We are concerned with understanding and describing natural processes in already existing natural systems.

- Engineered systems:- Based on our understanding of natural systems, we try to replicate the process at an artificial system. Eg:- water treatment plant, sewage treatment plant, greenhouse, etc.

The change we are concerned with may be physical, chemical or biological in nature. These changes are always associated with transformations in mass.

Input mass $\quad A+B \rightleftharpoons C+D \quad$ output mass

transformation in mass

Studying the mass change is part of natural system, trying to recreate the change is part of an engineered system.

Natural systems are irregular because the conditions governing them are haphazardly natural.

Engineered systems are regular because they are artificially controlled.

Yet, the underlying principles are same though the objective and expected outcome maybe different.

The character of a system is distinguished on the basis of its scale. Character means the properties of a system and the nature of properties and changes that occur in it.

Scale indicates the spatial and time scale over which the system is spread.

- In a generalized multiphase system consisting of solid, liquid and gas, the changes in the system are due to changes in the individual levels (solid, liquid, gas), mass transfer across various phases and accumulation/depletion of mass in the phase interfaces.

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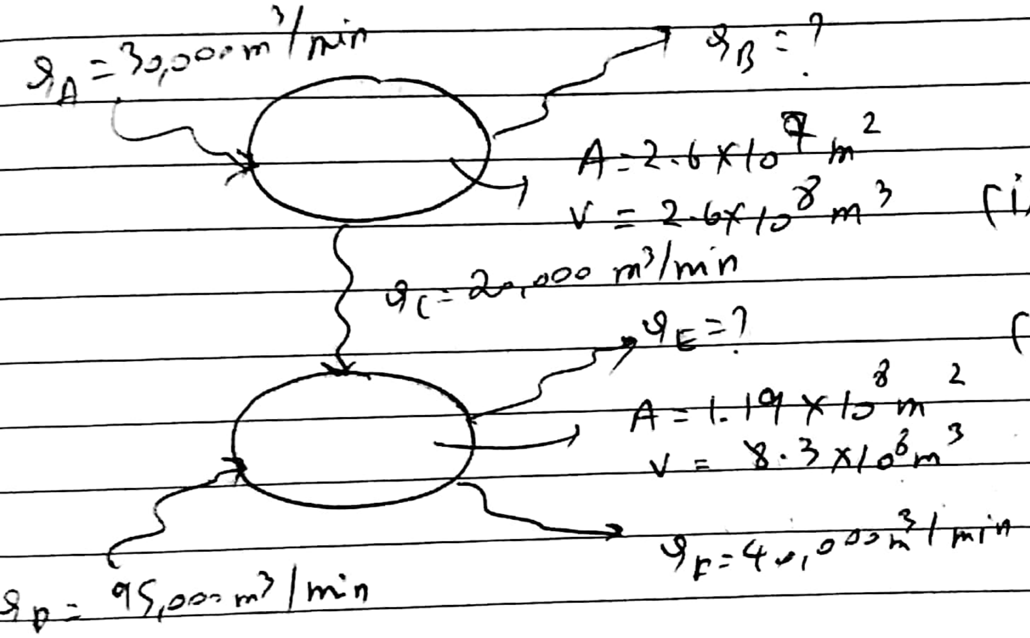

(i) $r_{ev} = 0.005\ m/day$

(ii) $(Cl^-)_A = 40\ mg/L$

$(Cl^-)_B = 60\ mg/L$

along with evaporation

(a) In the simple case, when even evaporation is not taking place, $q_B = 30{,}000 - 20{,}000 = \underline{10{,}000}\ m^3/min$

and $q_E = 115{,}000 - 40{,}000 = \underline{75{,}000}\ m^3/min$

(b) Evaporation is just another outflow of water, hence,

$$q_B = 30{,}000 - 20{,}000 - \frac{0.005}{1440}\ m/min \times 2.6 \times 10^7\ m^2$$

$$q_E = 20{,}000 + 95{,}000 - 40{,}000 - \frac{0.005}{1440}\ m/min \times 1.19 \times 10^8\ m^2$$

Hydrological retention time (or) retention time (or) detention time (in units of time)

$$= \frac{\text{Volume } (V)\,(L^3)}{\text{flow rate } (Q)\,(L^3/T)}$$

This is the average time for which a water particle remains in a given natural or engineered environmental system.

One must always remember that while superimposing the concepts of natural systems in order to create engineered systems, the nature must not be harmed.

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ECOLOGY AND SUSTAINABLE DEVELOPMENT

The term ecology was coined by the german biologist Ernst Haeckel in 1869.

Ecology
- Oikos : Home
- logos : Study

Meaning, study of biotic components and their interaction with abiotic components in their natural habitats.

Tansley in 1935 coined the term ecosystem, meaning the structural and functional unit of the biosphere, comprising biotic and abiotic factors and their interaction (exchange of mass and energy). It can also be called a self-regulating system of biotic components.

Individual → Population → Community → Ecosystem → Biome → Biosphere.

Ecosystems exhibiting similar charactesistics because of similar climatic conditions, together form a biome. So, deserts, tundra (plant systems growing in very cold climatic conditions), etc. are all biomes.

Types of ecosystem

1) Nature
   - → Natural
   - → Artificial or engineered

2) Size
   - → Large
   - → Small

3) Duration
   - → Permanent
   - → temporary

Natural ecosystems are permanent, whereas, artificial systems are engineered.

Natural ecosystem
- Aquatic
  - Marine (saline)
    - Oceans
    - Seas (partially surrounded by landmass, hence generally smaller than oceans).
  - Freshwater
    - Lentic (stagnant water)
    - Lotic (running watter)
- Terrestrial

• Basic characteristics of ecosystems:-

Structure of ecosystem

→ Biotic
→ Abiotic

Biotic
→ Producers
→ Consumers

Producers
↓
Photoautotrophs (plants)
and
chemoautotrophs
(from chemical reaction)
↳ sulphur bacteria produces glucose $C_6H_{12}O_6$ from dissolved CO_2, water and heat evolved from under the sea bed.)

Photo → light
auto → self
troph → food

Consumers
→ Herbivores
→ Carnivores
→ Omnivores

Herbivores
• (plant eaters, thrive on plants) primary consumer.

Carnivores
• Those thriving on other herbivores are called secondary consumers
• Those thriving on other carnivores are called tertiary consumers

Omnivores
• Can thrive on both plants and carnivores.

→ Detritivores or Saprotrophs (Scavengers):- Thrive on the dead meat or excreta of other organisms. Eg. earthworm, vulture.

→ Decomposers:- Convert complex dead organic matter (meat or excreta) and breaks them down into simple inorganic

matter. eg. microorganisms.
Detritivores consume the matter for themselves, while decomposers release it into the environment.

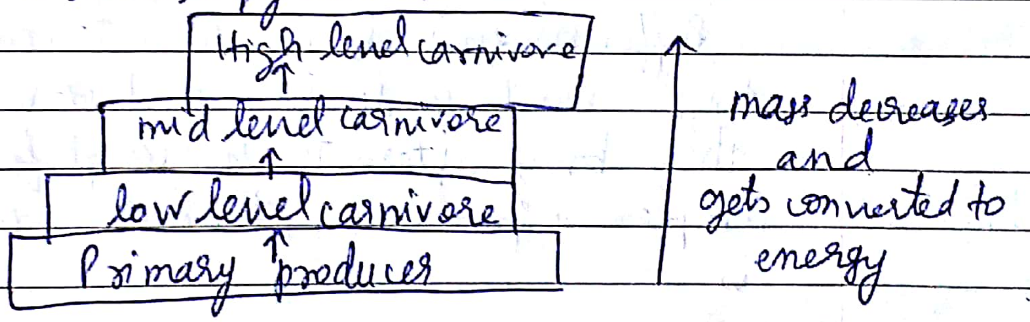
Abiotic

Physical
Climatic factors
such as rain, precipitation, temperature, water flow, etc.

Chemical
Organic and inorganic nutrients.

• The purpose of an ecosystem is the cycling of chemical elements (mass flow) and cycling of energy (energy flow).

For eg., in a biomass pyramid,



• A simple ecosystem community will have atleast one species which is a producer, atleast one that is a decomposer and any fluid medium. A consumer is not necessary.
(producer → produces sugar from $CO_2 + H_2O$, and then other compounds from sugar + organic compounds.)

• Trophic structure or level:- Refers to how the producers, consumers and decomposers are placed in the mass-energy flow along with their respective population.

Food chain :-

- Linkage of who feeds on whom.
- The sequence of eating and being eaten in an ecosystem is known as food chain. Energy, chemicals and some compounds are transferred from organism to organism.

. Biomagnification :- The accumulation or increase in concentration of pollutants as we move above in the food chain, through the trophic levels, is called bio-magnification. Since humans are in the highest trophic level, we are affected the most. The rise in concentration depends on mass of the trophic level.
Eg :- Chromium pollutant in tanery (leather) industry, pestiudes (such as DDT → banned).

Food web :-

Different food chains are interconnected at various trophic levels to develop a food web. There are never straight. These bring alternate sources of food. Thus, more complex a food web is, the more sustainable the ecosystem is.

Mass flow (nutrient flow) is a cyclic flow, human matter is also decomposed as plant manure, but energy flow is unidirectional, only autotrophs give us energy, we cannot give them energy in a direct form. Only they have ability to harness natural energy.

Ecological Pyramid :- Graphical representation of trophic structure with producers at the base and consumers forming successive apex of the pyramid. They are of three types, Number, biomass and energy.

Page No.:
Date:

A pond or lake ecosystem has an inverted ecosystem, meaning that the no. of large and medium size fishes are huge, followed by small fishes, then insects and finally, producers are least in number.

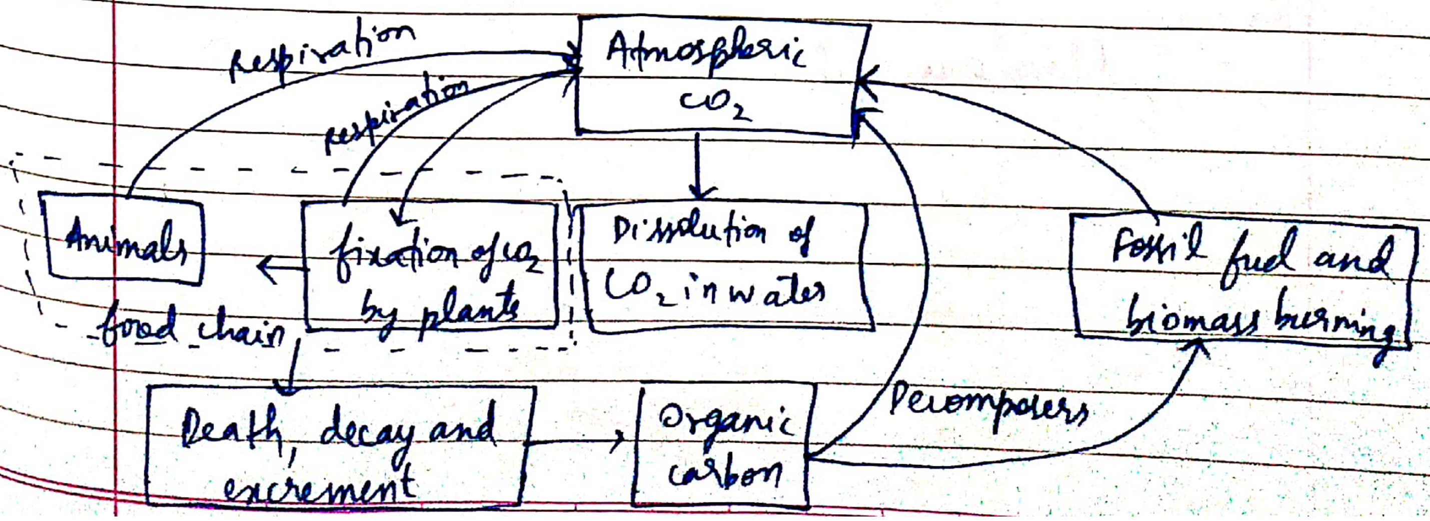
Pyramid of energy can never be inverted, as only producers have the ability to harness sunlight to produce food.

- The energy cycle in nature follows the first and second laws of thermodynamics, as in, energy can neither be created nor destroyed and energy is always dissipated as it is consumed.
  - Energy enters either through transfer by abiotic material or produced by biotic matter.

