Chapter - 1
Explosion of Environmental Issues

* → SPATIAL SCALES

LOCAL SCALE
- Micro scale (10-100m) Middle scal (100 to 500m)
- Neighbourhood scale (500m - 4km)

REGIONAL
- Urban scale (4 to 100 to 1000 km)
- Continental scale (1000 to 10000 km)

GLOBAL
- Global (> 10000 km)

* → EXTENT OF IMPACT

* → LOCAL

→ EXTENT OF IMPACT (1900 - 2000).

- Epidemics and bacterial contamination.
  - Typhoid : Salmonella typhi
  - Cholera : Vibrio cholerae
- Caused due to sewage improper treatment. Organic carbon and O_2 depletion
- All of this was common ~~ex~~ through the beginning of 20th century.

→ Scientific Response

- Sanitary engineering explored → chemistry & microbiology was focussed on

→ Regulatory Action

- US-Canada Boundary waters Treaty (1909)

Signed to prevent any conflict regarding ~~not~~ fresh water lakes shared by both countries. It also focussed on prevention of contamination.

- Local sewage and sanitary measures.

→ REGIONAL :

→ Extent of Impact →

- Years active : (1950 onwards)
- Presence of nutrients such as N & P in water causes algal blooms (mostly in season of summer). They are photosynthetic, take up oxygen & block sunlight. ∴ underwater organisms are harmed. This is called eutrophication. And it leads ~~of~~ to fish kills

- Toxic algae & bacteria: In ~~to~~ water bodies, we may have formation of toxic organisms such as blue-green algae and cyanobacteria
- Accidental Oil spills
- Large Dams & Water Diversions (restrict flow & affect biodiversity)
- Metal Contamination (contamination from factories, ~~so~~ say, into water)

→ Scientific Response

- Limnology: Study of everything abiotic element in water bodies, which adversely affect the biotic components in water.
- Hydrobiology (phytoplankton, zooplankton, fish), chemistry, hydrology.

→ Regulatory Action.

- Great Lakes Water Quality Agreement (GLWQ) (1972 & 1978): A treaty b/w US & Canada for sharing & quality of water in great lakes. It was based on US-Canada Boundary waters treaty.

Great Lakes: Superior, Michigan, Huron, Erie, Ontario

- Tertiary Sewage Treatment
- P-ban in detergents (formed from Na_3PO_4)

* → CONTINENTAL

→ Extent of Impact (1970 onwards)

- Acid Rain: Caused essentialy due to production of acid gases (SO_x, NO_x). May also be due to dry deposition of acidic material. On rain, this forms active acidic content.

NOTE: NO_x : $NO + NO_2$

- Chernobyl disaster (1986): Nuclear disaster, the biggest the earth has seen. Occured in Ukraine, previously Soviet Union. It affected all nearby countries, since wind carried the nuclear clouds to different places.

- Exotic species & wildlife deformities: Chernobyl like disasters cause wildlife deformities & force them to flee the native region

classmate
Date
Page

→ Scientific Response

- **Environmental Science**: Limnology with ecotoxicology, economics, sociology, political science, meteorology, medicine.

→ Regulatory Action

- **Zero discharge sanitation**: It is method of sanitation in which we generate zero discharge ie we discharge nothing into the environment. It promotes reuse & recycle.

- **Rio convention (1992)**: In this convention the term 'biodiversity' was firstly coined. All the participating nations agreed to preserve biodiversity either ex-situ (out of native region) or in-situ.

- **Montreal convention (1999)**: Hazardous (mainly electronic) waste was dumped into developing countries by developed countries. Montreal convention put restrictions on transfer of hazardous waste through air cargo so as to prevent the earlier cause.

- **SO_2 emission target**: Main byproduct of thermal power plant. Coal contains 10% of S.

- Sustainable development: Development that meets the need of present without compromising the ability of future gen. to meet their needs. It was coined by GH Broundtland (Norweigin Prime Minister) who was requested by UN to ~~conserve~~ bring solutions ~~to~~ for biodiversity conservation. (He cointed the term ~~in~~ at that time)

→ GLOBAL

→ Extent of Impact

1. Solid waste: municipal solid waste is a huge source of global pollution. Landfills are major source of global pollution.

2. Urban sprawl: Expansion of city in unplanned manner. Prevents proper percolation of water.

3. Genetic Defects

4. Population Explosion

5. Water Shortage

6. Ozone layer depletion

7. global warming: ~~Da~~ ~~Re~~ Long term rise in temp. of earth. Due to greenhouse

gasses. Sun's light comes in form of short wavelength and reflected in longer wavelength. But greenhouse gases don't let them escape. Hence, heating the earth.

- Scientific response & regulatory action are same as continental scale.

* → ENVIRONMENTAL SYSTEMS

1. NATURAL : We are concerned with understanding and describing changes. eg - forest, lakes, river etc.

2. ENGINEERED : We are concerned with the selection of conditions required to effectively accomplish specific changes. eg - greenhouse, water treatment plant etc.

ie systems that stimulate environmental conditions or which help conserving it.

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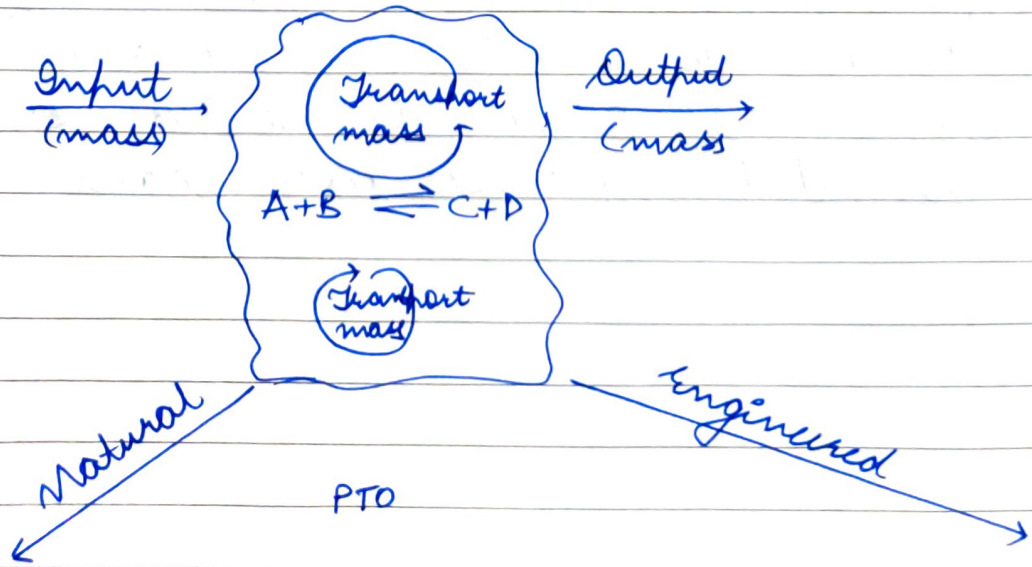

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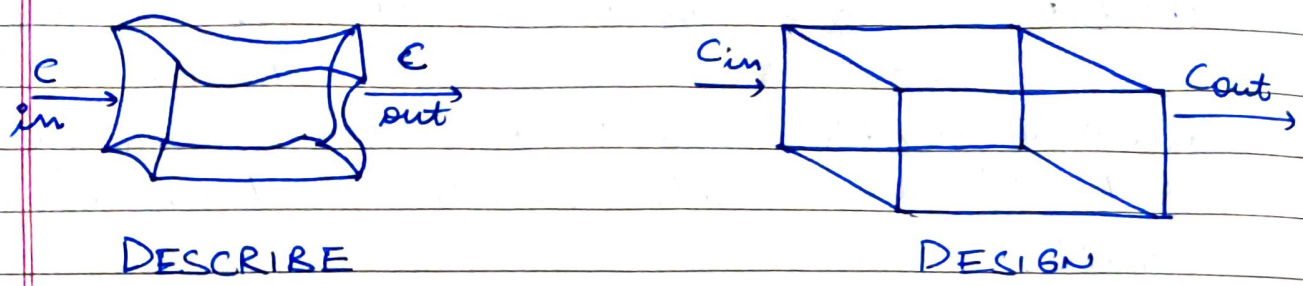

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- ~~Shade the~~

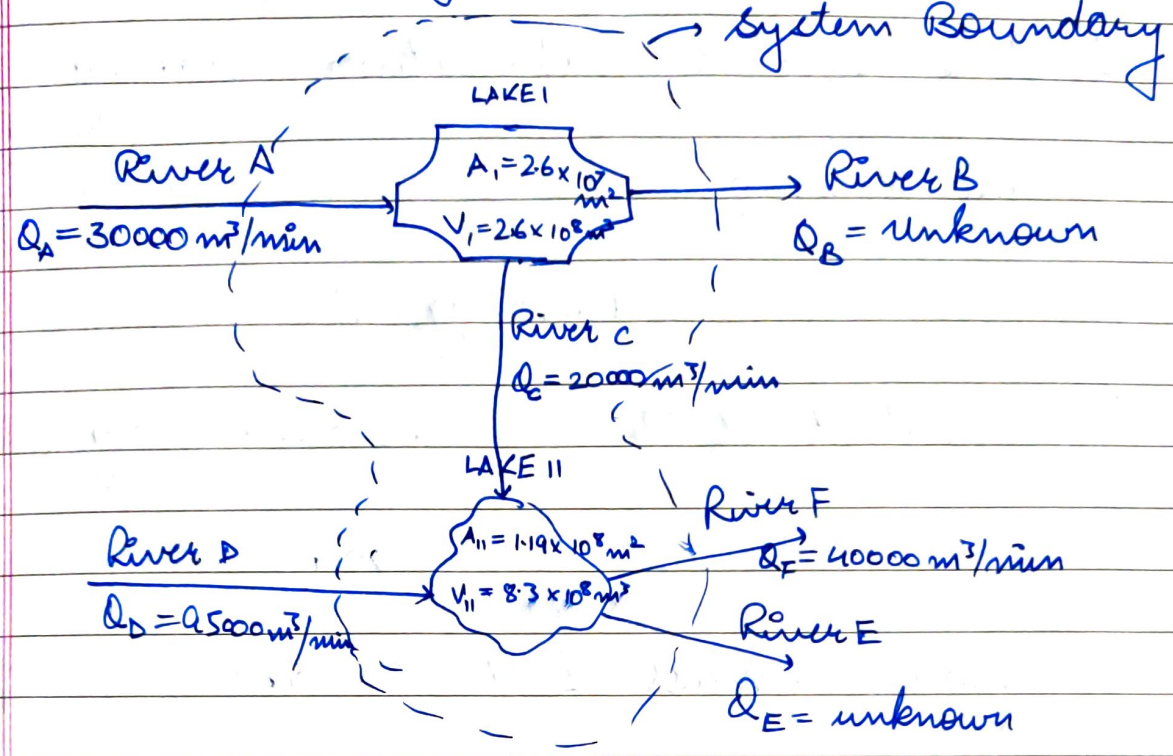
- Character and Scale : Natural & Engineered Environmental systems:

- At most elementary level we distinguish the character of System on basis of scale

- By character we the properties and the nature of changes within a system

- By scale we refer to the spatial scale, ie size and the temporal scale ie the time over which the change in a system is observed. Any system is bounded by these two scales.

Q. Consider system



i) Find Q_E, Q_B

Ans: We assume steady state ∴ the mass in both lakes.

∴ clearly In lake 1 $Q_B = 30000 - 20000$

$\Rightarrow Q_B = 10000 \ m^3/min$

similarly in lake 2 $Q_E = 75000 \ m^3/min$

ii) Consider evaporation rate $r = 0.5 cm/day$. Calculate Q_B & Q_E then

iii) Consider Cl^- in A & B C_A : 40 mg/L C_B : 60 mg/L

Find C_B & C_E if evaporation is taking place.

Ans: $1000\ cm^3 \times 1000$

~~40000 mg/m³~~

~~∴ Input of Cl⁻ = 40000 × 30000 mg/min~~

~~= 1200 kg/min~~

~~1200t = mass of Cl⁻ in lake~~

~~∴ $\frac{1200\ t}{2.6 \times 10^8}$ kg/m³ = Concentration_B~~

LAKE 1

Input of Cl^- = 40000×30000 mg/min

= 1200 kg/min

Mass of Cl^- = 1200 t

concentration = $\frac{1200\ t}{2.6 \times 10^8}$ = $\frac{12\ t}{2600}$ mg/L

Now

LAKE 2

Input = 60000×95000 mg/min = 950×6 kg/min

$+ 20000 \times \frac{1200t}{2.6 \times 10^8}$ kg/min $+ 20000 \times \frac{1200\ t}{26 \times 10^8}$ kg/min

mass of Cl^- = $\left(5700\ kg/min + \frac{2.4t}{26}\ kg/min\right) t$

concentration = $\left(5700 + \frac{2.4t}{26}\right) \frac{t}{8.3 \times 10^8} \times \frac{1000000}{1000}\ mg/L$

HYDRAULIC RETENTION TIME or RETENTION TIME or DETENTION TIME

$$\boxed{HRT \text{ or } RT \text{ or } DT\ (T) = \frac{V\ (L^3)}{Q\ (L^3/T)}}$$

The avg. amt of time required for which a particle stays inside a water body is known as HRT

Chapter-2
Ecology & Sustainable Development

ECOLOGY (oikos: Home ; logos: Study)

- Ecology is the study of organisms in their natural habitat (home) and their interaction with the surroundings.
- The term was coined by german scientist Ernst Haeckel in 1869.