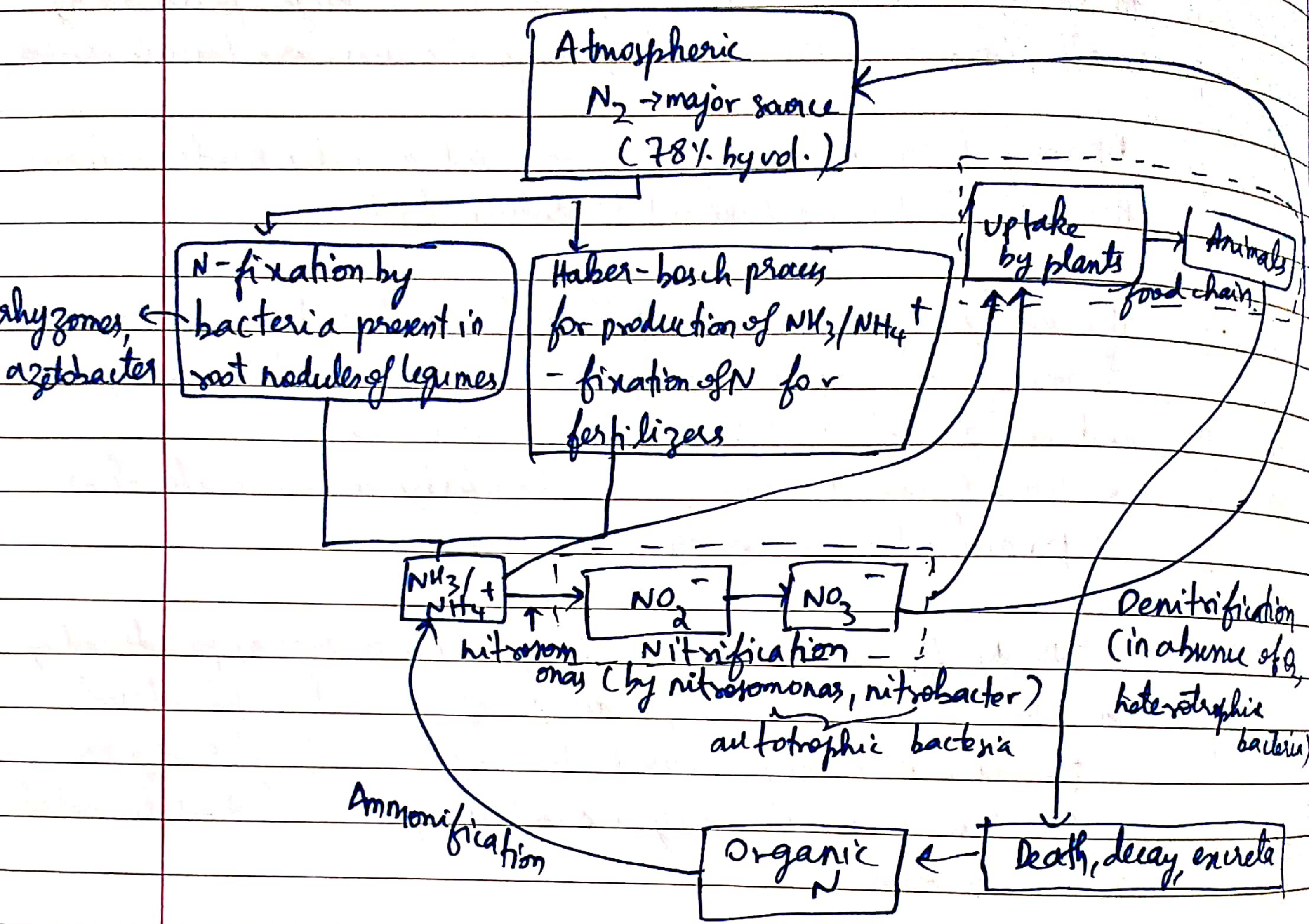
Energy efficiency / transfer efficiency = Ratio of energy produced by one trophic level to the production of the next trophic level. It is usually only around 1-3% for a natural ecosystem. Maximum is usually only around 10%, 90% is lost as dissipated to the environment.

- Bio-geo-chemical cycles:-
  - Carbon cycle:-

Atmospheric CO_2 serves as the major source of carbon on the earth.



- Nitrogen cycle:-

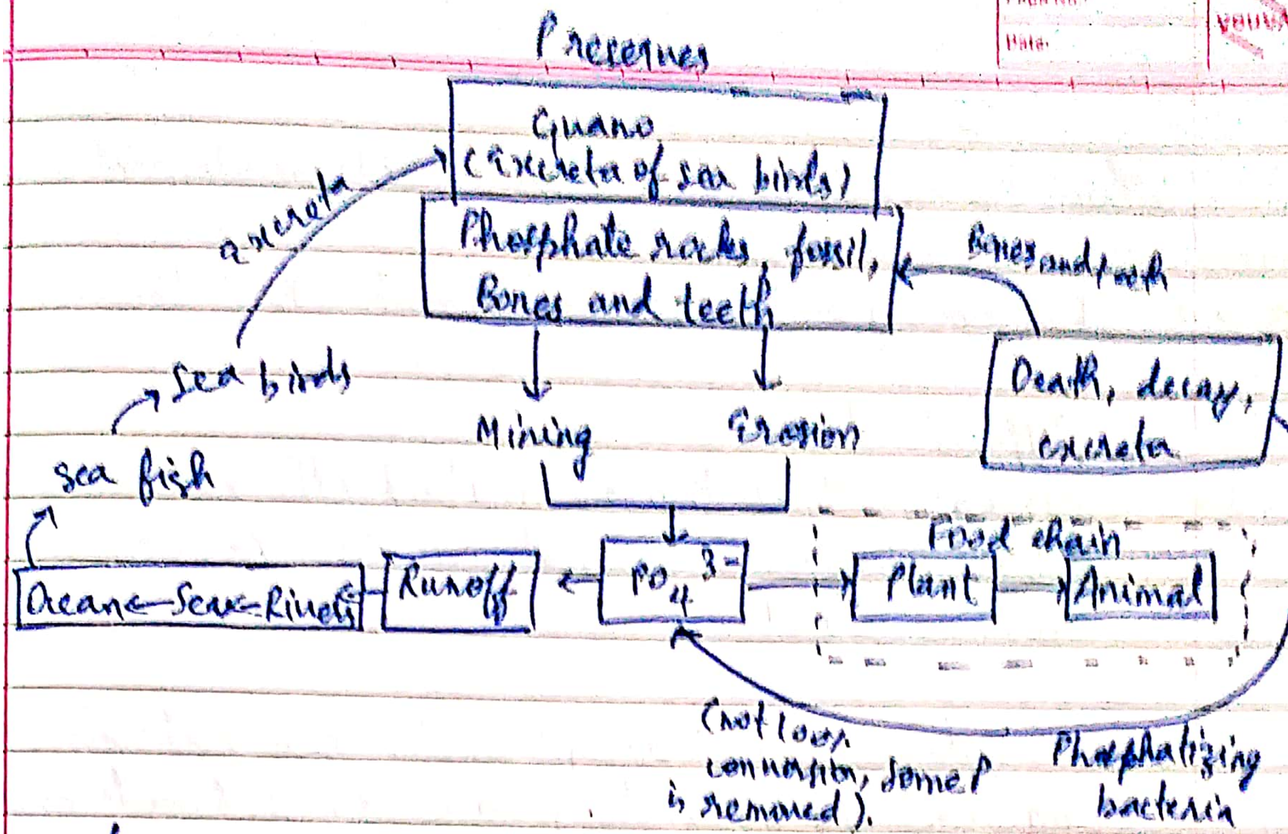


NO_2, NO_3 are pollutants, hence though they are produced in the cycle, we do not talk about their presence in the cycle.

Both carbon and nitrogen have gaseous end products.

- Phosphorus cycle:-

Scanned by CamScanner



There is no gaseous end product here, unlike C and N cycle. So, it becomes difficult to remove P from water. It can only be removed by assimilation by the phosphatizing bacteria.

Biodiversity:. Means variation and the variety coming with it. They can largely be categorized as genetic, species and ecosystem biodiversity.

India is one of the 18 megadiversity countries, other few being Brazil, Australia, etc. We have 47,000 (7% global) plant species and (81,000) (6.5% global) animal species.
Extinction of biodiversity is a natural process of evolution, but this has been aggravated by artificial interferance by man, largely attributed to the HIPPO model.

H - Habitat destruction
I - Invasive species
P - Pollution
P - Human population increase
O - Overharvesting

and apart from this, poaching and man-wildlife conflicts.

Thus, the need of the hour is sustainable development.

Economic growth v/s Environmental Protection:-

- Types of industries:-
  - Primary:- Those that are involved in the extraction of natural resources or raw materials. Eg:- Agricultural, Mining, Oil and gas, etc.
  - Secondary:- Those that process the raw materials in manufacturing plants to produce finished goods and sell those in the market. Eg:- Tanery, Rubber, etc.
  - Tertiary:- They offer any kind of services which may be useful for mankind. Eg:- Telecom, transportation, etc.
  - Quarternary:- They sell or process ideas rather than physical goods itself. eg:- IT industry, data processing services etc.

- Indicators of economic development / growth.

evelopment

Human development index (Poverty rates, illiteracy rates, sanitary conditions, standard of living, etc.)

Economic development

growth
- GDP
- G national P
- Per capita income

Other parameter
Should we have a GEP?
(Gross environmental product)

- In a recent survey, it was reported that around 55% of the population either wanted to prioritize economic growth over environmental protection or simply didn't care about the issue.

- United Nations Millennium development goals - Linking economic development goals to environment protection.

Goals :- (8 goals)
- Eradicate extreme poverty and hunger
-

These goals were supposed to be achieved by 2015, yet it was not completely productive at the end of its term, so UN general assembly proposed and accepted a refined set of 17 goals. The eradication / implementation of issues is still in progress.

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WATER RESOURCES

The entire globe is currently facing the burning issue of water shortage. In India, Bangalore is predicted to be the first city to face acute water shortage.

Main problem arises when the natural hydrological cycle is disturbed by human interaction. It usually involves us deliberately changing the residence time or retention time of water in its various physical forms.
As a result, various metro cities, which were previously recieving scattered rainfall, now recieve huge rainfall in short durations, leading to floods, etc.

97% as water, 2% as ice and 0.001% in atmosphere.
(composition of water in various forms).

99% of all water on earth is unuseable as it is very saline as it is unfit for human / plant consumption.
So, water is the most used and abused resource on our planet.

Hydrology is the science that deals with depletion and replenishment of water resources, both surface and sub-surface waters, including their spatial and temporal characteristics.

Hydrological cycle:-

Thus, water is neither created, nor destroyed. We can also see that distribution of water in the cycle is very uneven. The split is more in the oceans and lakes and comparitively less in the snow caps and groundwater flow. Anthropogenic activities (artificial, nature destructing) changes the residual time of water.
As an eg., the flow of water from oceans and streams into land is called flooding. It is not a part of the cycle itself, but a result of anthropogenic activities.

- Only 2.5% is consumable freshwater, of which 74% are locked away in ice caps in polar regions. 25.6% is the groundwater resource and 0.4% is in lakes and rivers. It is possible to treat surface water easily, but if groundwater is polluted, it becomes very difficult.

- Components of the Hydrological cycle:-

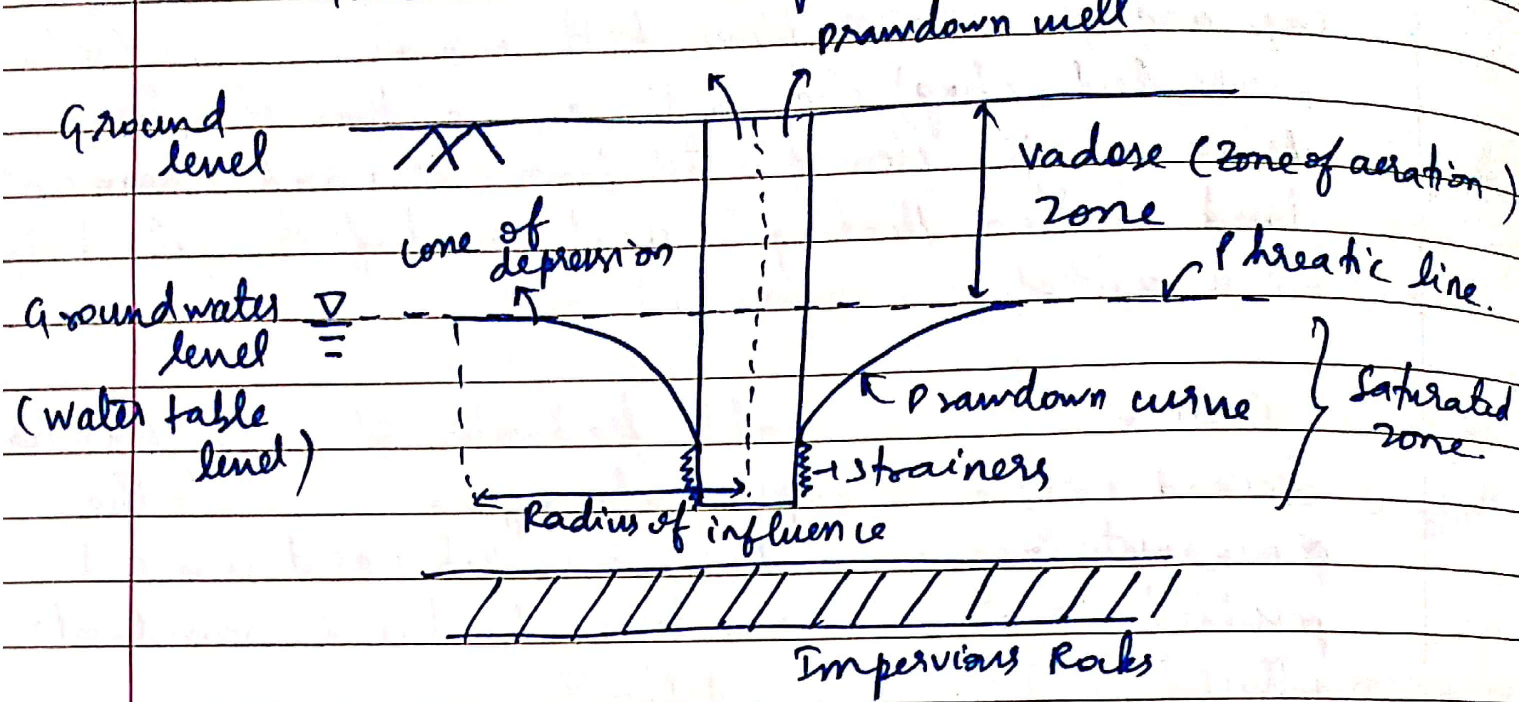
  - Precipitation
  - Runoff — surface / sub-surface waters
  - Storage — Groundwater
  - Evapotranspiration.