ECOSYSTEM

- It is essentially a set of self-regulating biotic communities interacting with each other in their natural habitat and thereby sharing matter & energy.
- ∴ we can define ecology as study of ecosystems.
- The term was coined by Tansley (1935)

BIOME:

- Multiple ecosystems with same characteristics because of similar climatic conditions is called biome.
- eg- Desert biome, Tundra biome

BIOSPHERE:

- Combination of muliple biomes forms a biosphere.

NOTE: The chain of organisms is described as

Individual → Population → community → ecosystem → Biome → Biosphere.

TYPES OF ECOSYSTEM

- Ecosystems can be classified based on

1. NATURE → Natural, Artificial
2. SIZE → Large, Small
3. DURATION → Permanent, Temporary

- Natural ecosystems
  - Terrestrial
  - Aquatic
    - Freshwater
      - Lentic (stillwater)
      - Lotic (runningwater)
    - Marine
      - Ocean
      - Sea

classmate
Date
Page

imp.
NOTE: A sea is a large water body surrounded ~~by~~ partially by land. And an ocean is a relatively larger water body, not significantly surrounded by land.

BASIC CHARACTERISTICS OF ECOSYSTEMS

1. ECOSYSTEM STRUCTURE:

Made up of two major parts:

a) Biotic Structure →

- Living (ecological community):
- Producers
  - Photoautotrophs (make food using light)
  - Chemoautotrophs (make food using chem rxns. eg- Sulphur bacteria)
- Consumers
  - Herbivores (primary consumers)
  - Carnivores
    - i) Secondary consumers
    - ii) Tertiary consumers
  - Omnivores (plant + meat eaters)
  - Detritivores or Saprotrophs (thrive on dead body of consumers or excreta of consumers)

    eg- vultures and earthworms

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- **Decomposers**
  microorganisms that convert dead material into simpler materials.
  eg- bacteria & fungi

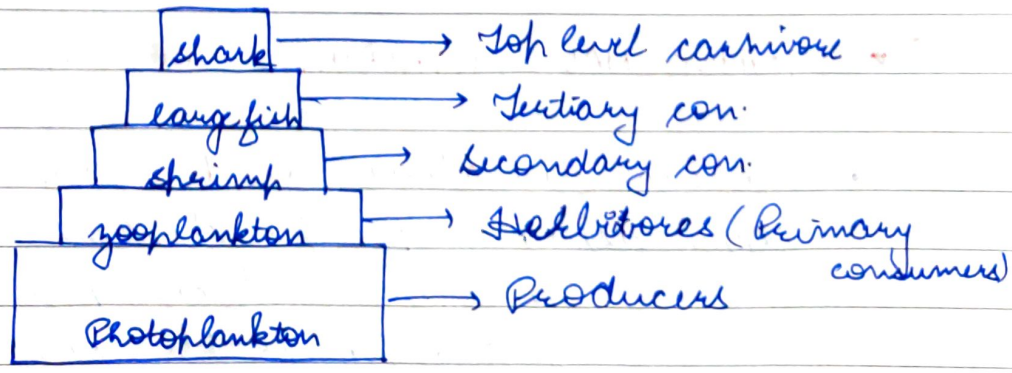
b) **Abiotic Structure** →

- Non-living (physical and chemical environment)

- Inorganic substances
- Organic substances
- Climate.

2. **ECOSYSTEM PROCESSES:**

- Cycling of chemical elements (mass flow)
- Flow of energy (energy flow)



- At its simplest an ecosystem community will have:
  - Atleast one producer species
  - Another species that is a decomposer.
  - Plus a fluid medium (for mass transfer)

- For complete recycling of chemical elements several species must interact i.e

a) Photosynthetic organisms must produce sugar from CO_2 and water and then,

b) From sugar and inorganic compound they ~~make~~ make other organic compounds (protein, woody tissue, etc)

c) Decomposers must then act to get back the produced into its respective inorganic compounds.

FUNCTIONAL ATTRIBUTES OF ECOSYSTEMS

- Trophic structure and level: The structure comprising of producers, consumers (level by level) & decomposers level by level along with the populations is called trophic structure and each level is called trophic level.

classmate
Date
Page

- **FOOD CHAIN :**

- Linkage of who feeds on whom.
- The sequence of eating and being eaten in an ecosystem.
- Involves transfer of energy, chemicals and some compounds from creature to creature in a chain or web (Food web: more complex)
- It is grouped by trophic level.
- If we introduce biodegradable waste, it decomposes ∴ causes no harm.
- But if we introduce non-biodegradable waste, say heavy metals, they get transferred from one trophic level to another and gets concentrated as trophic level rises. This is called biomagnification.

- **FOOD WEBS:**

- The different food chains are interconnected at various trophic levels to develop a food web.
- Food webs are never straight
- Food web is formed due to interlinking of

food chains.

- Some more attributes

- Ecosystem performs under natural conditions
- Energy flows from sun and passes on to biotic components. This is called flow of energy. Flow of energy is unidirectional
- Besides energy, nutrients and water are also needed by biotic components for exchange within themselves and with abiotic components.
- Biotic components also have mechanisms to handle environmental stress.

- The major functional attributes are:

a) Food chain, food webs and trophic structure
b) Energy flow
c) Cycling of nutrients (Biogeochemical cycles)
d) Primary & secondary production
e) Ecosystem development & regulation.

classmate
Date
Page

• ECOLOGICAL PYRAMIDS

- Graphic representation of trophic structure and function of an ecosystem, starting with producers at the base and successive trophic levels forming the apex is known as an ecological pyramid.

- Three types of ecological pyramids:

i) Pyramid of Energy
ii) Pyramid of Biomass (represented as mass per unit surface area)
iii) Pyramid of numbers (It can be upright but can also be inverted)

NOTE: Pyramid of biomass and numbers can be both upright and inverted but pyramid of energy will always be upright (due to unidirectional flow)

→ ECOSYSTEM ENERGY FLOW

- All life requires energy to do work

- Energy enters ecosystem by two pathways.
i) Energy fixed by organisms
ii) Transfer of heat energy by air, water, soil and living things.

- Ecosystem energy flow
movement of energy takes place from environment to organisms which transfer it among themselves during which it is lost back

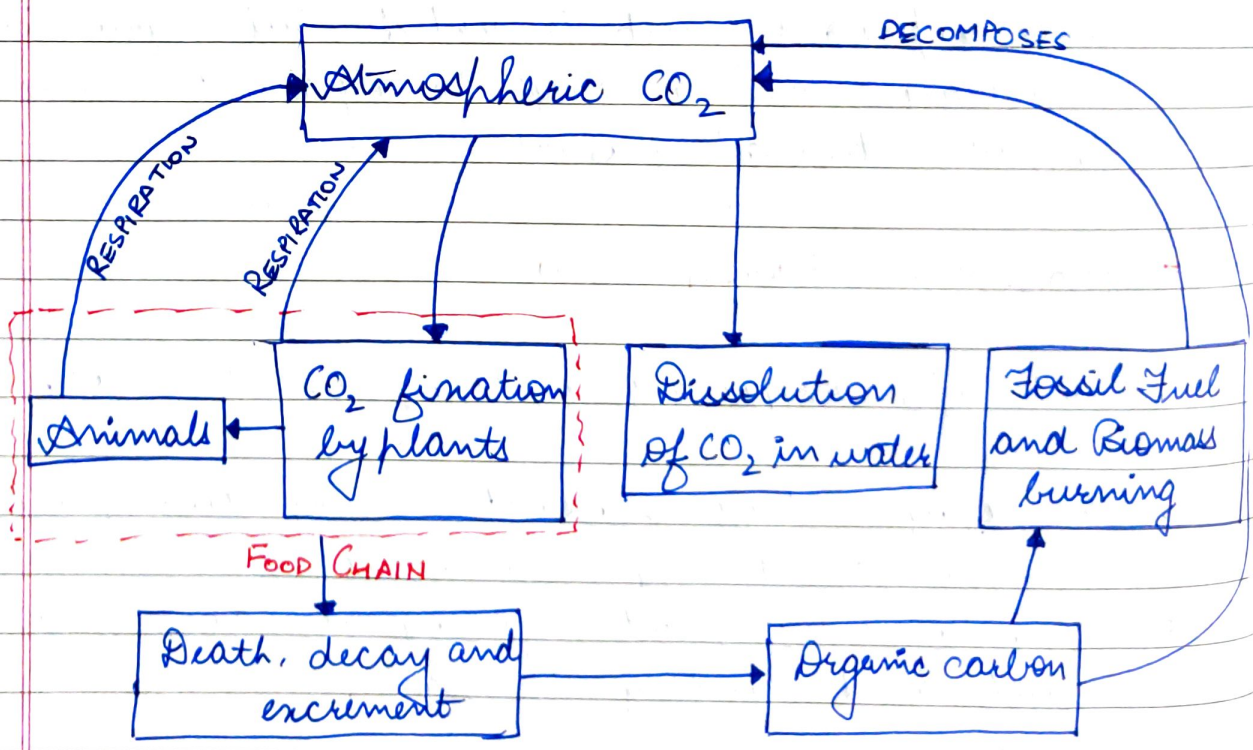
to environment.

* → NATURAL CYCLES: Bio-geo-chemical cycles:

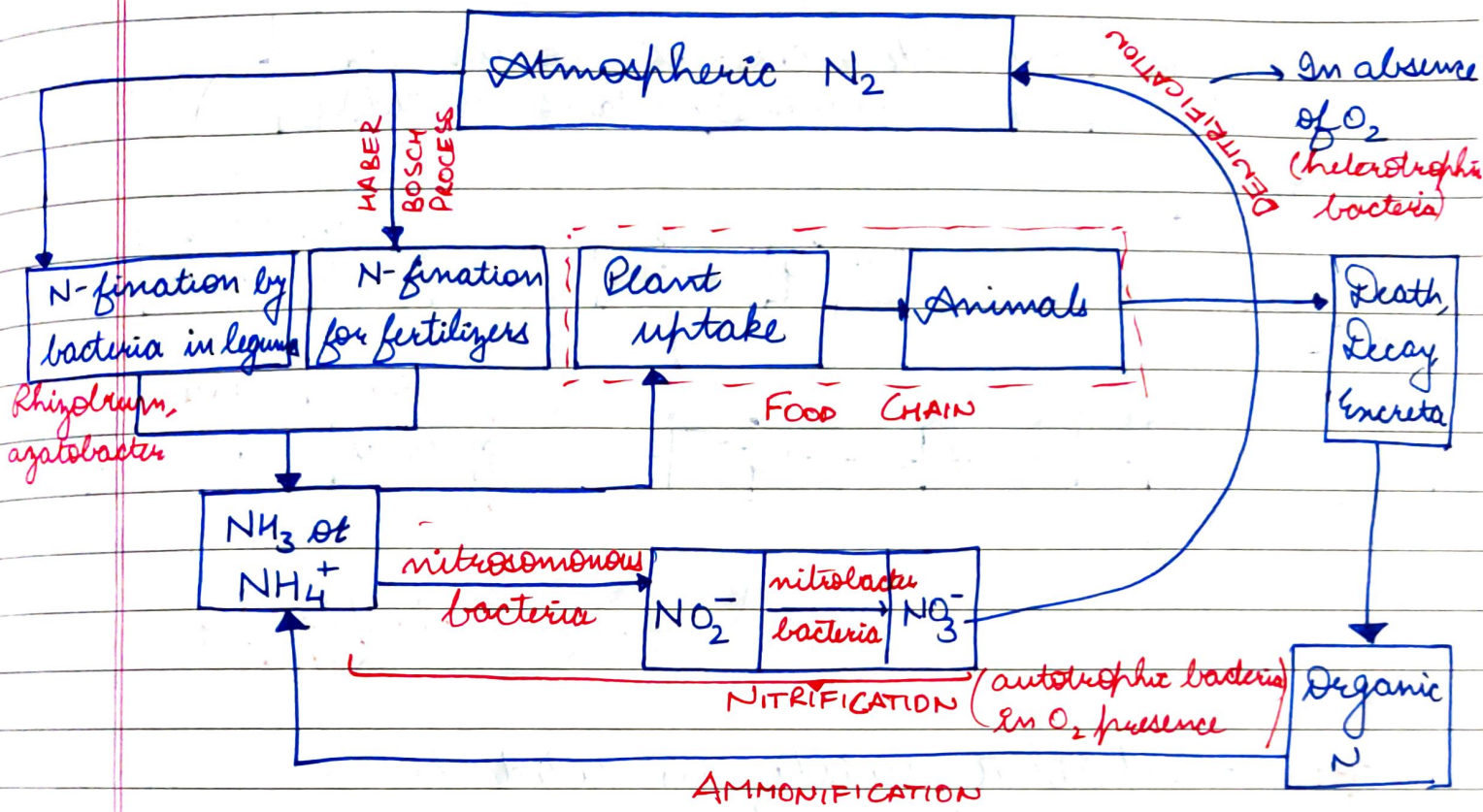
1. Carbon cycle
2. Nitrogen cycle
3. Phosphorus cycle

NOTE: The name biogeochemical comes from the fact that all elemental cycles occur between biotic (bio) components using elements from earth (geo) & through chemical processes (chemical).