- Common forms of precipitation:-
  - Drizzle or mist (droplet diameter is < 0.5 mm)
  - Rain (droplet size lies between 0.5 mm and 6 mm)
  - Snow (ice crystals with specific gravity of about 0.1)
  - Sleet (frozen rain drops falling at below freezing temp.)
  - Hail (ice balls of diameter > 8 mm)

Most precipitation is in the form of rain.
light rainfall :- intensity - 2.5 mm/hr
moderate rainfall:- 2.5 to 7.5 mm/hr

Heavy rainfall :- > 7.5mm / hr.

- Groundwater and surface water :-



Phreatic line or the groundwater level is the level till which atmospheric pressure can be experienced though it is below ground level.

The water till the phreatic line is just the water that has seeped to below the surface, it is only mixed with air bubbles. But water below the phreatic line is mixed with soil and physical minerals (Saturated zone). Strainers are attached below the drawdown well in order to filter off the soil particles. Due to the digging of the drawdown well, the water level below the phreatic line takes a conical shape (cone of depression).

This is an unconfined aquifer, if there is an additional level of impervious rocks above the already existing layer and if water exists between these two rock systems, it is called confined aquifer.

Recharge of groundwater:-

- By effluent streams:- Flows all round the year and recharges groundwater by sub surface runoff. Many a times it exists below the groundwater table. Particularly useful in the dry seasons.
- By influent (ephemeral) streams:- Helps to recharge the groundwater only when there is heavy precipitation. Exists completely above the groundwater table line. Its ability to recharge depends completely on the precipitation only.

· Effluent stream also acts a discharging zone. Meaning, when the effluent stream water level goes down, water from the groundwater moves out to refill it. That is why effluent streams rarely dry up.

Groundwater $\rightleftharpoons$ Effluent streams. But,

Influent streams $\longrightarrow$ Ground water

Usage of water:-

Offstream use	Instream use
- Water is removed from its source for usage - Usually returns back to the hydrological cycle, but consumptive use water does not return back to the source, eg. evapotranspiration, industrial use, etc.	- Water is used in its source itself, it is not removed from source. - Eg:- Navigation, hydroelectric power, recreation, etc.

Strategies for water conservation:-

- Reuse of wastewater (ie, Non potable and Non human contact use water).

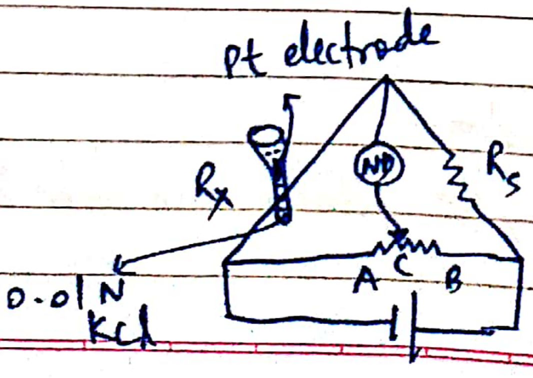
- Develop surface water resources and use groundwater in dry years.
- Use excess surface waters during wet season to recharge groundwater effectively.

Water quality :-

Water quality parameters

Physical	Chemical	Microbiological
- Temperature	- pH	- Coliform (total and fecal)
- Conductivity	- alkalinity	
- Colour	- Hardness	
- Solids	- Dissolved oxygen	
- Turbidity	- Chemical oxygen demand	
	- Biological oxygen demand	
	- Total organic carbon	
	- Nitrogen	
	- Phosphorus	
	- Cations, including heavy metals	
	- Anions	

- Electrical conductivity :-
  Helps to measure the amount of dissolved solids (in form of ions) in given sample. More the dissolved solids, more unpleasant is the taste and hence unfit for drinking.



This is a wheatstone bridge conductivity cell, thus,

$$\frac{R_X}{R_{AC}} = \frac{R_S}{R_{BC}} \quad (\text{when } i \text{ through ND} = 0)$$

We use 0.01N KCl to calibrate the conductivity cell. How is this done?

$$\frac{R_x}{R_{AC}} = \frac{R_S}{R_{BC}} \quad ; \quad R_x = \frac{\rho l}{A} \quad (\rho \to \text{ohm-cm})$$

$$K = \frac{1}{\rho} \text{ (specific conductance)} \quad K \to \text{mho cm}^{-1} = 1S$$

By doing this process, we calculate K_S (K of KCl (0.01N))

as = 0.001412 S.

We define calibration constant $C = K_{std} R_{std}$, it is constant for a given cell, now, $K_{\text{any water sample}}$ can be determined as

$$K_{water} = \frac{C}{R_{water}}$$

Std → standard sample taken in test tube.

(R_{water} is measured through wheatstone bridge concept)

Solids:-

Those matter that remain as residue upon evaporation or at a temperature range of 103° to 105°C, because at this temperature water completely becomes vapour, what does not become vapour at this point is called solids.

Total solids

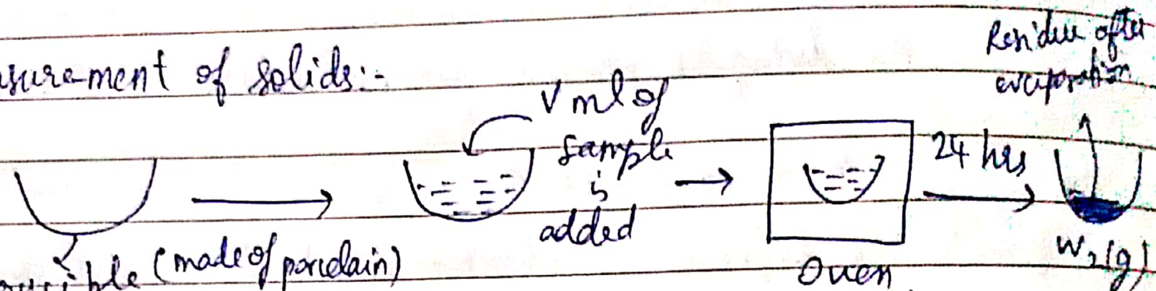
- Total suspended solids (TSS) (size ≥ 0.2 μm)
  - Volatile suspended solids (VSS) (organic source) (microbial suspended biomass)
  - Fixed suspended solids (FSS) (inorganic sources) (Sand)
- Total dissolved solids (TDS) (size ≤ 0.2 μm)
  - Volatile (VDS) (glucose)
  - Fixed (FDS) (NaCl, KCl)

VSS FSS VDS FDS

Total volatile solids (TVS) Total fixed solids (TFS)

Total solids (TS)

Measurement of solids:-

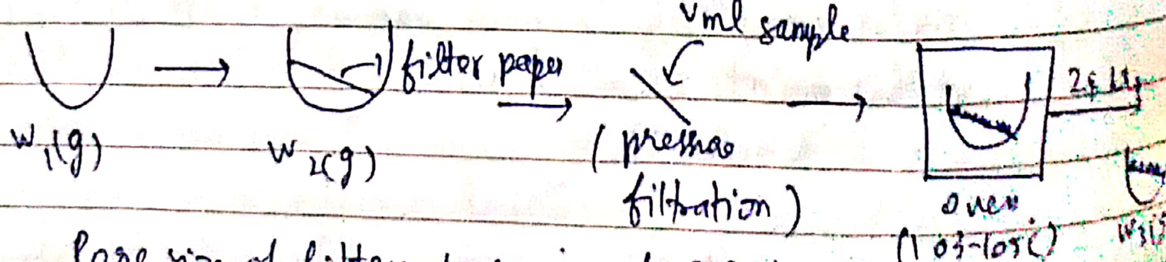


crucible (made of porcelain)
W_1(g) → weight of the crucible
(103–105°C)

$$\Rightarrow TS = \frac{W_2 - W_1}{V} \, g/mL$$; convert it to (mg/L), as it is the standard unit of expression.

(This is called gravimetric method).

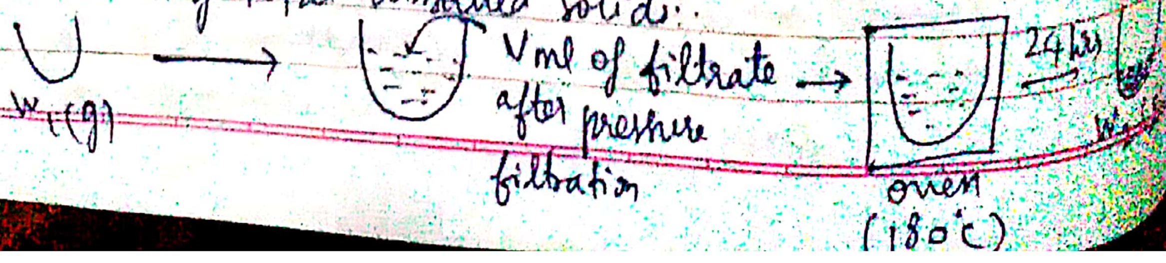
Measurement of total suspended solids:-



Pore size of filter paper is slightly less than 2 μm.

$$\Rightarrow TSS = \frac{W_3 - W_2}{V} \, g/mL \text{ (or mg/L)}$$

Measurement of total dissolved solids:-



⇒ $TDS = \frac{W_2 - W_1}{V}$ (g/mL or mg/L)

otherwise, we could also use, $TS = TDS + TSS$.

Here, we are heating at 180°C because dissolved solids are tightly interspersed with water, hence we need higher temperature.

Muffling :- Pyrolysis (thermal breakdown) of the given sample. (To separate volatile and fixed components).

⇒ Upon muffling in a muffle furnace,

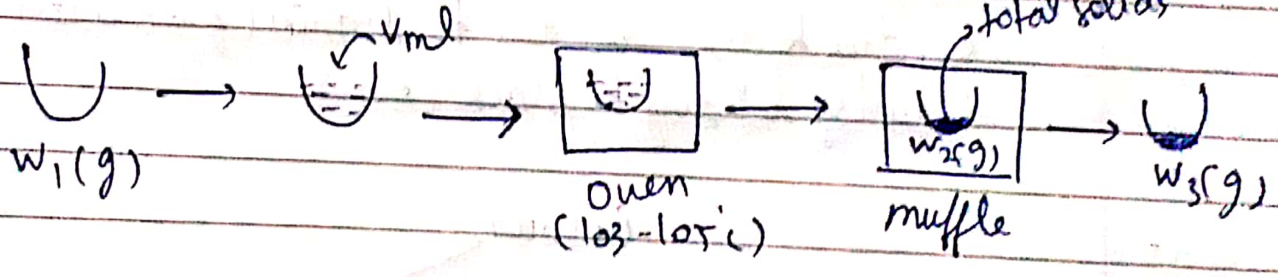
$$C_x(H_2O)_y \xrightarrow{550°C\ (1hr)\ \text{or}\ 600°C\ (15\ mins)} xC + yH_2O$$

(volatile part in sample) usually organic

and

$$C + O_2 \xrightarrow{\Delta} CO_2(\uparrow)$$

⇒ left behind residue is the inorganic fixed (nonvolatile component).



⇒ $TFS = W_3 - W_1$

⇒ $\frac{W_2 - W_3}{V}$ (in g/mL or mg/L) will be TS−TFS = TVS.