→ CARBON CYCLE



→ NITROGEN CYCLE



NOTE: Nitrogen and carbon have gaseous end products due to which their removal from ~~eg~~ ecological cycle is easy. This is not the case with P. Pond accumulated in water bodies, etc is not easy to remove.

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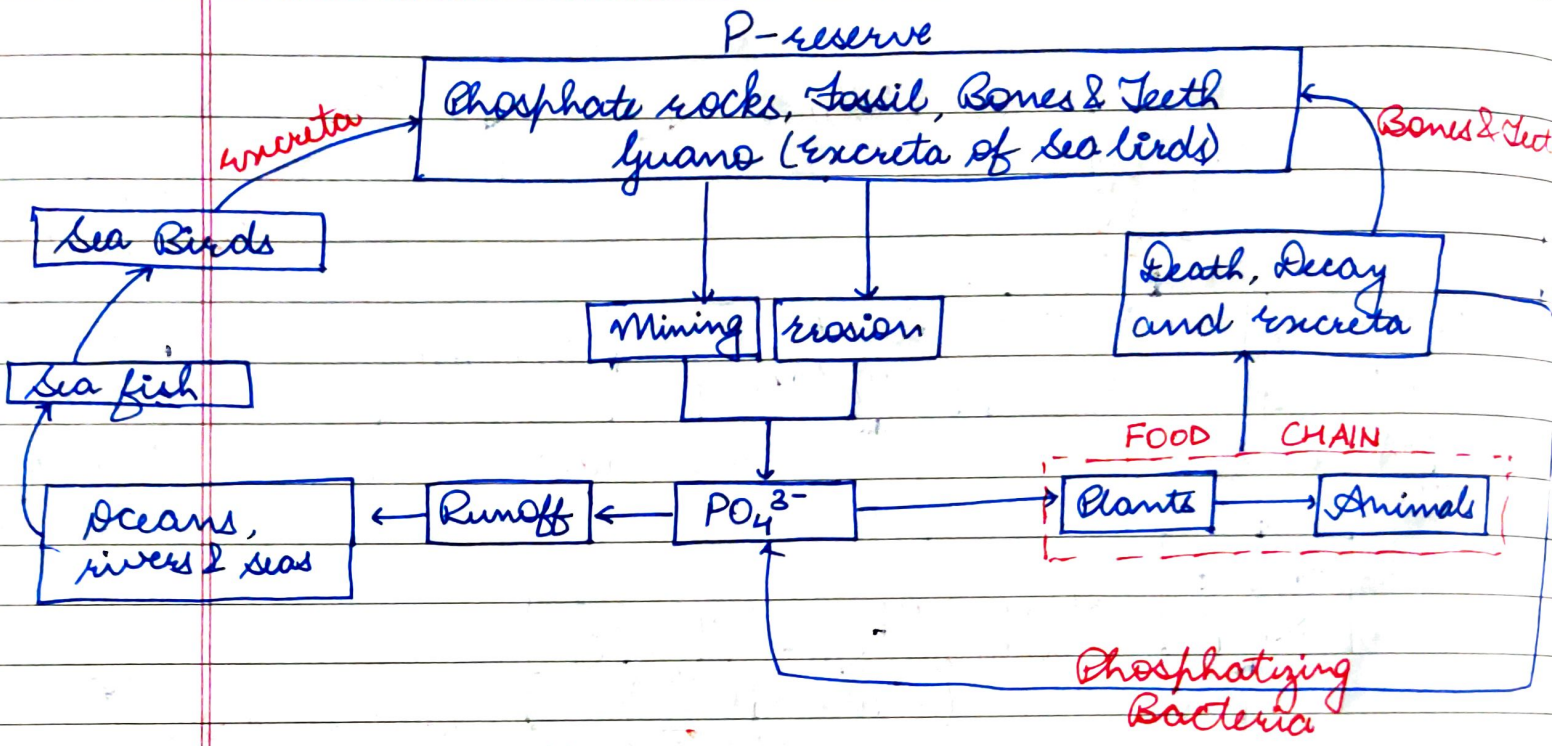
→ PHOSPHORUS CYCLE



NOTE: Phosphorus exists in solid form only. Therefore it is not easy to remove when mixed in water. The only biological procedure for reducing its concentration is the phosphatizing bacteria which will assimilate phosphorus for itself for division thus reducing concentration. It also form PO_4^{3-} however.

* → INDIA AS A MEGADIVERSITY NATION

- India is one of 18 - mega diversity nations.

- The Indian govt. (2000) recorded 47000 species of plants & 81000 those of animals which forms a huge percentage of global flora and fauna.

* → THREATS TO BIODIVERSITY

- Extinction ~~of~~ or elimination of species is natural process but humans have aggravated it.
- eg- earthworms are rather rare due to excess fertilizer use.
- The HIPPO model suggests the ways in which environment is being hampered
  H- Habitat Destruction
  I- Invasive Species
  P- Pollution
  P- Population (humans)
  O- Overharvesting.

* → ECONOMIC GROWTH VS ENVIRONMENT PROTECTION

- Industries are a major part of ~~economy~~ economy
- Industries are primarily of four types -

i) Primary Industries: These industries ~~operate~~ are involved in extraction and harvest of raw materials. eg- agriculture, mining

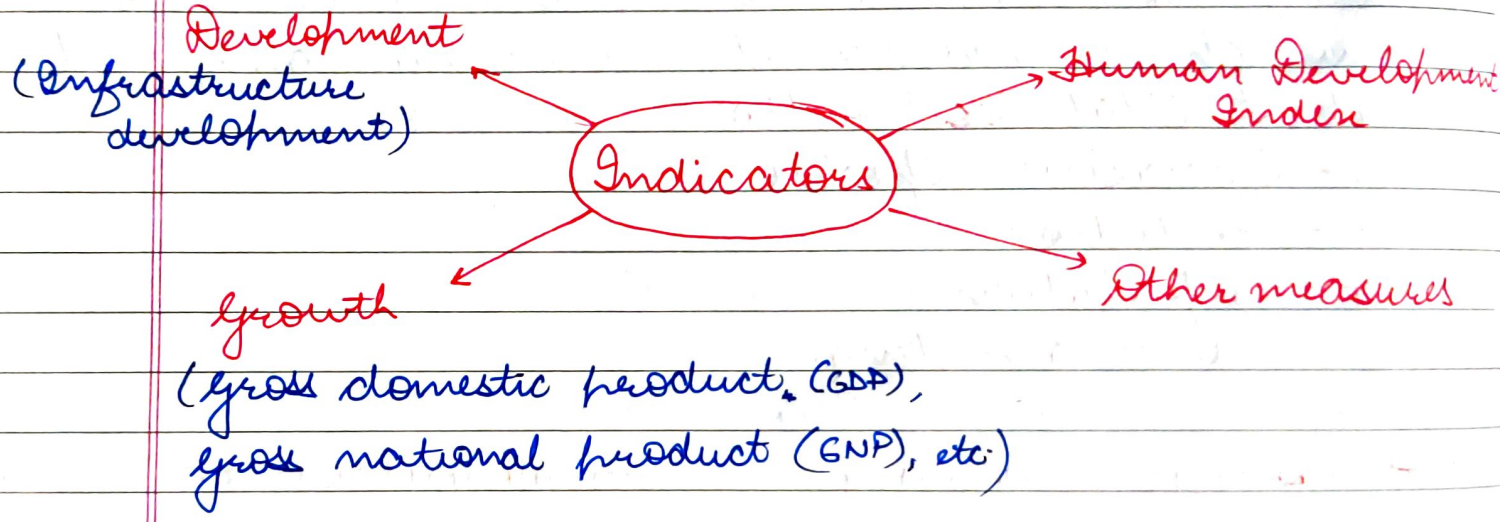
ii) Secondary Industries: They operate on raw materials from primary industries. eg- cloth industry

iii) Tertiary industries: They provide services to the other industries. eg- telecom industry

iv) Quaternary Industry: Industries involved in idea making. eg- IT industries.

- These industries & economic growth go hand in hand with environ. degradation.

- Indicators of economic development



* → UNITED NATIONS MILLENIAL DEVELOPMENT GOALS (UN MDG) and ENVIRONMENT

- 6 goals formed to ensure all over development through the millenium

- The goal was to achieve them by 2015.

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- The goals

i) eradication of extreme poverty and hunger

ii) Achieve universal primary education

iii) Reduce child mortality

iv) Improve mental health

v) combat major diseases

vi) Ensure environmental sustainability.

Look at their relations with environment in the slides.

Chapter 3
Water Resources

→ INTRODUCTION

- We are nearly facing global water shortage.
- In the global hydrological cycle, humans are tinkering with the residence time of water.
- Residence Time : Residence Time of water is the time for which it will stay at a particular position / location.
  eg— residence time of glaciers is thousands of years & that of ponds is maybe a few days.
- Residence time may vary from few days to thousands of years.
- 97% water resides in oceans and is not worth usage. 2% of freshwater is available, which we waste and abusi.

classmate

Date

Page

HYDROLOGIC CYCLE →

- The entire phenomenon of evap. & preci. that continues forever and maintains the balance b/w loss of water to the atmosphere as vapour from the earth and in gain of water by preci. such as rain, snow, hail, dew, etc. is referred to as hydrologic cycle.

- Water run off over the surface of earth is called surface run-off and that below the surface is called sub-surface run-off.

- The distribution of water in hydrologic cycle is not uniform. It is concentrated at lakes, oceans, ice caps etc. but is at low levels on the surface.

- This cycle of water amongst earth, oceans, and atmospheric systems is known as Hydrologic cycle where Sun and Coriolis force play important role in its completion.

SALIENT FEATURES OF HYDROLOGIC CYCLE

i) Water is conserved: neither created nor destroyed.

ii) Not equally distributed.

iii) Oceans have largest amt. of water but it is saline and undrinkable

iv) Ice caps, and glaciers have largest amount of freshwater (75% approx) followed by groundwater and then rivers & streams.

→ COMMON FORMS OF PRECIPITATION

a). Drizzle or mist (droplets of diameter less than 0.5mm)

b) Rain (droplets of size b/w 0.5mm & 6mm)

c) Snow (combined ice crystals of specific gravity around 0.1)

d) Sleet (rain water drops falling through air at or below freezing temp. turned to frozen rain drops)

e) Hail (precipitation in the form of ice ball of diameter more than abt. 8 mm)

- Most of the ~~rainfall~~ precipitation is generally in form of rains. ∴ the terms precipitation and rainfall are considered synonymous.

- Rainfal, ie liquid precipitation is considered light when rate of rainfall is up to 2.5 mm/hr, moderate when the rate is b/w 2.5mm/hr and about 7.5mm/hr and heavy when rate is higher than abt 7.5mm.

GROUND WATER AND SURFACE WATER

- Groundwater
- Water located below water table
- saturated conditions.

- Recharge zones
- Locations where surface waters move into the groundwater.

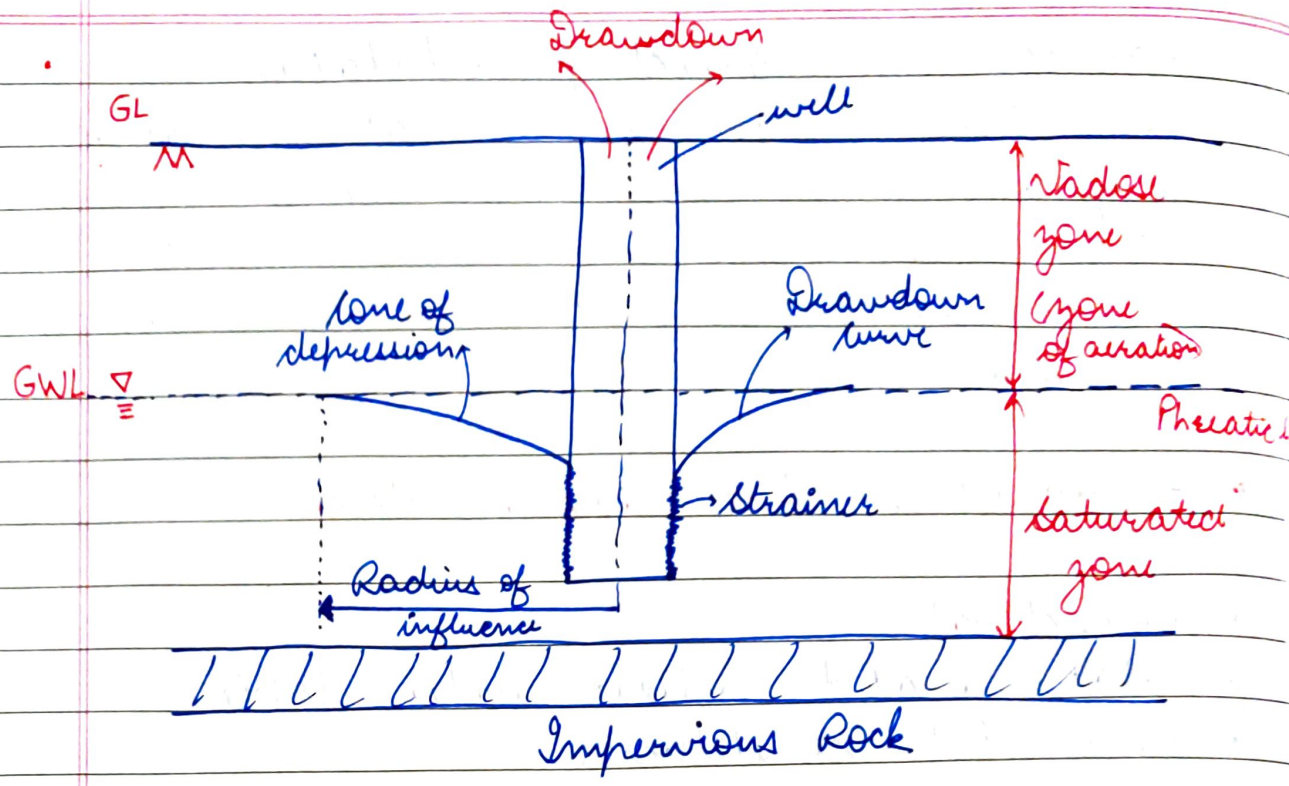
- Discharge zones
- Locations where water flows or seeps out of groundwater.