Exceptions (giving erraneous results):

- $NH_4HCO_3 \xrightarrow{105°C} NH_3\uparrow + CO_2\uparrow + H_2O\uparrow$
- $MgCO_3 \xrightarrow{350°C} MgO + CO_2\uparrow$

} exception under the assumption that inorganic components do not have volatile part in them.

Colour of water:-

Natural water is colourless, but when it comes in contact with natural organic matter (NOMs) (eg. leaves, dead bodies of animals, etc.), during its runoff, it picks up a yellowish-brown colour.

NOMs are basically humic substances that impart -vely charged colloid particles to the natural water, leading to yellowish brown colour.

(humic → comes from humic acid, an acid which is bio-metabolized in organic sources.)

Domestic wastewater's colour is due to human waste.
Industrial wastewater's colour is usually due to specific chemicals, eg. due to dyes or due to lignin (from wood) in pulp industry leading to black colour.

Colour → True, Apparant

True (caused due to -vely charged colloid particles, very difficult to remove).

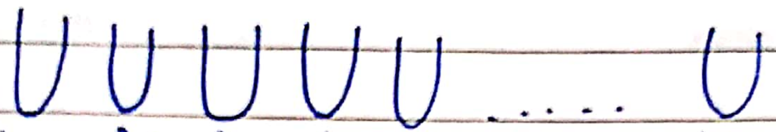
Apparant (caused due to suspended solids, can be easily removed through filtration.)

Unit of measurement of colour is mg Pt-Co/L (=1 mg of Pt-Co per litre).
We use Pt-Co mixture only, because, in most cases the colour of wastewater is yellowish brown. Pt-Co mixture in water also gives yellowish-brown colour. So it is used as a comparison standard.

1.246g of Potassium chloroplatinate (K_2PtCl_6)

\+

1.0 g $CoCl_2 \cdot 6H_2O$ $\longrightarrow$ 500ml distilled water (containing 100 ml HCl) $\xrightarrow{\text{distilled water}}$ 1000ml 500mg Pt-Co/L $\xrightarrow{\text{several dilutions}}$



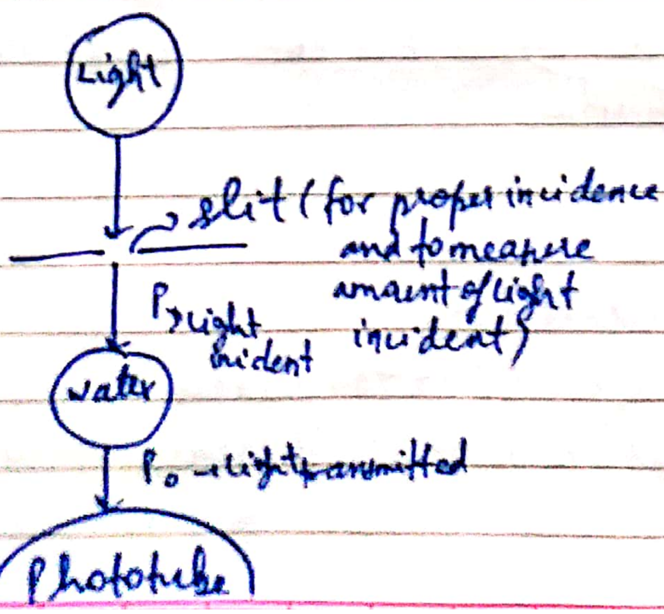
10 20 30 40 50 .... 100 mg Pt-Co/L

These are the visual standards that are used for comparison of colour of the waste water.

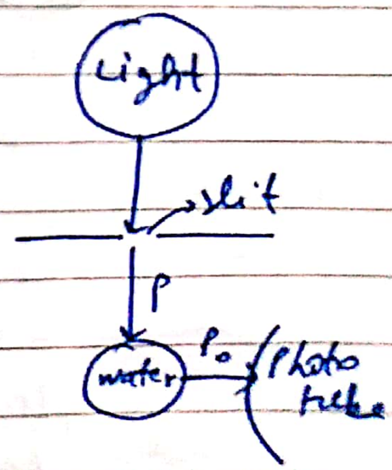
Turbidity:-

Many suspended impurities present in water cause scattering of light in a colloidal form, giving a turbid (non-transparent) appearance. It is not suitable for drinking as many pathogenic microorganisms can camoflage themselves in these impurities. Consuming it will cause water borne diseases.

Turbidimetry

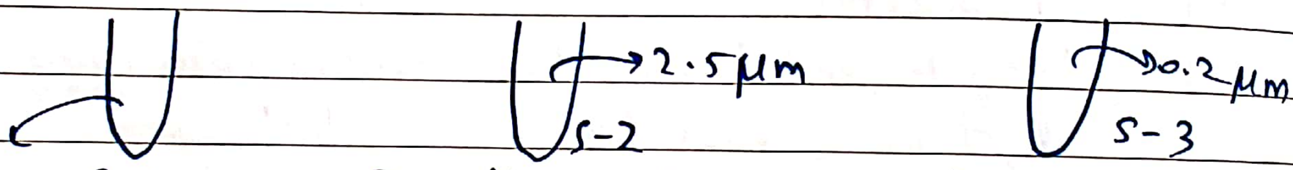


Nephelometry



The only difference between turbimetry and nephelometry is that the orientation of the phototube is different. In turbidimetry, we measure the light transmitted (P_0) and in nephelometry, we use it to measure light scattered.

Turbidimetry	Nephelometry
- More P_0/P ⇒ lesser turbidity.	- More P_0/P ⇒ more turbidity.
- Measured by JTU (Jackson turbidity unit)	- Measured by NTU (nephelometric turbidity unit)
- old method	- modern method.



3.5μm S-1
↳ particle size.

In all cases 100 mg/L of impurities.

2.5μm will show greatest turbidity because, 0.2μm is the size for dissolved solids, so it wont even scatter light. 3.5μm is too big, so as size increases, lesser light is scattered.
⇒ Size should be small, but above cutoff range for suspended impurities.

pH :-

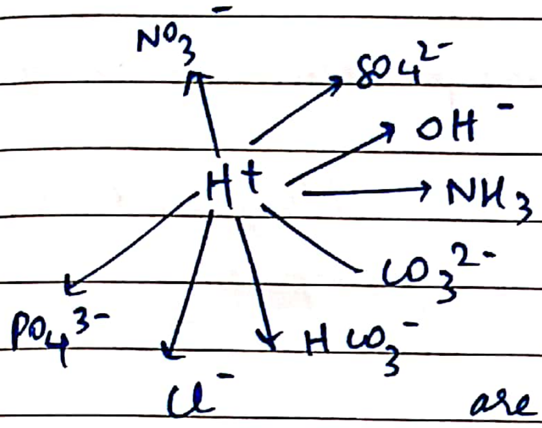
$-\log[H^+]$ is called pH.
The pH scale depends on temperature.
As temp. increases, neutral pH decreases. At 60°C, $pH_{neutral}$ = 6.5.

pH of distilled deionized water is slightly less than 7, because CO_2 from atmosphere dissolves to form H_2CO_3.

Alkalinity:-

can be defined as acid neutralization capacity of the sample.

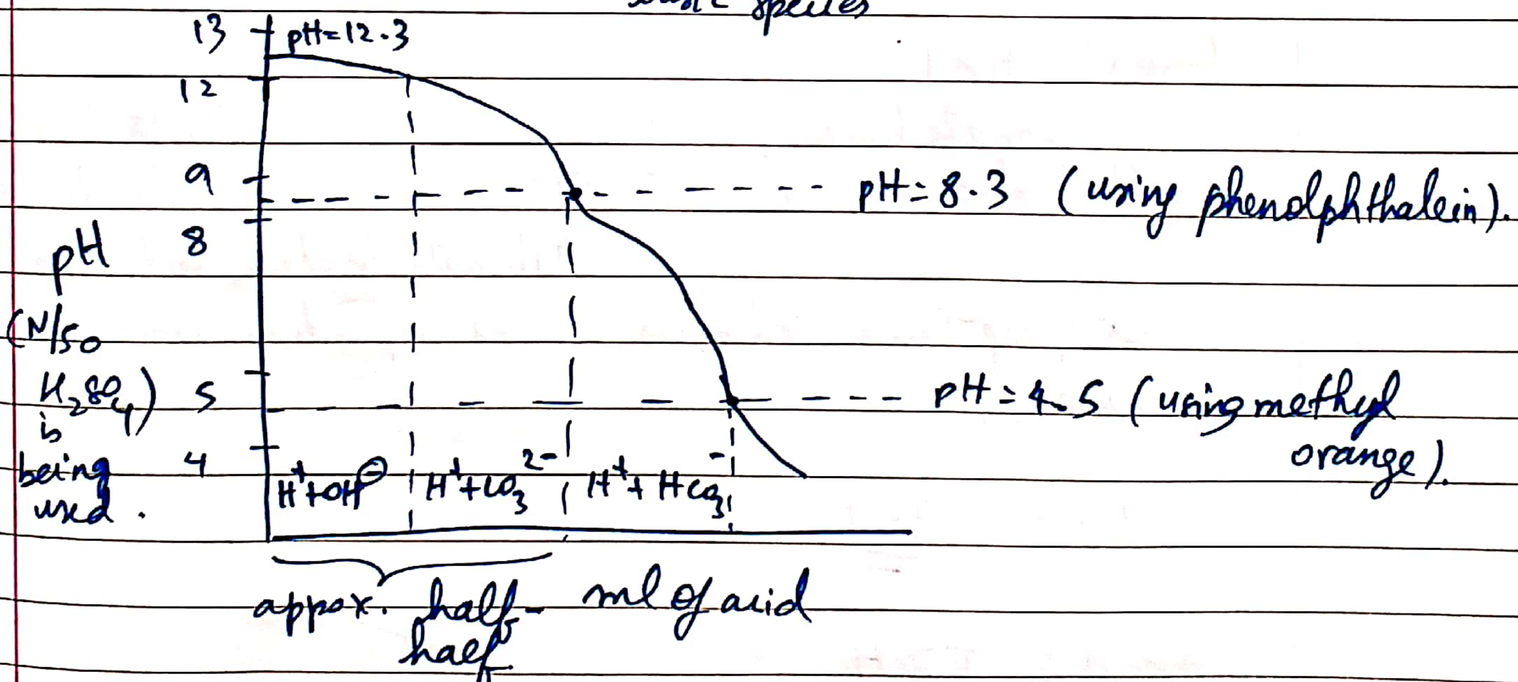
Relevant bases that can neutralize water (acidified).



It's measured as mg/L equivalent of $CaCO_3$.

Total alkalinity will be sum of all lewis base concentrations, but we can't add directly because the acidity of the bases are different. So we add their $CaCO_3$ equivalents.

$$\text{Alkalinity} = \underset{\text{basic species}}{M^-}\text{(in mg/L)} \times \text{Eq. wt. of } CaCO_3.$$



Hardness:-

Defined as ability to resist formation of lather when mixed with soap. It is caused only by the multivalent cations such as Ca^{2+}, Mg^{2+}, Mn^{2+} ..., Fe^{2+}, Sr^{2+}, Fe^{3+}, Al^{3+}, Mn^{4+}

Hardness of a particular multivalent cation
$= M^{n+}$ (in mg/L) $\times$ Eq. wt. of $CaCO_3$.

The total hardness is the sum of hardness caused by all the cations present.
(Eq. wt. of $CaCO_3 = \frac{100}{2} = 50$. 2 is the cationic/anionic charge)

- Hardness of water causes scaling problems in boiler operations in industries.
- Surface water is softer as compared to groundwater. So, surface water is used for washing purposes.

Hardness + Alkalinity

H → Total hardness ($Ca^{2+} + Mg^{2+}$) in mg/L of $CaCO_3$

T → Total Alkalinity ($HCO_3^- + CO_3^{2-}$) in mg/L of $CaCO_3$

Case I :- H > T

Carbonate hardness = $\underline{\underline{T}}$ (since H > T, Ca^{2+}, Mg^{2+} combine with HCO_3^- and CO_3^{2-}, leading to carbonate hardness and remaining Ca^{2+}, Mg^{2+} mix with other anions to produce non-carbonate hardness.
(Includes HCO_3^- also)

NCH = $\underline{\underline{H-T}}$.

Case II :- T ≥ H

CH = $\underline{\underline{H}}$ (all Ca^{2+}, Mg^{2+} mixed with CO_3^{2-}, HCO_3^-)

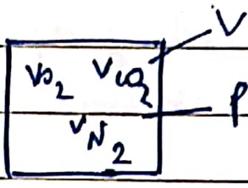
NCH = $\underline{\underline{0}}$ (since no Ca^{2+}, Mg^{2+} is left).

CH is called temporary hardness as it can be removed by simple boiling. While, it is difficult to remove NCH. It can only be removed by specific chemical processes.