- Vadose zone
- Area where water seeps through pore spaces.

- Aquifier
- Underground zone from which ground-water can be obtained.

- Cone of Depression
- Forms in water table elevation when water is pumped from an aquifier.

NOTE: Confined aquifers are found between impervious rocks on both sides of water, whereas unconfined is only confined below the water.



- The vadose zone is unsaturated zone as water concentration there is not at its highest. There are some air pores for aeration.

NOTE: The pressure at ground water level is atmospheric pressure.

- Streams

a) Effluent stream

- Flow is maintained during dry season as well, by seepage into channel from subsurface
- Perennial stream - flows all year.
- Its level is essentially below the GWL.

b) Influent stream

- entirely above the water table and flows only in direct response to precipitation.

- ~~Ephe~~ Ephemeral stream.

- A stream can have reaches that are both of these, or intermittent at varying times of year.

* WATER USE

1. OFF STREAM USE

- Refers to water removed from its source for use.
- May be returned back
- Consumptive use:
  Usage in which water is not returned to source.
  eg- a) Plants and animals
  b) Industrial use

2. IN STREAM USE

- Water usage takes place within the stream itself. eg- navigation, hydroelectricity.

* WATER CONSERVATION →

a) Careful use and protection of water resources
- Involves both quantity and quality of water.
- Important component of sustainable water use.

b) Three components
- Agricultural use
- Domestic use
- Industrial use

c) Advanced planning of Water Management

- Reuse of wastewater
- Develop surface water and use groundwa in dry years.
- In wet years pump excess surface water underground to recharge groundwater

WATER QUALITY

PARAMETERS OF WATER QUALITY

1. PHYSICAL

a) Temperature b) Conductivity c) Colour
d) Solids e) Turbidity

2. CHEMICAL

a) pH b) Alkalinity c) Hardness d) Dissolved Oxygen e) Chemical Oxygen Demand (COD) f) Biochemical Oxygen Demand (BOD) g) Total Organic Carbon (TOC) h) Nitrogen (Org-N, NH_4^+, NO_2^-, NO_3^-, (TKN)] i) Phosphorus
j) Cations including heavy metals.
k) Anions (F^-, Cl^-, SO_4^{2-}, S^{2-}, CN^-)

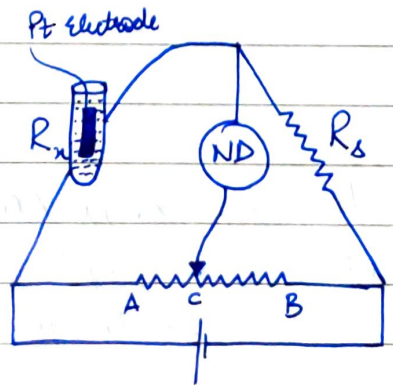
3. MICROBIOLOGICAL

a) Coliforms (Total & Fecal)

1 PHYSICAL

b) Conductivity

- Measure of electricity carrying capacity of water
- Conductivity of a water sample gives us a measure of the conc. of dissolved (inorganic) ions in that samples.
- Water with high conductivity generally has high dissolved solid conc.
- Waters with high dissolved solids often have unpleasant tastes, and hence are not suitable for drinking.
- Unit of measurement for conductivity is siemens (S) or mho/cm (mho = ohm^{-1})
  [1 S = 1 mho/cm]
- We measure conductivity using wheatstone bridge as



For zero current in (ND), we have a condition

$$\boxed{\frac{R_x}{R_{AC}} = \frac{R_s}{R_{CB}}}$$

Consider Ohm's Law

$V = IR$

$R \propto l/A$

$R = \rho l/A$

$\rho \rightarrow$ Resistivity

Conductivity $\boxed{K = 1/\rho}$

For instrument calibration, we use a standard solution of 0.01 N KCl sol^n.
For this, we know $K_{std} = 0.001412$ S
We measure R_{std} and obtain our calibration const. or cell const. as:

$$\boxed{C = K_{std} R_{std}}$$

Now for any random calculation of conductivity

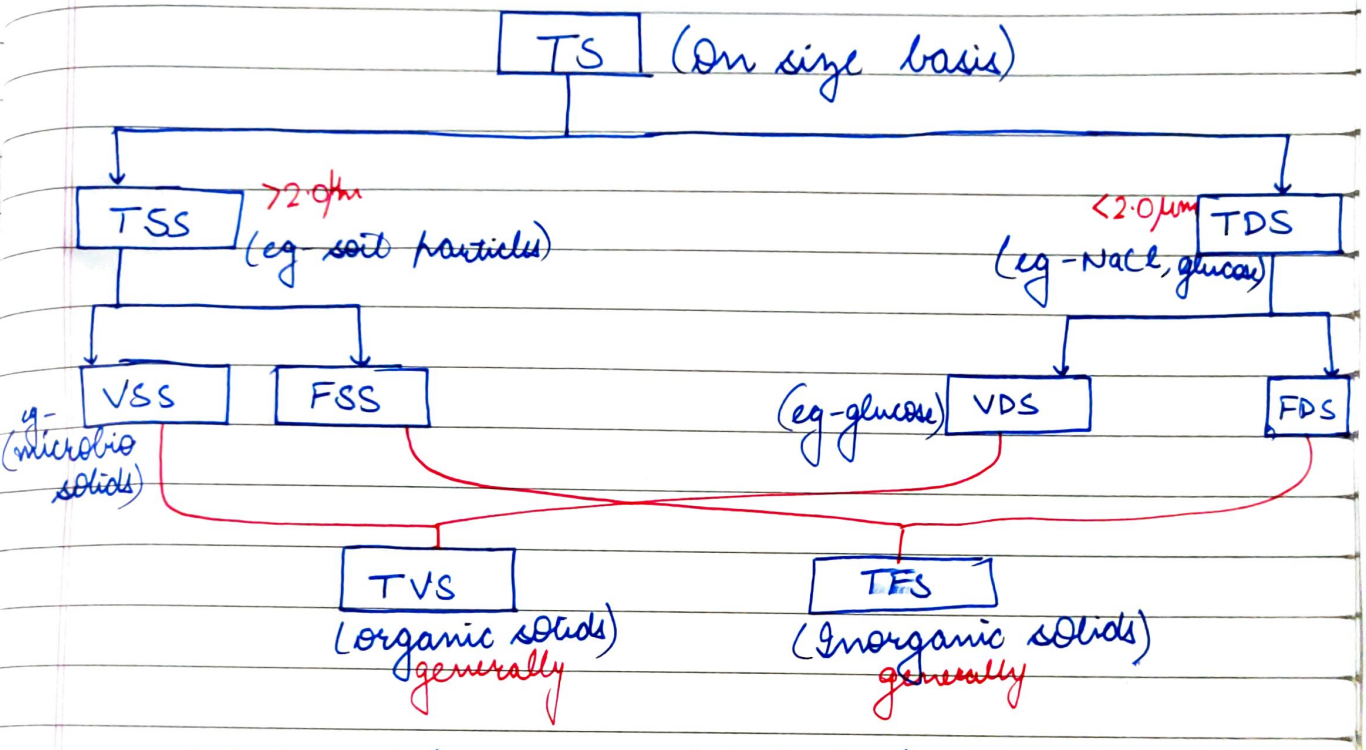
$$\boxed{K_{sol^n} = \frac{C}{R_{sol^n}}}$$

d) Solids

- We classify solids in this case as the residue material left when the water is heated at 103°C to 105°C overnight.
- At this temperature, water + all the

materials with higher vapour pressure (ie more volatile materials) vapourize away.

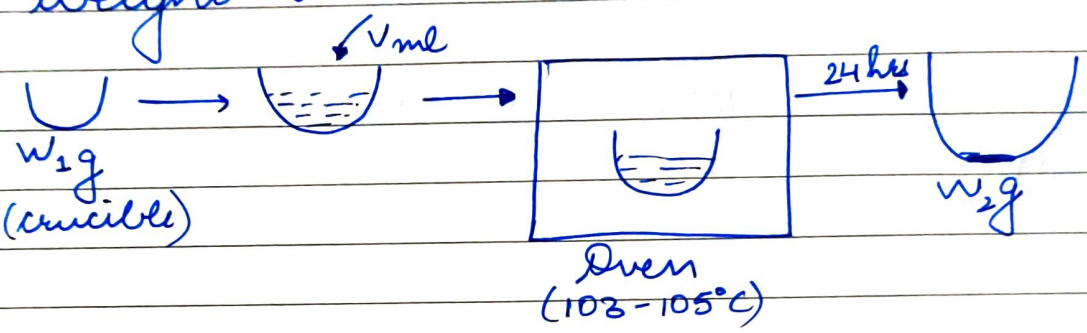
Solid classification



TS: Total solids; TSS: Total Suspended solids TDS: Total Dissolved solids; VSS: Volatile Suspended solids; FSS: Fixed suspended solids; VDS: Volatile dissolved solids; FDS: Fixed Dissolved solids; TVS: Total volatile solids TFS: Total fixed solids.

- Total solids in a sample consist of total dissolved solids and total suspended solids.
- Gravimetric methods for separation

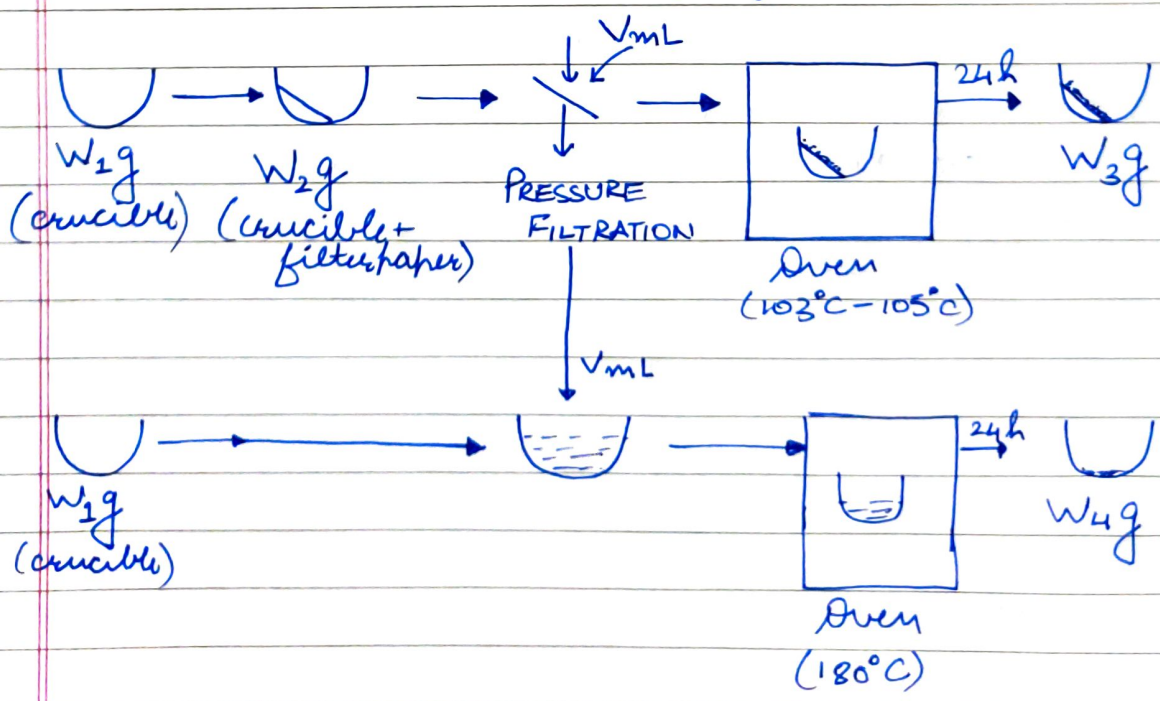
TS → To determine weight, we take a crucible & weigh it, add sample, vaporize the water and weigh it again. The difference in weight



$\therefore TS = \frac{W_2 - W_1}{V}$

convert it to mg/L

TSS & TDS → TDS pass through filter paper with 2 μm or smaller pores and remains as residue upon evaporation and drying at 180°C overnight.