Dissolved Oxygen (DO) :- (Pollution Parameter)

- Daltons law of partial pressure :-

In a mixture of gases each gas applies pressure independent of each other, and this partial pressure is directly proportional to the amount (mole fraction (or) mass per volume percentage) of the gas in the mixture.



$$P_{O_2} = \frac{V_{O_2}}{V} \times P$$

- Henry's law :-

The mass of any gas dissolving in a given volume of a liquid, at a constant temp., is directly ∝ to partial pressure of the gas above the liquid.

$$\frac{m_g}{V} = \text{conc.} \propto p_{gas}$$

$$\Rightarrow \text{conc} = \frac{p_{gas}}{K_H} \quad K_H \to \text{Henry's law constant.}$$

$DO_{20^\circ C} \to mg/L$ when $K_{H(20^\circ)} = 0.73\ atm-m^3/mol$

$$\Rightarrow \text{conc.} = \frac{p_{gas}^{O_2}}{K_H} = \frac{p_{gas}^{O_2}\ mol}{0.73\ atm-m^3}$$

$$= \frac{\frac{21}{100} \times 1\ atm\ \ mol}{0.73\ atm-m^3} = \frac{21}{73}\ mol/m^3$$

$$= \frac{\cancel{21}}{16} \quad \frac{21 \times 16 \times 2 \times 10^{-3}\ g}{73} = \frac{21 \times 16 \times 2}{73}\ mg/L$$

$$= 4.602 \times 2\ mg/L$$

$$= 9.2\ mg/L$$

Scanned by CamScanner

During summers due to increased temperatures, the conc. of dissolved O_2 in water reduces, as it gets the energy to escape. Further, if we dispose waste into the water, due to decay, it further consumes dissolved O_2, putting the life of aquatic animals in danger.

- A healthy water body has 8-10 mg/L of DO, whereas groundwater may have as low as 1-2 mg/L. Reduction of DO to below 4 mg/L leads to death of aquatic species. (critical minimum concentration).

- Henry's law, being an equilibrium equation, gives the final equilibrium conc. of the gas in water. But, it does not talk anything about the kinetics of the process.

$$\Rightarrow \frac{dC}{dt} = \underbrace{K_L a}_{O_2 \text{ transfer rate coeff. } (h^{-1})}(C_s - C)$$

$C \rightarrow$ O_2 conc. in water at any instant 't' (mg/L)

$C_s \rightarrow$ saturated O_2 conc (mg/L)

$(\underbrace{C_s - C}) \rightarrow$ dissolved O_2 deficit (mg/L)

This is a very slow process, thus we need engineered systems to increase the rate of dissolution. (Surface aerator, bubble aerator, etc.)

Oxygen Demand:-

It is a measure of the amount of organic and inorganic matter present in water, since, organic matter and inorganic matter consume DO (dissolved oxygen) to decompose. Thus OD and DO are related.

Theoretical oxygen demand (ThOD):-

Generalized balanced eqn:-

$$C_n H_a O_b N_c + \left(n + \frac{a}{4} - \frac{b}{2} - \frac{3}{4}c\right) O_2 \rightarrow nCO_2 + \left(\frac{a}{2} - \frac{3c}{2}\right) H_2O + cNH_3$$

for glucose, $C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$
180   6×32

=) OD = $\frac{6 \times 32}{180}$ mg O_2/mg of glucose = 1.07 mg O_2/mg of $C_6H_{12}O_6$

If glucose conc. in water is 360 mg/L, ThOD = 1.07 × 360 mg/L
= 385.2 mg/L.

(Practice for sucrose ($C_{12}H_{22}O_{11}$), KHP ($C_8H_5KO_4$) → potassium hydrogen phthalate)

Chemical oxygen demand:-
Amount of O_2 required to chemically oxidise the given organic matter into CO_2. We use $K_2Cr_2O_7$ as a strong oxidising agent in excess.

1.5 mL of $K_2Cr_2O_7$ + 3.5 mL of H_2SO_4 (Ag_2SO_4 as catalyst) + 2.5 mL of sample (wastewater)
↓ heat digestion (at 150 ± 2°C) for 2 hrs.

Excess $K_2Cr_2O_7$ is used because we want a potassium dichromate solidified residue which can be titrimetrically determined using ferrous ammonium sulphate.

A blank (1.5 ml $K_2Cr_2O_7$ + 3.5 mL of H_2SO_4 + 2.5 mL distilled water)
is used as a reference for the amount ~~as~~ of $K_2Cr_2O_{7(s)}$ residue because distilled water is free of organic matter, so there is no residue in this case. So, the base reference is set as zero. This has to be done because the strength of open $K_2Cr_2O_7$ keeps decreasing in the lab.

- For all practical purposes, we take, <u>ThOD = COD</u>.

exam. # Water mixed with 100 mg/L Urea ($NH_2-\overset{O}{\overset{\|}{C}}-NH_2$). Assuming that ThOD = COD. Calculate chemical oxygen demand.

- Biochemical Oxygen demand (BOD):-

Defined as the amount of oxygen utilised by microbes for the biochemical oxidation of organic (carbonaceous) and inorganic (nitrogenous) matter. Since microbes use enzymes to oxidise, there is a bio part to the process. We cannot use an oxidising agent to oxidise the waste in water, as oxidising agents blindly oxidise all waste. But, microbes can only oxidise the biodegradable portion of waste. If we use O.A, we will never know which is bio-degradable and which is non-biodegradable.

Since BOD (100%) is a very long process (even upto 20 days), we use BOD_5 (which considers only 5 days of decay - around 60% to 70%) and then using kinetics of the reaction, we estimate $BOD_{100\%}$ theoretically.

Also, $BOD_5 (20°C) \equiv BOD_3 (27°C)$

We can practically say BOD_5 equivalent to BOD_3.

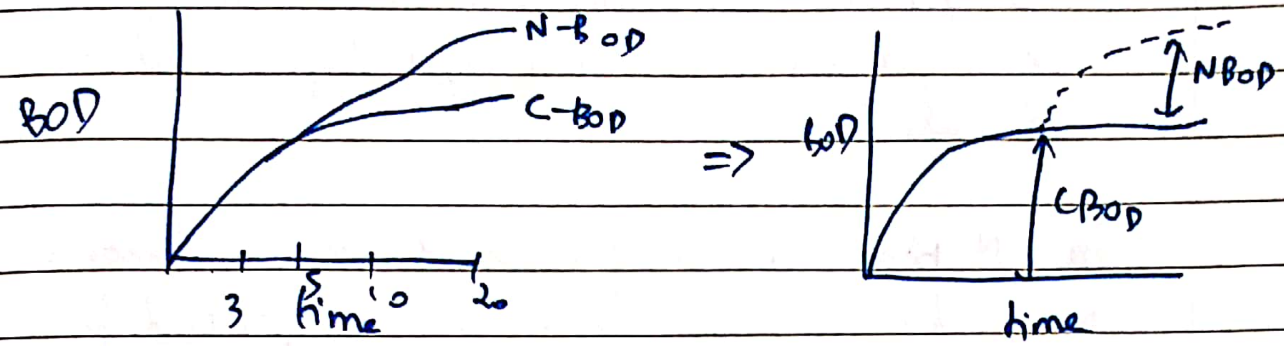
Total BOD =

C-BOD + N-BOD

$C_{org} + O_2 \rightarrow CO_2 + H_2O$

$NH_4^+ \rightarrow NO_2^- \rightarrow NO_3^-$

When we plot a graph of the decay process, we find,



This can be interpreted as at around 5 days only NBOD starts, and secondly the rate of NBOD and CBOD are different

=> Can we say that $BOD_5 \equiv BOD_3$?

We can, because at around 3-5 days, the rate of NBOD decay is very small that it can be considered negligible as compared to CBOD decay.

NBOD (Complete rxn) :-

$$NH_3 + 1.5\,O_2 \xrightarrow{\text{Nitrosomonas}} NO_2^- + H_2O + H^+$$

$$NO_2^- + \tfrac{1}{2}O_2 \xrightarrow{\text{nitrobacter}} NO_3^-$$

$$\Rightarrow \quad NH_3 + 2O_2 \longrightarrow NO_3^- + NO_2^- + H_2O + H^+$$

=> 2 moles oxygen / mole of NH_3. (= BOD).

also equal to 3.76 mg oxygen / mg of NH_3

also equal to 4.57 mg of oxygen / mg of $\underbrace{NH_4^+ - N}_{\text{means we consider } NH_3}$

as only N => molecular mass is 14, not 17.

For C-BOD and N-BOD, we just write the chemical reaction and find O_2 stoichiometrically. For ThOD, we write chemical reaction as mentioned before and stoichiometrically calculate O_2.

In N-BOD, since H^+ is released, system becomes acidic. We need to an alkali to increase the pH and bring back neutrality (basically, a buffer system).
The alkalinity requirement here is 7.14 mg as $CaCO_3$/mg NH_4^+-N

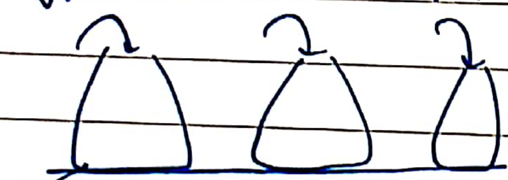
exam:{ This can be calculated using the alkalinity expression discussed before.

· Calculation of BOD_5:-

case 1:- when unseeded water is used.

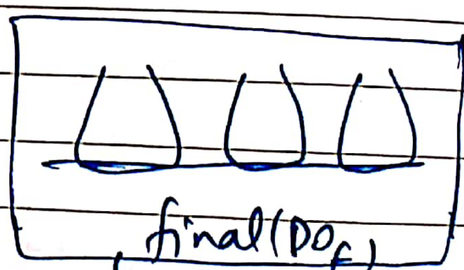
BOD bottle = 300ml.

V ml   V ml   V ml



We also add (300-V) ml of aerated distilled water.

Initial (DO_i)



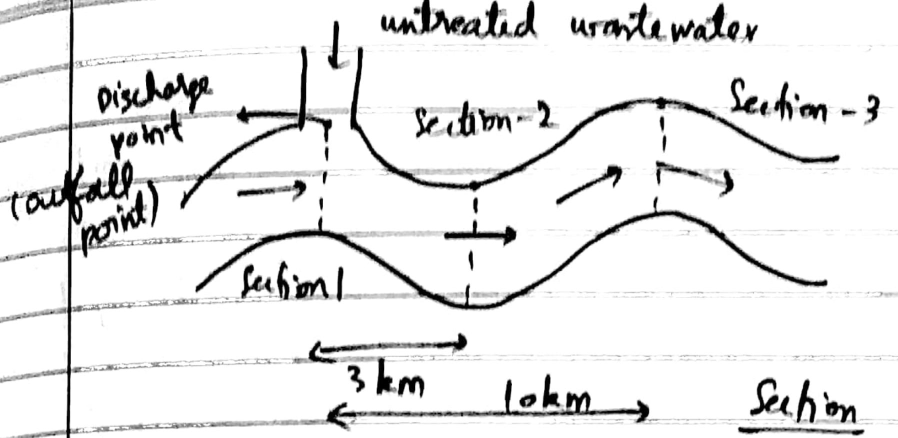
incubator
20° / 27°
5d   3d

three samples are taken just for average purpose.

$$\text{Dilution factor } (D) = \frac{300\,ml \rightarrow \text{bottle volume}}{V\,ml \rightarrow \text{sample}}$$

$$\text{Volumetric fraction } (P) = 1/D$$

$$BOD = \frac{DO_i - DO_f}{P} \text{ or } (DO_i - DO_f) \times D$$



Conc. of N-species (mg/L)

Section	DO (mg/L)	Org-N	NH_4^+-N	NO_2^--N	NO_3^--N
1	8	4	3	0	0
2	3	2	0	1	1
3	0	1	0	0	3

cities usually dump wastewater in the downstream flow of the river, because they take water from the upstream flow for drinking purposes.
Much of the initial DO comes from the wastewater itself, due to the plethora of microorganisms present here, they consume DO to breakdown organic matter (or nutrients, in this case).

- Nutrients :- Phosphorus :-

Mainly found in water as soluble mineral phosphate ($H_2PO_4^-$, HPO_4^-, PO_4^{3-}), soluble mineral (organic P) and particulate P. It is expressed in units of PO_4^{3-}-P/Litre. Most common source in water is through detergents.
Excessive presence of N and P nutrients leads to algal bloom (eutrophication).

- A Routine water quality analysis usually includes all major constituents (except carbonic species) and also some minor constituents.

Checking ion balance of the water helps to eliminate the gross errors induced in the quality check.

Some sources of errors are:-
- Improper sample storage (including sealing of containers and buffering).
- Not measuring on-site parameters such as DO, pH, alkalinity, etc at the site of water collection itself.
- Not filtering suspended solids out properly, as they potentially hide the bacteria. So, turbidity measurement may be wrong.

An error of less than 10% is acceptable.

- The charge / ion balance check has to be done by taking the equivalent conc. (meq./L) of the ionic species so as to have a normalized unit.
(It can also be expressed in a bar format where the concentrations have to be expressed in a cumulative format.)

- Microbiological parameters:-

Aquatic organisms:-
Their natural habitat is water, they are not pathogens. But their activities may affect colour, taste, odour, clogging, corrosion, etc. These are actually the natural flora and fauna of water bodies. Eg:- Pseudomonas, algae, etc.

Soil organisms:- They live naturally in soil. They enter water through water-soil contact. They are also usually non pathogenic.

Intestinal organisms:- These are usually the pathogenic species. They are usually viruses, but bacterias, fungi, etc.

also cause various diseases. they cannot survive for long in the water without a host body. they are excreted by sick warm blooded animals and when this fecal matter comes in contact with drinking water, and it is consumed, they infect the intestine of a warm blooded animal.

- Difficulties in measurement :-
  - There are many times of pathogens and microscopic measurement of each type is not feasible.
  - Treated water is usually free of pathogens.
  - Many pathogens are host-specific.

So, we use an indicator organism which is non-pathogenic.
- these have the same source as that of pathogenic organisms.
- These are present in large no.s as compared to pathogens.
- It is comparitively easier to measure them.
- they are highly resistant to disinfection of water (chlorination of water).

So, we use Coliform bacteria. they are universally accepted as indicators of fecal contamination. (not necessary)
Higher the no. of Coli. bacteria, higher is the possibility that there are multiple pathogens.

Water quality	Groundwater	Surface water
Alkalinity	More	less
Hardness	More	less
Turbidity	less	More
DO	less	More
Presence of MO (microorganisms)	less	More

ENVIRONMENTAL LEGISLATIONS AND STANDARDS

- Subclause (g) of Article -51(A) :- It shall be the duty of every Indian citizen to preserve and improve the natural flora and fauna of the country.

  The state laws regarding environmental conservation are governed by Article 48-A (42nd amendment).

- Central government → Ministry of Environment and Forest → Central pollution control Board

  State government → State dept. of Environment → State pollution control Board → Regional offices

  Central pollution control Board ←monitors→ State pollution control Board

- Various comittees and action plans were setup according to successive 5 year plans. (Refer slides).

- It is the responsibility of the state pollution control board to prosecute individuals or organizations which are violating the conservation laws. If the state board fails to do so, the central board has the sweeping power to overrule the state board and prosecute them according to Environmental protection act (1986).

- Some of the environmental legislations in India are, Biomedical waste (management and handling) rules, 1998 (amended 2003).

Municipal solid wastes (Management and handling) Rules, 2016.

Batteries (Management and Handling) Rules, 2001 (amended 2010).

(Indian Railways is the largest consumer of lead-acid batteries, so proper disposal of lead is necessary).

Plastics (Usage, management, disposal) rules (2009).

- The Drinking water standards are governed by IS 10500-2012

Indian Standards

Alternatively, WHO standards can also be used.

When multiple sources are present in a region, the acceptable limit has to be followed. Otherwise, if only single source, then permissible limit may be followed.

For drinking water, even indicator organism (measured in most probable no. /100mL) must not be present.
(MPN)

- For industrial effluent discharge into surface water bodies, the $BOD_{5\,max} = 30mg/L$ (under the premise that atleast

10 times more water is discharged along) ⇒ effectively $BOD_{5\,max}$ becomes $3mg/L$.

$\Rightarrow$ The $DO_{min} = DO_{healthy} - BOD_{5\,max} = 8 - 3$

$\Rightarrow$ $DO_{min} = 3-4 mg/L$

Page No.:
Date:

- Surface water is classified into 5 types (A, B, C, D, E) based on its usage according to quality.

A - Drinking water source without conventional treatment and only disinfection.

B - Outdoor bathing.

C - Drinking water source with conventional treatment and disinfection.

D - Propagation of wild life and fisheries

E - Irrigation, Industrial cooling, controlled waste disposal.

- Air quality is governed (or standardized) by NAAQ (National ambient air quality).
It does not specify standards for NO. (as NO is a primary pollutant => as soon as it is emitted from source, it turns to NO_2).

Particulate matter is measured by its size as PM_x. x here indicates the maximum size of that particle. The smaller the PM, more finer the particle is => more finer regions of the lung it can reach.

98% of the times the readings must be within the limits, 2% they may exceed the limits, but they should not do so on two consecutive days of monitoring.

- Noise pollution:-

The faintest sound (in terms of air pressure) is around $20 \mu Pa$ and loudest sound is around 20

To accomodate the range of pressure of variations, we use the unit bell (or decibell)

Sound level $L = \log_{10} \frac{Q}{Q_0}$ (Bel)

$Q \rightarrow$ Sound pressure/power/intensity.

$Q_0 \rightarrow$ Reference level.

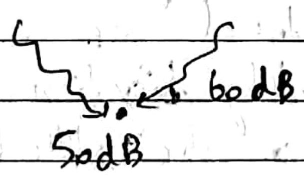
Decibel $= 10 \log_{10} \frac{Q}{Q_0}$

Sound power level $- L_p = 10 \log_{10} \left(\frac{P_m}{20 \mu Pa}\right)^2$ $\rightarrow$ instruments measure RMS value, so, square here.

$= 20 \log_{10} \left(\frac{P_m}{20 \mu Pa}\right)$ $\rightarrow$ measured power.

- Silence zones (schools, colleges, hospitals, etc.) are designated by the government authorities.

exam



effective dB at the point?

Page No.:
Date:

ENVIRONMENTAL SANITATION

- Sanitation :- Provision for defecation with privacy, safety and dignity while preventing environmental contamination. (Isolation of human excreta from water bodies until the same is converted into safe usable product.

- Onsite management :- Management of excreta at the site of generation itself.
- Offsite management :- Management of excreta at the waste treatment plants.

- One of the major Millenium development goals of UN was to halve the no. of people practicing open defecation by 2015.

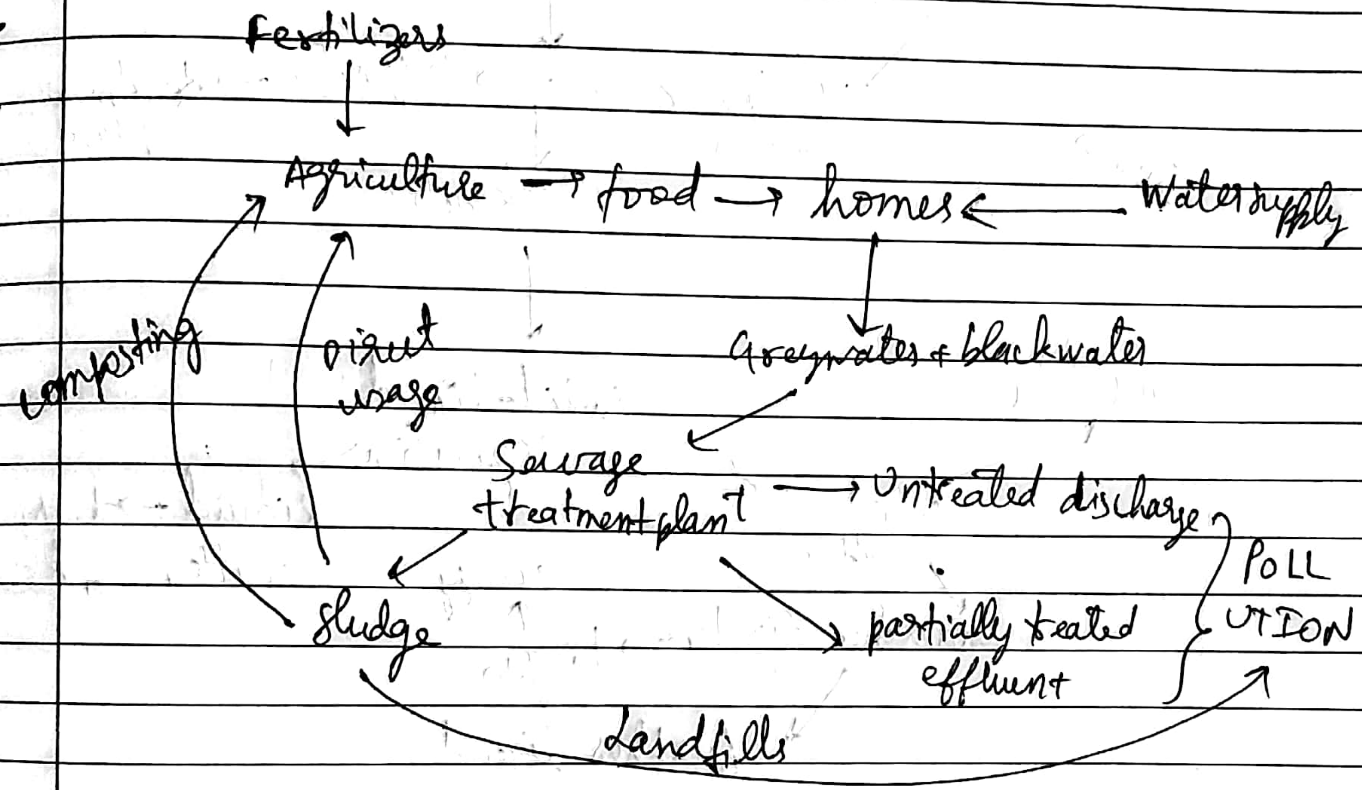
  Even in 2014, around 590 million Indian's continue to practice open defecation, making India the largest country to do so.

- A septic tank is essentially an anaerobic digester where human excreta is stored for around 6 months - 3 years. The liquid generated by digestion is usually let into the soil absorption system. The settled fecal matter called sludge is periodically removed and cleaned. This is called the drop and store method, usually followed in rural / semi urban areas.

  The flush and forget method is common in cities where fresh drinkable water is used to transport the solid waste directly from homes to sewage treatment plants.

Page No.:
Date:

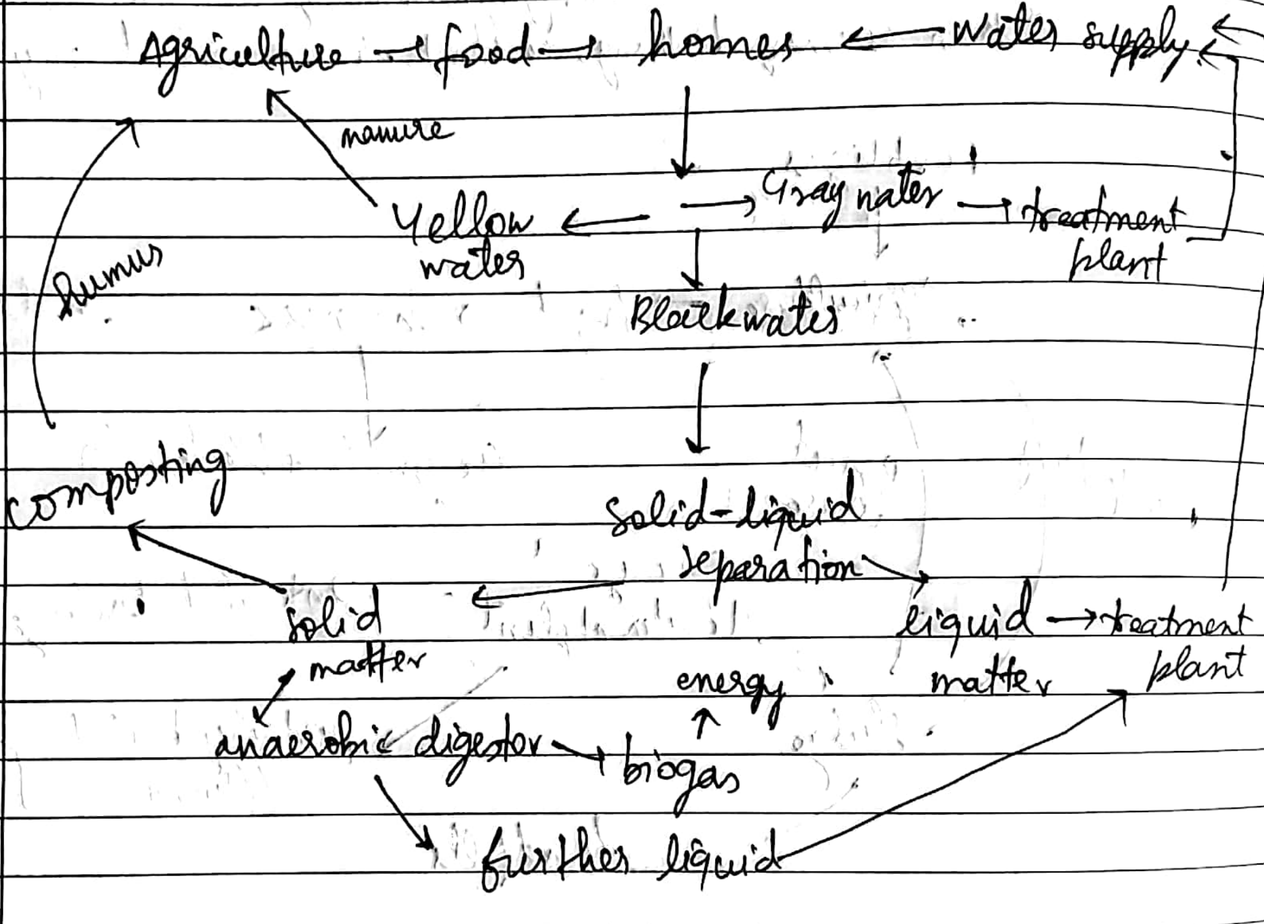
- Wastewater generated from usage of toilet and related activities is called blackwater. Any other kind of domestic wastewater (from washing, bathing, cooking), etc. are called grey water.