$TSS = \frac{W_3 - W_2}{V}$

$TDS = \frac{W_4 - W_1}{V}$

NOTE: TDS need to be heated at high temperatures (180°c) because TDS bind to water strongly. To completely remove water, we need high amounts of heat.

TFS & TVS → Total solids → W_2 gms in W_1 g crucible → muffle furnace → W_3 g

$$\therefore \boxed{TFS = \frac{W_3 - W_1}{V}} \quad \& \quad \boxed{TVS = \frac{W_2 - W_3}{V}}$$

We can find VSS, FSS, VDS, FDS similarly

NOTE:
- Fixed solids correspond to the matter that remains as residue upon muffling (ignition) at 550°c for 1 hour or 600°c for 15 min.
- muffling helps in pyrolysis of volatile compounds. Volatile compounds are limited to organic compounds only.

$$C_x(H_2O)_y \longrightarrow xC + yH_2O\uparrow$$
$$xC + O_2 \longrightarrow CO_2\uparrow$$

NOTE: Substances like NH_4HCO_3 and $MgCO_3$ can give errors in TFS since they liberate CO_2 upon heating.

$$NH_4HCO_3 \xrightarrow{105°C} NH_3\uparrow + CO_2\uparrow + H_2O\uparrow$$

$$MgCO_3 \xrightarrow{350°C} MgO + CO_2$$

9 Colour

- Determined by visual comparison
- The colour in natural waters is due to the presence of natural organic matter (NOM) ie dissolved extracts of rotting leaves, trees etc. picked up by water flowing over the ground as runoff.

NOM → Humic Substances → -ve colloid
yellowish brown colour.

- Colour in domestic wastewaters due to presence of human wastes (excreta).
- Colour in industrial wastewaters due to specific chemicals ie dyes etc.
- Colour
  - True
    on removal of suspended solids. It is kinda yellowish brown.
  - Apparent
    Coloured by presence of suspended solids.
- Unit of measurement for colour is

$$\boxed{mg\ Pt\text{-}Co/L}$$

We use Pt and Co combination (inspite of costs) because platinum with a tinge of cobalt gives a colour which exactly resembles the natural yellowish brown colour.

classmate
Date
Page

We mix

1.246 g K_2PtCl_6
+
1.0 g $CoCl_2.6H_2O$

→ 500 ml Distilled, deionized water (100 ml HCl)

↓ distilled water

dilutions 1000 ml (500 mg Pt-Co/L)

10 20 30 ----- 100 mg Pt-Co/L

Turbidity

Scattering of light by suspended (particulate) or colloidal matter in water, gives water a turbid appearance.

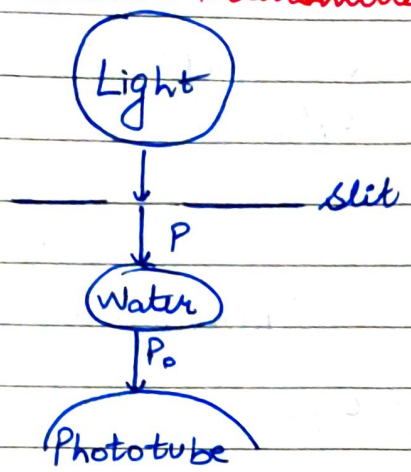
Turbid waters have an aesthetically unappealing quality, and hence are unsuitable for drinking purpose.

Additionally turbid water may also contain a high conc. of microorganisms

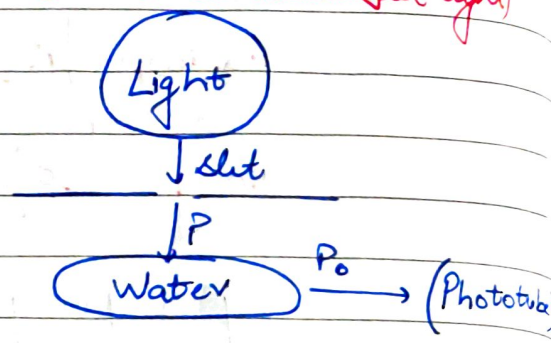
Unit of measurement for turbidity is NTU (Nephelometric Turbidity Unit)

We have 2 processes for turbidity analysis:

Turbidimetry
(measures transmitted light)

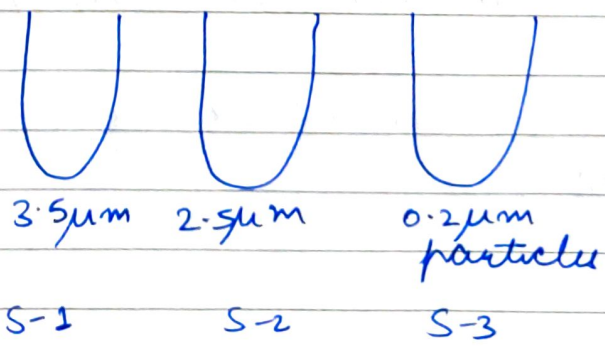


Nephetometry
(measures scattered light)



- Turbidimetry was followed in the past and turbidity measurement unit was Jackson Turbidity Unit (JTU)
- Nephelometric measurement is a modern method & unit is Nephelometric Turbidity Unit (NTU)
- The light used may be visible or infrared

Q- which of these ~~set~~ samples will show highest turbidity?



100 mg/L all

Ans: S-2.

S-3 is a dissolved solid ie (< 2μm) size
∴ it won't cause scattering.

b/w S1 and S2, S2 has smaller particle size ∴ more surface area per unit volume for scattering. ∴ S2

2. CHEMICAL

a) pH

- $pH = -\log_{10}[H^+]$ $[H^+]$ in moles / litre

- At 25°C $[H^+][OH^-] = K_w = 10^{-14}$

- At 0°C pH = 7.5
  60°C pH = 6.5

Q→ What will be pH of deionized distilled water when boiled in a beaker in lab?

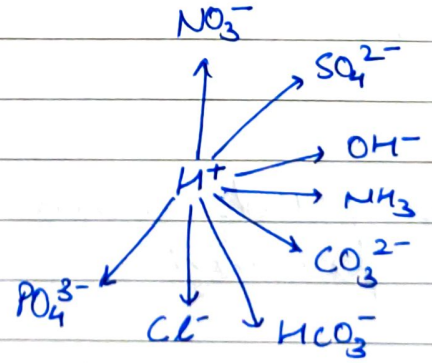
Ans: Slightly ~~greater~~ less than 7 due to CO_2 dissolution

b) Alkalinity

- measure of acid neutralizing capacity (ANC) of water sample expressed as mg/L of equivalent of $CaCO_3$
- Alkalinity in water is caused by presence of following ions CO_3^{2-}, HCO_3^-, hydroxyl, etc.
- Total alkalinity of water is sum of CO_3^{2-}, HCO_3^- & OH^- conc.
- Alkalinity (mg/L as $CaCO_3$)

  = M^- (in mg/L) × Eq. weight of $CaCO_3$ i.e. 50 / Eq. wt. of M^-

  anions

- 

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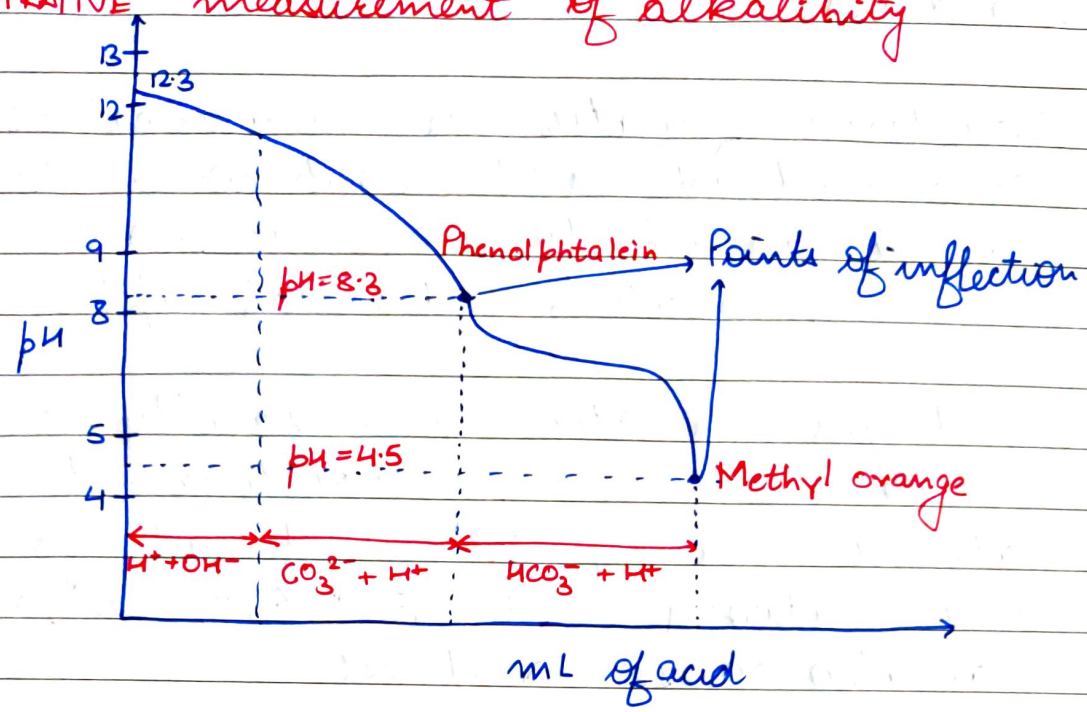
Titrative measurement of alkalinity



- pH < 4.5 : All aq. carbonate species is present as $H_2CO_3^*$ (ie either $CO_{2\,(aq)}$ or carbonic acid)
- 4.5 < pH < 8.3 : $H_2CO_3^*$ and HCO_3^- will dominate
- 8.3 < pH < 12.3 : HCO_3^- and CO_3^{2-} will dominate
- pH > 12.3 : All aq. carbonate species is present as CO_3^{2-}

c) Hardness

- Hardness of water on economical aspect is considered as the soap consuming capacity or ability to resist foam or lather formation upon soap application.

- Hardness of water is generally caused due to presence of multivalent cations mainly Ca^{2+} and Mg^{2+} in water. Other cations like Fe^{2+}, Mn^{2+}, Sr^{2+}, Al^{3+}, Fe^{3+} & Mn^{3+} may also cause hardness.

- Total hardness is sum of Ca^{2+} & Mg^{2+} conc.

- Unit of measurement is mg/L as $CaCO_3$

- Hardness (mg/L as $CaCO_3$)

$$= M^{2+} \text{ (in mg/L)} \times \underbrace{\text{EW of } CaCO_3}_{\text{i.e. } 50/\text{EW of } M^{2+}}$$

- Alkalinity and Hardness

Alkalinity	Hardness
Total titratable bases	Total divalent salts
HCO_3^-	Ca^{2+}
CO_3^{2-}	Mg^{2+}
$Ca(HCO_3)_2$	$Mg(HCO_3)_2$
$CaCO_3$	$MgCO_3$

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- Consider

H → Total Hardness (Ca^{2+} and Mg^{2+}) in mg/L as $CaCO_3$

T → Total alkalinity (HCO_3^- + CO_3^-) in mg/L as $CaCO_3$

Case I : H > T

Carbonate Hardness (CH) = T
Non-carbonate Hardness (NCH) = H-T

Case II : H ≤ T
CH = H
NCH = 0

d) Dissolved Oxygen (DO)

- DO in natural waters is of great importance as it is critical for aquatic ecosystem sustainability.
- DO is derived from atmosphere or oxygen producing biological processes.
- normal DO for a surface water body ranges from 8-10 mg/L, while the value for groundwater may be as low as 1-2 mg/L
- DO < 4 mg/L may lead to aquatic wildlife deaths.

- DO in water is governed by Dalton's law of Partial Pressure and Henry's law

- **Dalton's law**

$O_2 + N_2 + CO_2$

$$P_{O_2} = \frac{x_{O_2}}{x} \times P$$

P_{O_2} → O_2 pressure

P → total pressure

x → mole fraction

or say

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

V → volume ratio.

- **Henry's law**

- It governs the dissolved gas concentration in liquid in relation to pressure of gas

$c \propto p_g \Rightarrow \boxed{c = p_g / K_H}$ in $\boxed{mg/L}$ ← convert to

↳ you get result as per units of K_H

Q→ Calculate O_2 conc. in water i.e. DO at 20°C

$(K_H)_{20°C} = 0.73$ atm-m³/mol

Ans:

$$P_{O_2} = \frac{21}{100} \times 1 \text{ atm}$$

$$c = \frac{21}{100 \times 0.73} \text{ mol/m}^3$$

$$\Rightarrow c = \frac{21}{73} \times 32 \text{ g/m}^3 \Rightarrow c = 9.205 \text{ mg/L}$$

- Henry's law is an equilibrium law and does not give rate of transfer of dissolved oxygen.

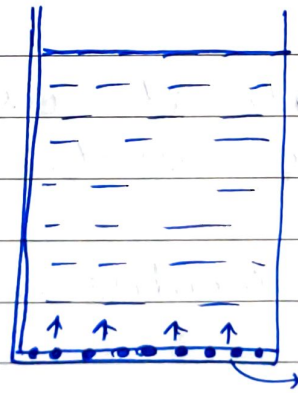
- Following Henry's law, the rate of oxygen transfer in water is given by:

$$\boxed{\frac{dc}{dt} = K_L a (C_s - C)}$$

where, C_s = Saturated O_2 conc., mg/L
C = O_2 conc. at any time 't', mg/L
$K_L a$ = Oxygen transfer rate coefficient, h^{-1}
$C_s - C$ = Dissolved Oxygen deficit, mg/L

- Natural dissolution rate is very slow & to increase rate, engineered systems like these could work.

i)



bubble aerator at base of WTP

Due to high P, we get faster dissolution rate.

ii) Surface aerator decreases particle size of water by aerating it thus increasing dissolution rate.

e) Oxygen Demand

- It is measure of amount of organic and inorganic matter present in water (which demands O_2 eg- respiration, nitrification)

- Relates to O_2 consumption due to pollution as well

- 3 subdivisions

i) Theoretical Oxygen Demand (ThOD)
ii) Chemical Oxygen Demand (COD)
iii) Biochemical Oxygen Demand (BOD)

i) Theoretical Oxygen Demand (ThOD)

- We can estimate it using concentration of compounds present.

- We theoretically oxidise them to calculate ThOD

- Generalized balanced eqn

$$C_nH_aO_bN_c + \left(n + a/4 - b/2 - \frac{3}{4}c\right) O_2 \longrightarrow nCO_2 + \left(\frac{a}{2} - \frac{3c}{2}\right) H_2O + cNH_3$$

- Practice for: Sucrose ($C_{12}H_{22}O_{11}$), Glycine ($C_2H_5NO_2$), $C_5H_8KO_4$, Acetic acid (CH_3COOH) etc

ii) Chemical Oxygen Demand (COD)

- COD is the amount of oxygen that will be required to completely oxidise all the organic matter.

- Measure of oxygen eq. of organic matter present in the water sample is susceptible to oxidation by a strong chemical oxidant (acid + heat)

- Known (but excess) amount of $K_2Cr_2O_7$, a strong oxidising agent is added to the sample under acidic conditions to find the amount of organic matter.

- Acidic condition is ensured by addition of conc. H_2SO_4 in presence of Ag_2SO_4 as catalyst.

- mixture heated (digested) at $150 \pm 2°C$ for 2 hours.

- Expressed in mg/L.

- 1.5 ml $K_2Cr_2O_7$
  + 3.5 ml of H_2SO_4 (Ag_2SO_4)
  + 2.5 ml sample

  $\xrightarrow{\Delta}$ $150 \pm 2°C$ for 2 hrs.

SAMPLE

- We also prepare a sol^n 1.5 ml $K_2Cr_2O_7$ + 3.5 ml H_2SO_4 + 2.5 ml distilled water called blank. It is prepared for reference.

- we check amount of residual $K_2Cr_2O_7$ in the sample to estimate COD. This is done by taking ~~reference and~~ blank into consideration

Q- If ThOD = COD, then find COD for 100 mg/L $CO(NH_2)_2$ (urea)

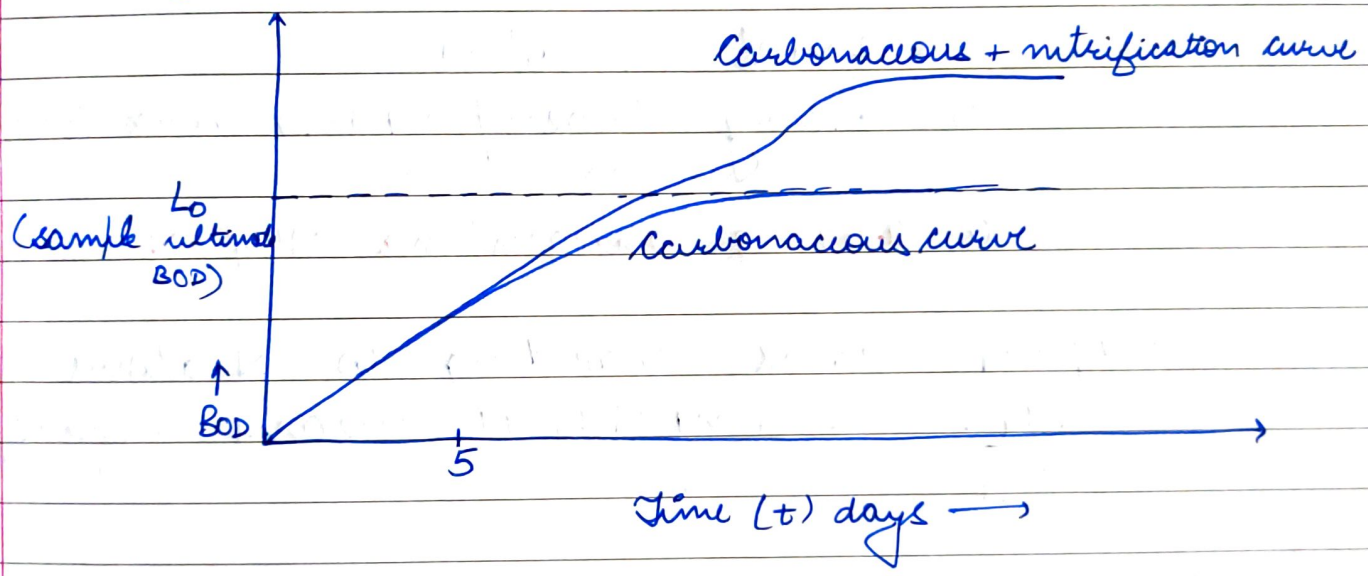
EXAM ME AYEGA

iii) Biochemical Oxygen demand (BOD)

- BOD is the amount of dissolved oxygen utilized by microbes for biochemical oxidation of organic (carbonaceous BOD) and inorganic (nitrogenous BOD) matter
- BOD determination involves the measurement of the dissolved oxygen (DO) used by microorganisms in biochemical oxidation of organic matter.
- Biochemical oxidation is a slow process & theoretically takes ∞ time for completion.
- within 20 days, oxidation is abt. 95-99% and 60-70% within 5 days.

- 5 day (BOD_5) at 20°C is most widely used parameter.
- BOD_5 at 20°C is equivalent to BOD_3 at 27°C.
- Expressed in mg/L.
- CBOD + NBOD ⟶ BOD

The graph for BOD is as:



Carbonaceous demand & nitrification demand go hand in hand

$$\underset{(org)}{C} + O_2 \xrightarrow{CBOD} CO_2 \qquad NH_4^+ \longrightarrow \underset{NBOD}{NO_2^-} \longrightarrow NO_3^-$$

- The bacteria responsible for carbonaceous demand (Heterotrophic ~~autotrophic~~ bacteria) divide rapidly ∴ increasing CBOD immediately

Nitrosomonas and Nitrobacter (autotrophic bacteria) divide slowly thus NBOD is initially negligible.

- Nitrogenous BOD (NBOD) →

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

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

Total rxn

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

Oxygen demand

= 2 mol O_2 / mol NH_3

i.e. 3.76 mg oxygen / mg ammonia (NH_3)

i.e. 4.57 mg oxygen / mg NH_4^+-N

NOTE: NH_4^+-N means according to N atoms in NH_4^+. ∴ 1 mg NH_4^+-N means 1 mg of N in NH_4^+.

~~NOTE~~ EXAM ME AYEGA

Q→ Alkalinity requirement in nitrification is 7.14 mg as $CaCO_3$ / mg NH_4^+-N. Show this.

- Calculation of BOD_5
- Case 1: When unseeded dilution water is used.

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

where

DO_i = initial DO conc

DO_f = final DO conc.

P = volumetric fraction

D = dilution factor $= \frac{1}{P}$ = Total volume / sample volume

NOTE: We dilute the sample with distilled deionized water and then perform calculations.

- Case 2: When seeded dilution water is used.

Seeding: It is a process under which we artificially introduce microorganisms into our sample. It is used in cases where our sample doesn't have microorganisms. eg- industrial waste.

Dilution ensures decrease in toxicity of water such that the microorganisms survive.

$$\boxed{\underset{(mg/L)}{BOD_5} = \frac{(D_i - D_f) - f(B_i - B_f)}{P}}$$

where D_i & D_o = initial DO and final (5day) DO of mix respectively.

B_i and B_f = initial DO & 5day DO of seeded blank

P = volumetric fraction.

f = fraction of seed in the incubated sample $= 1-P$

BOD KINETICS

- BOD_5 only represents the oxygen consumed in 5 days and is about 60 – 70% of total BOD or ultimate BOD.

- Total BOD or ultimate BOD or BOD at any time period can be determined knowing the BOD kinetics.

- Assumption:

Refer to slides for BOD Kinetics

Q→ Consider 2 samples

S-1 $K_1 = 0.15 d^{-1}$

S-2 $K_2 = 0.47 d^{-1}$

Consider S_1 & S_2 are at same temp and no. of microorg. are also same. Then what does difference in K value indicate ?

Ans: Biodegradability. S-2 is more biodegradable

- COD vs BOD

- COD does not distinguish b/w biodegradable and non-biodegradable organic matter whereas BOD only measures biodegradable organic matter.

- COD is not specific to oxygen-consuming organics or inorganics whereas BOD is specific to oxygen consuming organic or inorganic compounds.

- COD and BOD do not necessarily measure the same types of oxygen consumption.

- COD determination requires less time (2-3 hrs) as compared to BOD determination (5d)

~~COD > BOD~~

- ThOD ≥ COD > BOD

- But for this course ThOD = COD = BOD

8 Total Organic Carbon (TOC)

- TOC is a general measure for organic pollutants mass in water/wastewater (similar to COD but more precise).

- TC (Total Carbon)
  - TOC (Total Organic Carbon)
    - DOC (Dissolved Organic Carbon) ⇒ f(VDS)
    - POC (Particulate Organic Carbon) ⇒ f(VSS)
  - TIC : simply IC (Total Inorganic Carbon)

g) Nutrients : Nitrogen

- Nitrogen forms are found in water as (expressed in mg-N/L)
  - Dissolved gaseous N_2
  - Dissolved free (unionized) ammonia (NH_3)
  - Ionized ammonia (NH_4^+)
  - Nitrite ion (NO_2^-)
  - Nitrate ion (NO_3^-)
  - Organic nitrogen.
- In surface water samples, nitrogen is present mainly as NO_3^- which is most oxidised nitrogen form.

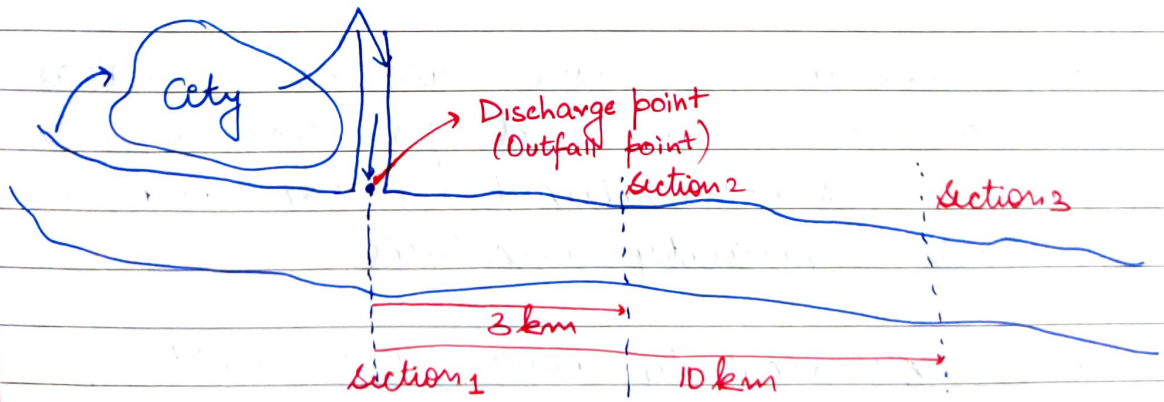
In groundwater samples nitrogen may be present as both nitrate & nitrite.

In raw wastewater samples, an in water contaminated with domestic and industrial water, nitrogen is mainly present as ammoniacal nitrogen ($NH_4^+ - N$ or $NH_3 - N$) & organic nitrogen (org-N)

- Total Kjeldahl nitrogen (TKN) = $NH_4^+ - N$ + org-N and expressed in mg $NH_4^+ - N$ / L

- Depending on pH (at 9.3) of water system free & ionized ammonia are in equilibrium acc/to the following eqn:

$$NH_4^+ \longrightarrow NH_3\uparrow + H^+$$

- 

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

h) Nutrients : Phosphorus

- Phosphorus is mainly found in water as soluble mineral phosphate

→ read from slides

→ ROUTINE WATER QUALITY ANALYSIS

- A routine water quality analysis usually includes all major constituents (except carbonic species)

- All the minor constituents (also regarded as trace constituents) are also to be expected.