- 

- The biggest problem is that C, N and P content in untreated and partially treated dishcharge directly causes pollution instead of going back to the soil for agriculture.

- Thus, "solution to pollution is dilution" (usage of fresh drinkable water for carrying MSW (municipal solid waste) to treatment plants is not environmentally viable or justifiable.

- We need to opt for an ecological sanitation system.



Yellow matter is essentially urinal waste that is rich in N, C and P nutrients.
The point here is that, usage of freshwater for excreta management is unavoidable, but surely minimizable. Yellow water does not need water dilution, it can directly be used as manure. Treated gray water and liquid matter can directly be used as reusable water source. thus, it is a cyclic process as well. Further, for flushing purpose, the same treated water can be used as well.

ENVIRONMENTAL POLLUTION CONTROL

Water purification system

Water treatment plant (WTP), usually for drinking water
Sewage treatment plant (STP), usually for domestic wastewater
Effluent treatment plant (ETP), for industrial waste water

Multiple industries can come together and set up a treatment plant which is capable of treating complex mixture of industrial effluents, this is called common ETP (CETP).

Purification :- Improvement in the water quality

Natural treatment   Engineered treatment.

Drinking water treatment :-

- Sources of raw water :-

Surface sources :- Ponds, lakes, streams, rivers, storage dams and reservoirs.

- Subsurface source or underground source :- Springs, infiltration wells, wells and tube wells.

Springs :- When, in a particular area, the underground recharge is very large, the groundwater level comes up above the ground. It is usually hot, as heat of the Earth plays a major role in the groundwater flowing out.

Extent of treatment required depends on source and quality and characteristics of the given water and its intended use.

Page No.:
Date:

Conventional water treatment plant :-

Raw water → Screening → Primary sedimentation → coagulation flocculation → Secondary Sedimentation → filtration → Disinfection → To supply.

Screening :- Using iron/steel rod filters to remove large solid materials which are not contributing to the water quality characteristics. These are essentially floating solids.

Sedimentation :- Settling down of suspended solids by means of action of gravity.

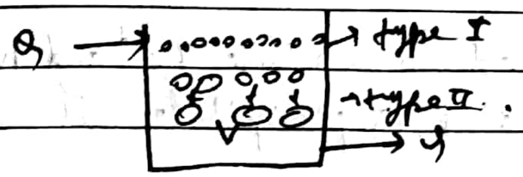
From screening to sedimentation processes, the area of the sedimentation chamber is larger than area of screener → so that volume flow rate is reduced and the suspended solids can settle down.

- Types of suspended particles :

Type I :- Those particles that have the property of maintaining a fixed shape and size throughout the settling process.

Type II :- these are the particles that coalesce with similar kind of particles and hence their mass keeps getting larger and larger. So, as the particles settle down, the differential settling velocity keeps reducing.

- Primary sedimentation is for type I particles, eg. sand and silt.



$\therefore$ Retention time $= \frac{V}{Q}$

Coagulation:- Process of charge neutralization for the negatively charged colloid particles so that they will coalesce with each other. Usually, $Al_2(SO_4)_3$ (alum) (in form of Al^{3+}) is added.

Flocculation:- thorough mixing after adding coagulant, to facilitate settling down of particles.
The settled down solids are now of type 2 kind. These are removed by flocculation and filtered.

Filtration:- Unremoved particles from secondary sedimentation are removed here. These are usually ~~dissolved~~ suspended solids whose size is way too small. It happens in a layer basis, finer layers of sand are placed on top and larger sand particles are placed in below layers. These sand layers produce an incremental layer of fine size pores which will carry out a filtration process. A gravel layer is placed at the bottommost layer to support the weight of the sand layers.

Disinfection:- To kill potentially harmful microbes which may be present, the water is chlorinated. An extra amount of chlorine is added to account for contamination while transporting water.

Backwashing:- Passing water from under (starting from gravel layer to clean the pores of the sand layer). The gravel layer remains undislodged as it is very heavy, while the space b/w sand layers and pores are cleaned.

Date:

- A cascade aerator is used to oxidise Fe^{2+} and Mn^{2+} present in groundwater. As it oxidises, it precipitates out and is thus removed.

Treatment requirements:-

- Ground water and spring water fairly free from contamination	No treatment / Chlorination.
- Ground water with chemicals (Fe^{2+}, Mn^{2+}) minerals and gases	Aeration, coagulation, filtration and disinfection.
- Lakes, surface water with less pollution	Disinfection.
- Other surface waters (like rivers), with considerable amount of pollution	Complete treatment

(We will have to draw treatment plant systems depending upon input water type).

- WASTEWATER TREATMENT :-

Major objective is to prevent environmental degradation by treating organic carbon / inorganic substances that will consume dissolved O_2, prevent pathogenic spread and eutrophication.

Techniques

- Physical
  - Screening, Mixing, Flocculation, flotation, Filtration, Sedimentation, Gas transfer
- Chemical
  - Precipitation
  - Adsorption
  - Disinfection
- Biological
  - Aerobic
    - Suspended
    - attached
  - Anaerobic

Page No.:
Date:

Flotation:- Air at high pressure is pumped at the bottom of tank and released at atm. pressure, the bubbles that produced as they rise up through the height of the water, they will trap materials such as oil and grease which will then be skimmed at the top.

Precipitation:- Adding chemicals that will increase the solubility product above K_{sp} of the contaminant (like Fe^{2+}/Fe^{3+} compounds, etc.) and thus precipitate out.

Adsorption:- Arsenic and chloride are removed by adding activated alumina or activated carbon to remove by adsorption.

Suspended:- The microorganisms employed to treat the waste water are maintained in a suspension system. This is called suspended growth process.

Attached:- The responsible microorganisms are maintained over a solid surface and waste water is passed over that.
(polymeric/plastic)

Hybrid growth system:- It is a combination of suspended and attached system. It is not useful if strength of wastewater is less, as then the organisms will die out.

- Wastewater treatment levels:-

Preliminary:- Physical removal of large solids, rags, papers, etc.

Primary:- Physical sedimentation removal of suspended particles.

Secondary:- chemical and biological treatment to reduce organic load of waste water.

Tertiary:- Chemical/biological recycling of released effluents

Grit :- Fixed suspended solids such as sand and silt present in wastewater. Removed in grit chamber by type I sedimentation.

Primary clarifier :- In drinking water plant, used to remove fixed suspended solids, in wastewater plant, used to remove fixed volatile solids by type II sedimentation.

Linkage between primary and secondary treatment is the Activated sludge process (ASP). It involves growth of microorganisms in the Return sludge structure which will then be passed onto the secondary treatment plant. It will feed back some sludge to the Return sludge so as to maintain growth of organisms.

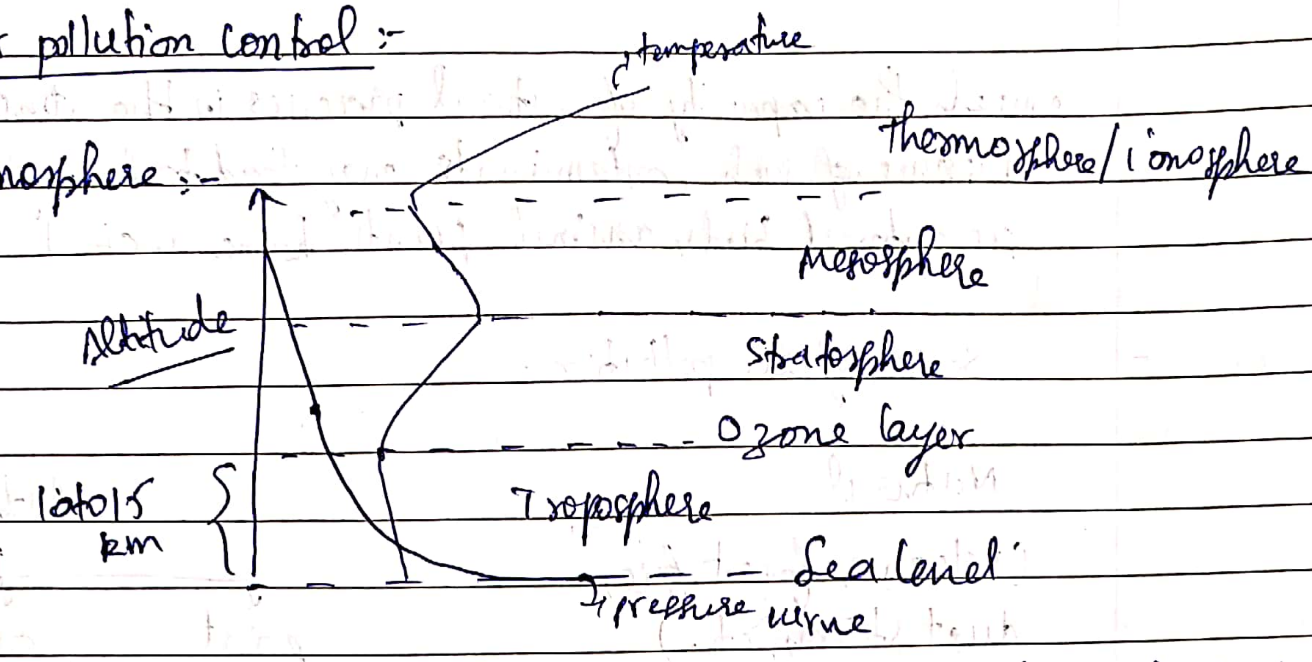
In the aeration tank we remove the dissolved volatile solids.

In drinking water plant, water flow from chamber to chamber is through pressure difference, whereas in waste water plant, it's through gravity

The equalization basin is used to store the wastewater and release it in appropriate amounts so that the plant is neither underutilized nor overutilized. So, a pump is used here in order to store, since storage under gravity is not possible. Another pump is present in the secondary clarifier in order to store and then send some of the sludge back to the aeration basin. In case of industrial effluents, the equalization tank also helps in neutralizing the pH of wastewater. It is actually, a self-neutralization process where acidic / alkaline effluents mix among each other.

Air pollution control :-

Atmosphere :-



With respect to air pollution, we are concerned only with about 600 m from ground level.
The main difference between water pollution and air pollution is that, we can treat the wastewater away from source of generation as well, but air pollution can be controlled only at its source.

Sometimes, particularly in winters, the temperature curve is reversed in the troposphere.
Usually, the polluted air released from the industries is hot. This hot polluted air rises through the air and disperses / dillutes the pollutant. But in winters, due to differential heating and cooling of earth's surface and air mass, there is concentration of pollutant instead of dillution.

Stratosphere has much less water content (moisture) in air. Secondly, higher ozone content in troposphere is a pollutant, while in the stratosphere it is an essential advantage to survival of human life.

Transfer of harmful and/or of natural / synthetic materials into the atmosphere as a direct / indirect consequence of natural and human activities is called air pollution.
It is caused by emission of hazardous substances at a rate that

exceeds the capacity of natural processes in the atmosphere. Presence of such contaminants may tend to be injurious to receptors(birds, animals, plants, humans, etc.)

Sources of air pollution:-

- Natival (volcano, forest fire, dust storms, etc.)
- Antropogenic
  - point (industries)
  - area (community burning, fuel burning, etc.)
  - mobile (moving source, eg. locomotives)

Air pollutants :-

Primary air pollutant:- Those pollutants emitted directly from an identifiable source and harm the nature directly.

Secondary air pollutants:- primary pollutants interact with one another, sunlight or natural gases to produce new harmful components.

Primary
- Particulate matter (PM)
- CO
- SO_2
- NO
- Volatile organic compounds (VOCs)
- lead

Secondary
- ozone
- NO_2
- Photochemical smog
- Aerosol, mist
- Peroxy acetyl nitrate.