- Checking the ion balance or charge balance is a good practice to eliminate gross errors induced in the routine water quality analysis.

- Errors mainly arise as a result of

a) Improper sample storage (including sealing of container and

b) Failure to measure rapidly changing on-site parameters in water (eg- pH, alkalinity)

c) Poor or no filtration for removal of suspended solids.

- Errors less than 10% are generally acceptable.

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→ MICROBIOLOGICAL PARAMETERS →

→ read from slides.

NOTE: Coliform bateria group is a group of gram negative bacteria ie they don't retain crystal violet stain used in gram-staining method of bacterial differentiation

→ COMPARISON OF GROUND & SURFACE WATER

WQ	GW	SW
Alkalinity	More	Less
Hardness	More	Less
Turbidity	Less	More
DO	Less	More
Presence of MO (micro-organisms)	Less	More

Due to dissolution of minerals during water seepage

Chapter-4
ENVIRONMENTAL LEGISLATIONS AND STANDARDS

CONSTITUTIONAL DUTY

1. For every citizen →

According to sub-clause (g) of Art 51A, every citizen in India must protect & improve the environment

2. For State

According to Article 48-A (42nd Amendment) ~~every~~ the State (nation as a whole) must take steps for protection and improvement of environment.

→ Informative chapter — read from slides.

NOTE: Indian Railways is the largest consumer of batteries in India.

NOTE: IS 10500:2012 (Indian Standard) is a standard defining water (drinking) standard

NOTE: Requirement (Acceptable limit) for water parameters is applicable in case of multiple sources. whereas, permissible limit is when we have only a single source of water.

NOTE: MPN: most Probable numbers

NOTE: decibel scale

$$\boxed{\text{Sound Level } (L) = \log_{10}\left(\frac{Q}{Q_0}\right) \text{ Bel}}$$

Bel → unit in honour of Alexander Graham Bel

where,

Q = Sound Pressure
or Sound Power
or Sound Intensity.

Q_0 is minimum audible sound pressure ($20\mu Pa$)

$$\therefore \boxed{L = 10 \log_{10}\left(\frac{Q}{Q_0}\right) \text{ deciBel (dB)}}$$

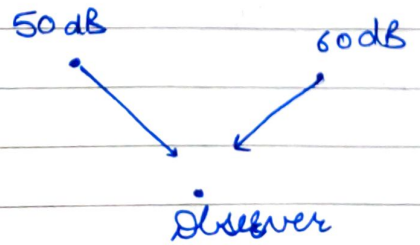
The instruments used for measuring pressure generally measure r.m.s pressure.

∴ we need to write

$$L = 10 \log \left(\frac{p_m}{20\mu Pa}\right)^2 \text{ dB}$$

$$\Rightarrow \boxed{L = 20 \log\left(\frac{p_m}{20\mu Pa}\right) \text{ dB}}$$

Q: Consider



what sound level will be heard by the observer?

Chapter-5
Environmental Sanitation

SANITATION

- Environmental Sanitation refers to provision for defaecation with privacy, dignity and safety while preventing environmental ~~sanitation~~ contamination.

- Isolation of human excreta from water bodies (surface or under-ground)/air/soil until the same is converted into safe usable product.

- Offsite & Onsite measures are necessary (as name suggests)

CHARACTERISTICS OF AN IDEAL TOILET

- Hygienic
- Odourless
- Easy to use
- Not many usable parts.
- Privacy.
- no insect menace
- Safe and usable

BUILDING SANITATION

Two types of toilet pans: Indian & Western.

In rural areas, we collect sewage through manholes into septic tanks where excreta is stored for 6-12 months (but not >3 yrs!) The liquids generated during this period are let out in the environment. Anaerobic decomposition makes it safe for environmental release. There is an outlet for gases to prevent odour.

PRESENT SANITATION MODEL: Conventional water borne sanitation.

WASTEWATER: Includes blackwater (water from ~~fr~~ toilets) and graywater (from kitchen and other sources).

This wastewater is then disposed off

Either directly: In rural regions. The solid waste gets absorbed into soil and liquid waste gets into ground water with pathogens and viruses thus spreading diseases

Through water treatment plants: In India most WTP's are secondary ie they only treat

the carbon content and pollute the rivers through their output.

→ **ALTERNATIVE MODE - ECOLOGICAL MODE SANITATION (Ecosan)**

NOTE: The 2 buttons in flush are for flushing different quantities of water. Smaller button is for urine contents & biggerone for daefacation content.

- In ecological sanitation, we separate blackwater and graywater & yellow water (urine content).

Graywater: Treated and directly used for drinking

Blackwater: Solid & liquid parts separated. Solid part is converted to compost and used in agriculture and liquid part is treated & made drinkable.

Yellow water: Can be directly used for agriculture.

- Also drinkable quality water ~~waste~~ is provided only for anal cleaning and for flushing the water quality can be compromised.

- Ecological sanitation is followed in Southern States as of now (particularly Kerala).

Chapter - 6
Environmental Pollution Control

* → WATER PURIFICATION SYSTEM

- It can be achieved by:

a) Natural Systems: Water quality / characteristics improvement by natural processes

b) Engineered Systems: Engineered system designed to achieve water quality improvement by maximising processes in natural systems.

- Water discharge can be of 2 types:

a) Domestic wastewater
b) Industrial wastewater

- Their treatment is followed by installing water treatment plant:

Water Treatment Plants (WTP's):

a) Sewage Treatment Plant (STP): It is for domestic wastewater

b) Effluent Treatment Plant (ETP): It is a plant in each manufacturing industry for effluent treatment

c) Common ETP (CETP): When multiple factories have common sort of discharge they may request for CETP to be set up.

→ **Drinking water Treatment:**

- Raw water sources:
  The various sources can be categorised as:

a) Surface sources such as ponds and lakes, streams and rivers, storage reservoirs (from water bodies for summers) and oceans (not used for water supplies

b) Sub surface sources: such as springs (when on excessive recharge, groundwater breaks the surface), infiltration well (a well which collects surface runoffs), tubewells, borewells etc.

- The extent of treatment depends on the source and quality of available water.

- Layout for conventional WTP

removal of large floating solids like plastics primarily through straining

Raw water → Screening → Primary Sedimentation → Coagulation Flocculation → Secondary Sedimentation → Filtration → Disinfection → to Supply

- **Screening** → removal of large floating matter from water by straining.

- **Sedimentation** → removal of suspended solids from water. For sedimentation, we increase surface area, thus reducing flow and after some time these particles settle down.

We can devide sedimentation particles in 2 categories.

i) **Type I:** They don't change their shape & size while settling, eg- sand, etc. They have constant velocity while settling down.

ii) **Type II:** They change their shape and size while settling. As they go downwards, they clang with other particles and increase in size. Their velocity increases differentially while going downwards. eg- colloidal particles

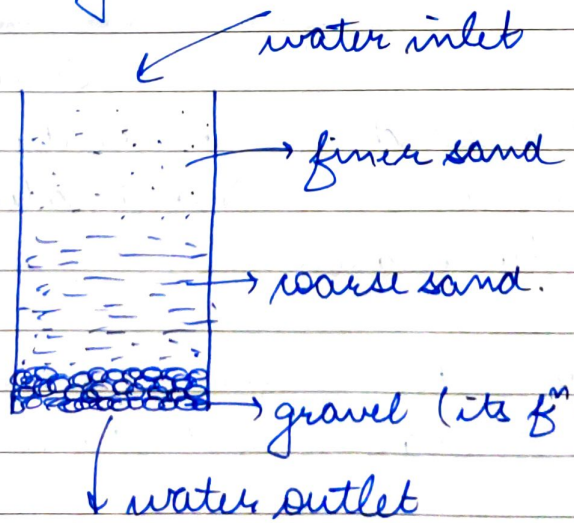
Primary sedimentation is used for type I particles, essentially fixed suspended solids.

NOTE: Colloids consist of negatively charged particles in general.

- **Coagulation**: Colloidal particles are generally -vely charged. ∴ we add ions with high +ve charge to help neutralize the charge else otherwise, the particles won't engage with each other & won't settle down. We generally add chemicals like alum ($Al_2(SO_4)_3$) and mix the water thoroughly so that the particles gang up to form larger particles.

Then, in secondary sedimentation, these particles are allowed to settle down & thus Type I & Type II particles have been removed.

- **Filtration**: There are still some particles which can't be removed from sedimentation. They are removed through filtration.



NOTE: We can' also have a layer of charcoal in b/w)

After some time sand will get ~~fto~~ blocked. To clean it, we ~~take~~ reverse the water flow under high pressure for some time.

- **Disinfection** : Done generally by chlorination.

NOTE: In cases when our water is free from sediments in general, then, we directly add alum & ~~they~~ move to secondary sedimentation.

NOTE: We may also add an aeration step just before screening step. This is done to remove any sort of colour or odour. It may also help in removal of Iron and manganese by oxidising them and making them precipitate.

- **Types of treatment for water from diff. sources**

Source	Treatment
1. Ground water and spring water fairly free from contamination	No treatment or chlorination
2. Groundwater with chemicals, minerals and gases	Aeration, coagulation, filtration & disinfec.
3. Surface water with low pollution	Disinfection
4. Other surface waters with considerable amt of pollution	complete treatment

NOTE: Chlorination oxidises the cell wall of the bacteria / pathogens.

→ WASTEWATER TREATMENT →

- Major objectives of wastewater treatment:

a) So as to avoid any permanent damage to the natural environment.

b) To remove extra carbon content so as to maintain BOD.

c) To remove pathogens so as to minimize biological harm

- Treatment Techniques

Wastewater treatment techniques

- PHYSICAL
  - SCREENING
  - MIXING
  - FLOCCULATION
  - FLOTATION → look at note on next page
  - FILTRATION
  - SEDIMENTATION
  - GAS TRANSFER → lowering of pressure to remove dissolved gases acc. to Henry's law.
- CHEMICAL
  - PRECIPITATION
  - ADSORPTION
  - DISINFECTION
- BIOLOGICAL
  - AEROBIC
  - ANAEROBIC
  - SUSPENDED
  - ATTACHED

NOTE In flotation, we add air from the bottom at high pressures. Due to this materials like grease, oil etc get aerated and come on the surface and can then be skimmed off

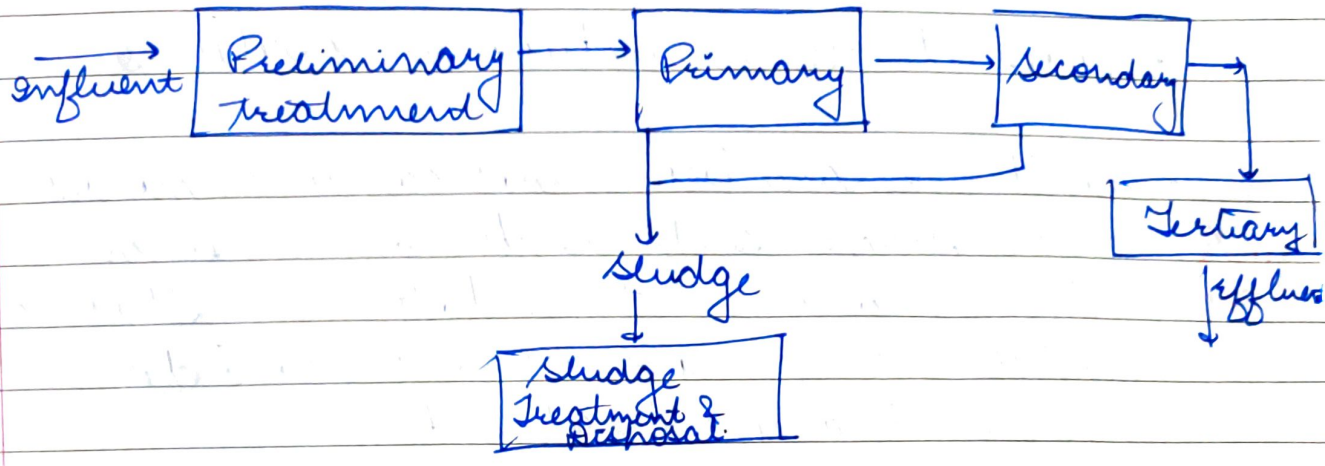
- In Biological part of treatment, suspended and attached refer to suspended and attached growth system.

Suspended growth system: In this system, the micro-organisms responsible for treatment grow in the suspended liquid itself.

Attached growth system: In this system the micro-organisms grow on solid surfaces. The surface could be natural (eg- gravel) or some polymer specially available.