NO is primary and NO_2 is secondary because NO is emitted from factories, but it gets converted NO_2 and that is the major pollutant.

Breaking seas :- Due to high and low tides, the sea water breaks into smaller saline particles (droplets). These droplets are carried away by wind, and can be deposited anywhere. It may cause corrosion, etc.

- Photochemical smog is produced when strong sunlight triggers photochemical reactions in the atmosphere. It consists of peroxyacetyl nitrate (PAN), formaldehyde, ozone in major quantities.

- Criteria air pollutants :- CO, NO_x, SO_x, VOCS, PM, Pb
These often violate air quality standards, leading to pollution.

In case of water, mg/L = ppm unit, but it is not true for air, as its volume differs w.r.t pressure and temperature.

$$\mu g/m^3 = ppm \times \frac{M.W \text{ of Pollutant}}{L/mol \text{ of pollutant at P\&T}} \times 10^3$$

1% by volume of CO. what is conc. of CO in $\mu g/m^3$ at NTP.

$$\frac{1 \text{ parts}}{100 \text{ parts}} = \frac{10^4}{10^6} \Rightarrow ppm = \underline{10^4}.$$

$$\mu g/m^3 = \frac{10^4 \times 28 \times 10^3}{L/mol \text{ at P,T}} \Rightarrow PV = nRT$$

$$\Rightarrow \frac{P}{RT} = \left(\frac{n}{V}\right) mol/L$$

$$= \frac{10^7 \times 28 \times RT}{P} \quad ; \quad P, T \to \text{NTP values.}$$

Particulate matter (PM):-
Mixture of solid phase and absorbed materials. Contains carbonaceous core of 40-60%.

Terminal Settling Velocity:-
Based on stokes law
Applicable only to spherical PM of size $\geq 0.1 \mu m$, $< 100 \mu m$
Can be used only for laminar flow $\Rightarrow R_e < 1$ ↳ Reynolds no.

$$V_t = \frac{g(\rho_p - \rho_a) d_p^2}{18\mu} \quad ; \quad R_e = \frac{\rho_a V_t d_p}{\mu}$$

ρ_p :- density of particle ($1000-2000 \, kg/m^3$)
ρ_a :- density of air ($1.2 \, kg/m^3$)
d_p :- diameter of particle
μ :- dynamic viscosity of air $1.85 \times 10^{-5} \, kg/ms$

Aerodynamic diameter:-
It is the diameter of a unit density spherical hypothetical particle that has the same inertial properties as the particle of interest.

$$\underset{\mu m}{d_{\text{particle aerodynamic}}} = \underset{\mu m}{d_{\text{stokes diameter}}} \sqrt{\rho_{\text{particle}}}$$

(ρ_{particle} → g/cm^3)

We obtain its stokes diameter by putting its V_t in the above formula, $\rho_p = 1 \, kg/m^3$, and calulate d_p from there.

Pollutants size :-

Based on aerodynamic diameter :-

- Large - Local irritation $>100 \mu m$
- Inhalable $(<100 \mu m)$
- Thoracic fraction $(<20 \mu m)$
  - coarse PM_{10} $(<10 \mu m)$
  - fine $PM_{2.5}$ $(<2.5 \mu m)$
  - Ultrafine $(<0.1 \mu m)$

} respirable.

The more finer the particle size, the deeper it can go into the lungs and choke the bronchioles, leading to diseases like asthma. Secondly, finer the particles, greater is their absorption capacity.

- Physical attrition :- Activities like grinding, etc. which produce supercoarse particles (of size $>10 \mu m$)
- Nucleation mode :- Of sizes ultrafine and fine. Here the particles almost behave like gas molecules itself. They have absorption capacity and brownian motion also.
- Accumulation mode :- Particles of fine size. It is called accumulation as particles come here from coarse mode and nucleation mode as well.

  ⇒ Which is why the atmosphere has major particles of size $<2.5 \mu m$ (fine).

CO has higher affinity to haemoglobin than O_2, hence, inhaling CO forms toxic carboxyhaemoglobin, rather than oxyhaemoglobin.

$$SO_2 \xrightarrow[H_2O_2]{O_3} SO_3 \text{ (very soluble in water)}$$

$$SO_x + H_2O \longrightarrow H_2SO_3 \xrightarrow{\text{oxidise}} H_2SO_4.$$

Emitted by burning of S containing fuels, specially in thermal plants.

$NO_x = NO + NO_2 \rightarrow$ NO converts to NO_2, forming secondary pollutant
primary pollutant

NO_2 manifests as a brown cloud over large polluted cities.

- UV sunlight + hydrocarbons + $NO_x \rightarrow$ Ozone
photolysis of NO_x

It thus acts as a precursor to photochemical smog.

Ozone (O_3)
- Short lived due to high reactivity.
- Very highly soluble in water and can oxidise all pathogens present.
- Absorbs UV rays to create warm thermal structure of stratosphere.

hydroxyl radical (atmospheric detergent as it helps to remove CO)

- $CO + OH \longrightarrow CO_2 + H$

$H + O_2 \longrightarrow HO_2$ → hydroperoxy radical

$HO_2 + NO \longrightarrow OH + NO_2$

$NO_2 + h\nu \longrightarrow NO + O$

$O + O_2 \longrightarrow O_3$

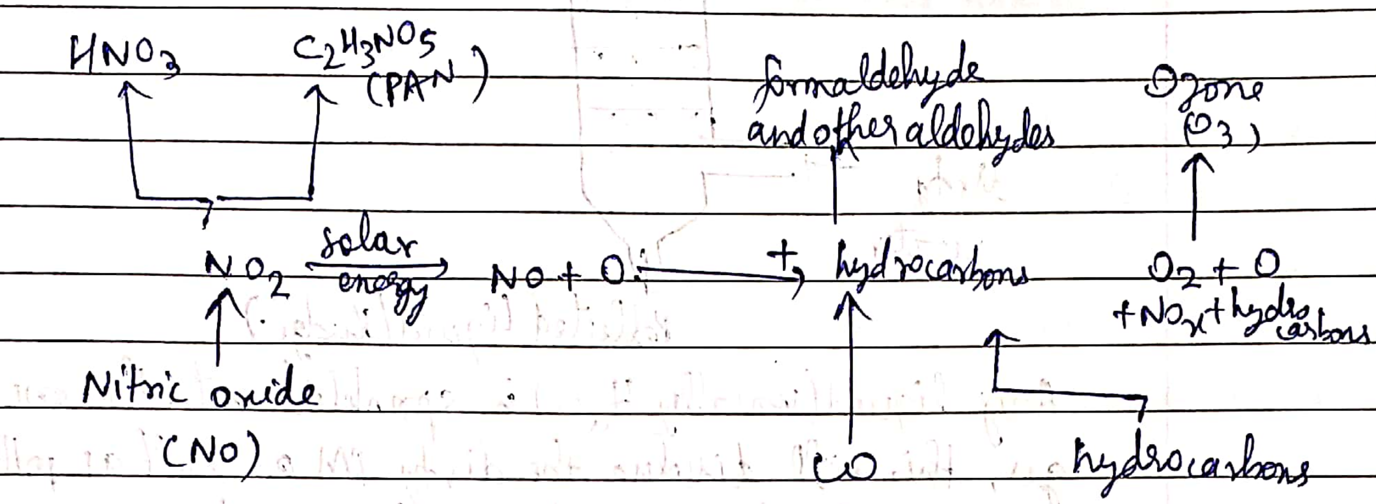
Lead:-
Earlier, used mainly as an anti-knocking agent in 'leaded petrol'.
used to increase calorific value of petrol.

They used: TEL (tetra ethyl lead)
But, lead emission from burning the fuel, leads to organ damages, brain and nervous system damage, Lower IQ in younger children.
Heart diseases and
Chronic poisoning

Scanned by CamScanner

Anti knocking agent — improves engine performance by easing the starting process of the engine.

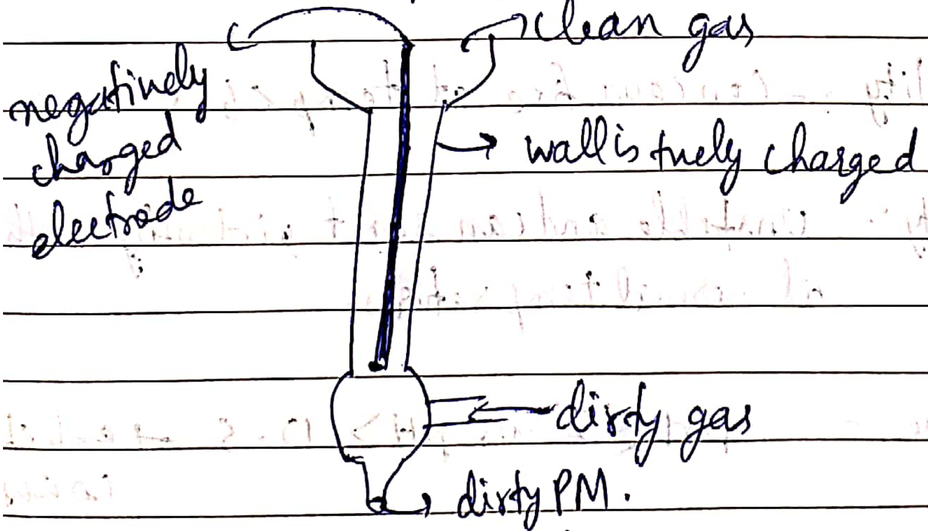
Photochemical smog :-



=) Photochemical smog is essentially HNO_3 + PAN + aldehydes + O_3. (secondary pollutant)

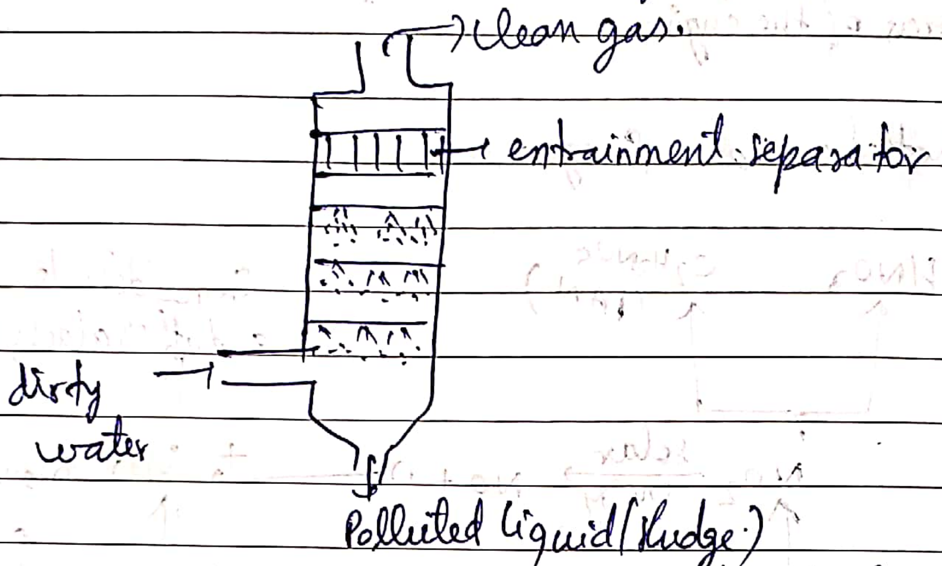
Controlling Air pollution :-

Electrostatic precipitator (ESP) :-



As the dirty particles come in contact with -ve electrode, a -ve charge is induced in these particles. Since the wall is +vely charged, the dirty particles stick onto the wall and clean gas comes out. The -ve electrode undergoes corona discharge, thus the particulate matter (previously -ve, now no charge) fall off.

Scrubber (Removes PM and gaseous pollutant as well)



Any liquid (usually H_2O) is sprinkled onto the oncoming dirty gas, this will dissolve the dirty PM as well as pollutant gases (Henry's law), the entrainment separator removes the excess moisture and gives out clean gas.

Waste management:-

Characteristics of hazardous waste:-

Atleast one of the four properties must be exhibited

- Ignitability :- Can cause fire at temp $< 60°C$
- Reactivity :- Unstable and can react violently with water/air at normal temperatures.
- Corrosive :- $pH \leq 2$ or $pH \geq 12.5$ → exhibits corrosive nature
- Toxicity :- Fatal if exposed to humans / can pollute groundwater if released on land.

Reduce, Reuse, Recycle.

Prevention > minimisation > reuse > recycling > energy recovery > disposal

favoured options

Sanitary landfill:-

- Plastic liner:- Prevents percolation of pollutant into groundwater table.
- Leachate collection pipe:- Collects and removes the sludge periodically from the landfill.
- Vadose monitoring zone:- Alarm system which indicates level of percolation into groundwater at the vadose level (Primary alarm)
- Groundwater table zone:- Alarm system monitoring the groundwater table, To ensure complete prevention of percolation.