Hybrid growth system: This system (not mentioned in table) is a hybrid of above 2 systems. In this we have such polymers which float or remain suspended in water system. It provides maximum growth for microorganisms & is the best form of treatment method (implemented in our campus as well)

- Treatment scheme



- Treatment Level:

- Preliminary treatment is a physical process that removes large solids, rags, papers etc
- Primary treatment involves physical sedimentation / settling of particulates.
- Secondary treatment involves chemical and biological treatment to reduce organic load of wastewater.
- Tertiary or advanced treatments include mostly physical or chemical treatments

- Wastewater Treatment plant →

- Look at the structure in slides simultaneously

- Grit chamber basically removes the large sediments as in form of primary sedimentation. This, along with screening chamber provides preliminary treatment.

TYPE 1 SEDIMENTATION

TYPE 2 SEDIMENTATION

Primary Clarifier further provides primary sedimentation.

- In aeration tank, we aerate it for micro organisms to grow with VSS.

TYPE 3 SEDIMENTATION

- In Secondary Clarifier, we provide secondary sedimentation. As such the bacteria also goes down with the sediment. Some of this is returned to aeration tank to recharge micro organism conc. there. This is called return activated sludge (RAS). Rest of sludge is called waste activated sludge (WAS).

- Further we carry out filtration in filtration tank and then disinfection. Then the water is a suitable effluent.

- The sludge: Primary sludge (from primary clarifer) & secondary sludge (WAS)

(from sec. clar.) and scum (oil & grease content) from both clarifiers is sent into sludge processing.

TYPE 4 SEDIMENTATION: In sludge processing, we carry out further sedimentation in sludge thickener.

- From there, it is sent for Anaerobic/Aerobic sludge digester (required to process the sludge)

- Then sludge is sent for dewatering after which the sludge concentrate (in form of solid cakes) is sent for disposal or for incineration

NOTE: In morning time the waste water generation is greater than noon. ∴ we have irregularities in water inflow. To correct this, we have equalization and neutralization basin which stores water and provides a constant flow through pump. In case neutralisation is required (due to say industrial waste), then it is also provided and pH maintained b/w 6.5–8.5.

- 2 pumps are provided in WTP. One after the equalizer & another after secondary clarifier to pump RAS into aeration tank

* → AIR POLLUTION AND ITS CONTROL

→ EARTHS GREAT SPHERES

a) Lithosphere: consists of land, soil & rocks

b) Hydrosphere: consists of water containing elements in all states - liquid, solid or gas

c) Atmosphere: consists of gaseous unit

d) Ecosphere: where living things reside. i.e biosphere

→ ATMOSPHERE

- Atmosphere consists of several layers: Troposphere, Stratosphere, Mesosphere, Thermosph...
- Bottom 10-15 km (Troposphere) is most important part in terms of whether and biogeochemical cycles.
- The lowest 600 m of Troposphere: Air Quality Studies.
  This 600 m mark is because wind direction is decided within this mark and since solution to pollution here is only dilution.
- Air pollution can only be controlled by

NOTE: Lookat temp profile of atmos very carefully.

treating it at source

- TROPOSPHERE
- Troposphere has 75-80% of earth's air mass
- Closest to earth's surface
- Varying chemical composition.
- Higher content of water.
- The temp. in general decreases with height but in winters it is also possible that it increases with height (due to differentia heating of ~~earth~~ land & air. In that case hot pollutants may settle down. Due to this industries are kept away from residen or urban areas

- STRATOSPHERE

- Similar composition to troposphere with 2 exceptions :

a) much less H_2O
b) Ozone layer filters UV radiation

→ AIR POLLUTION →

- Air is never perfectly clean
- Transfer of harmful and/or ~~of~~ synthetic/natural materials into the atmosphere as a direct/indirect consequences of natural & human activity.
- Combination of such elements in concentrations ~~or~~ which may harm the receptors ~~etc~~ or may exceed a limit causes air pollution.

→ TYPES OF AIR POLLUTION

- **Personal air exposure:** It refers to exposure to dust, fumes & gases to which an individual ~~exposes~~ exposes himself/herself.
- **Occupational air exposure:** It refers to exposure to fumes, vapours or aerosols in the working environment of people
- **Community air exposure:** Exposure to pollutants on a community scale.

NOTE: Receptors may be human receptors or buildings

→ SOURCES OF AIR POLLUTION

- Natural: Volcano, forest fire, dust storms etc.

- Anthropogenic: created by humans or their activities.

a) Stationary:
   - Point sources: Industrial processing, power plants, fuels combustion etc)
   - Area sources: Residential heating coal gas oil, on site incineration, open burning etc.

b) Mobile sources: Line sources: Highway vehicles railroad locomotives etc.

→ AIR POLLUTANTS →

- Primary air pollutants: materials those emitted directly from identifiable sources or when released pose health risks in unmodified forms. They include particulate matter (PM), CO, SO_2, NO, Volatile organic compounds (VOC), lead
- Secondary air pollutants: Primary air pollutants interact with one another, sunlight or natural gases to produce new harmful compounds. They include O_3, NO_2, Photochemical smog, aerosol and mist and peroxyacetyl nitrate (PAN)

- Conc. of air pollutants is generally expressed in parts per million (by volume) (ppm or ppmv) or $\mu g/m^3$

→ PRIMARY AIR POLLUTANTS

- major component is CO (49%)
- Sources

Human created

- Combustion
- Chemical
- Nuclear processes
- Roasting, heating, refining processes
- Mining, quarrying, farming

Natural

- Volcanoes
- Breaking seas
- Pollen, terpenes
- Fire
- Blowing dust
- Bacteria, viruses

Accentuated by humans.

NOTE: During tides, the saline particles in sea may get to the surface & get blown away with the wind. They also have bacteria absorbed on them. Breathing them may cause serious harm to us. This is called breaking seas.

NOTE: In case of water, mg/L is equivalent to ppm

→ SECONDARY AIR POLLUTANTS

NOTE: The most frequently violating pollutants w.r.t. NAAQ are:
CO, NO_x, SO_x, PM, Pb, VOCs

→ AIR POLLUTION: CONVERSION OF UNITS →

- Conversion from $\mu g/m^3$ to ppm for gaseous air pollutants →

volume basis: $1 \text{ ppm} = \frac{1 \text{ vol of gaseous pollutant}}{10^6 \text{ volumes (air+poll)}}$

mass basis : $1 \mu g/m^3 = \frac{1 \mu g \text{ of gaseous pollutant}}{\text{cubic meter (air+poll)}}$

- Conversion expression at a combination of Pressure (P) & Temperature (T):

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

Q→ The exhaust gas from an automobile contains 1% by vol of CO. What is conc. of CO in $\mu g/m^3$ at NTP?

Ans. 1% by vol $= 10^4$ ppm

MW = 28g

$$\frac{\mu g}{m^3} = \frac{10^4 \times 28 \times 10^3}{24.5} = 17.1 \times 10^6$$

→ AIR POLLUTANTS : PARTICULATE MATTER

- PROPERTIES

- mixture of solid phase and absorbed materials (organic, inorganic or even pathogenic)

- Read sources from slides.

• Terminal settling velocity

• Assumptions:

a) Terminal settling velocity of PM is based on Stoke's law

b) Only considers quiescent settling rather than turbulent nature of atmos.

c) Applicable to only spherical PM in range of 0.1 to 100 μm

d) Can only be used when Reynolds num (R_e) is less than 1. ie under laminar flow condition.

$$\boxed{v_t = \frac{g(\rho_p - \rho_a) d_p^2}{18\mu}} \qquad \boxed{R_e = \frac{\rho_a v_t d_p}{\mu}}$$

where, v_t = terminal settling velocity (m/s)
g = acc. due to gravity (9.81 m/s²)
ρ_p = density of particle (1000 – 2000 kg/m³)
ρ_a = density of air (1.2 kg/m³)
d_p = diameter of particle, m
μ = dynamic viscosity of air (1.85×10^{-5} Ns/m or kg/ms)

NOTE: Terminal velocity helps us to design such tanks at source (of PM) which provide for settling of PM.

classmate

Date
Page

(depending on source)

NOTE: Particles may not always be spherical ∴ we introduce a concept Aerodynamic diameter.

- Aerodynamic diameter:

- It is the diameter of a unit density spherical hypothetical particle that has the same inertial properties ie terminal settling velocity in the gas/air as particle of interest.

- The aerodynamic diameter for all particles greater than 0.5 μm can be approximated using the following eqn.

$$d_{pa} = d_{ps}\sqrt{\rho_p}$$

where

d_{pa} = aerodynamic diameter
ρ_p = density of particle

d_{ps} = Stoke's diameter.

v. imp NOTE: Stokes' diameter for any general particle is the diameter of a spherical particle with same settling velocity as the practical sett vel. of general particle.

- Physical size:

Large
Small ~ 10 μm
~~Fi~~ Fine ~ 2.5 μm

- Based on aerodynamic diameter

a) Large (causes local irritation) > 100 μm
b) Inhalable (< 100 μm)
c) Thoracic fraction (< 20 μm)
   - Coarse PM_{10} (< 10 μm)
   - Fine $PM_{2.5}$ (< 2.5 μm)
   - Ultra fine (< 0.1 μm)

} respirable (may cause asthma)

→ Chemical reactivity is very high

- Water content

- Trimodal distribution of PM in atmosphere:
(look at graph in slides)

- It refers to the frequency distribution statistics of the PM according to their size in air.

- Practically we see 3 peaks ie 3 modes (most freq. occuring values)

- The 3 modes are distributed according to size.

a) Coarse mode: mode of particles of high

size (>10μm). They are emitted from industries like brick industries etc. They easily settle down.

b) Nucleation mode: The mode of particles of fine size (0.002 - 0.1)μm. Emitted from sources like metallurgical sources. They show brownian motion & may combine in process.

heterogenous: when diff. size of particles combine

homogenous: when same size of part. combine

c) Accumulation mode: They are formed from the rest of 2 modes. From nucleation, particles combine to form particles of size (0.3 - 0.5 μm) & from coarse mode, they break down (during settling) to form part. of size (1-2 μm)

NOTE: In urban areas, the major PM content is from accumulation due to its source being the rest of 2 modes.

Also it lies in fine PM range.

→ AIR POLLUTANTS : CARBON MONOXIDE — (CO)

- Colourless, odourless, tasteless gas - stronger binder to haemoglobin (Hb) than O_2

- Forms carboxyhaemoglobin (COHb) rather than oxyhaemoglobin (HbO_2)
- "Silent killer" due to its properties.
- Formed from automobiles & partial combustion.

→ AIR POLLUTANTS: SULFUR DIOXIDE (SO_x)

- It is a major primary pollutant
- Read in detail from slides.

→ A.P. : NITROGEN OXIDE (NO_x)

- NO is primary air pollutant
- NO_2 is secondary but if it is directly released in an industry, then, it is ~~called~~ a primary pollutant.
- It can lead to production of PAN & Ozone which may act as severe pollutants.
- In large urban areas, NO_2 manifests as the 'Brown Cloud' seen over large polluted cities.
- UV sunlight + Hydrocarbons + NO_x → Ozone.

→ A.P.: OZONE (O_3) →

- Short lived, highly reactive, & highly water soluble & a good oxidising agent.
  ∴ can be used in disinfection (~~Gases~~ (for both waste & drinking water)

- Source: Photochem. rxns.

- O_3 absorbs UV radiation & creates a warm layer of air responsible for thermal struc. of strata.

- O_3 in troposphere is basically man-made pollution (higher in urban areas)

- O_3 is formed when NO_x combines with VOC (chem vapours) in presence of sunlight.

$$CO + \dot{O}H \longrightarrow CO_2 + \dot{H}$$
$$\dot{H} + O_2 \longrightarrow HO_2 \quad (\underbrace{H-O-\dot{O}}_{\text{hydroperoxy radical}})$$
$$HO_2 + NO \rightarrow \dot{O}H + NO_2$$
$$NO_2 + h\nu \rightarrow NO + \dot{O}$$
$$\dot{O} + O_2 \rightarrow O_3$$

$$CO + 2O_2 \longrightarrow CO_2 + O_3$$

NOTE: $\dot{O}H$ is called neutral form of hydroxyl ion & is also called atmospheric detergent since it helps in cleaning pollutants i.e. NO from atmosphere.

→ A.P. : LEAD →

- Source: burning fuels that contain lead (phased out), metal processing, waste incinerators.

- Absorbed into blood.

- Accumulates in blood, bones, muscles, fat & may cause detrimental effects on body (read from slides).

- It was added manually as an anti-knocking agent (to help the starting of the engine & improve combustion performance.

$(C_2H_5)_4Pb$ (Tetraethyllead) (TEL)

NOTE: • Acute: High conc. of pollutant but for short period of time.

Chronic: Low conc. of pollutant may be low but for a very long period of time.

NOTE: PAN: Peroxyacetyl nitrate : $C_2H_3NO_5$

CONTROLLING AIR POLLUTION →

- Gravity precipitator: A duct installed to provide for settling of particles. But works well with only large particles.

- Electrostatic precipitator (ESP): It is a structure comprising of a -ve electrode suspended in a region b/w a wall of +ve electrode (called precipitator). The ~~dust~~ PM particles get to the -ve electrode which discharges electrons over them (called corona discharge) & now due to mobility of dust, it gets to the +ve walls discharges & settles down.

used for PM

- Scrubber: It can be used both for PM & for other gases. In its structure water is poured at diff. levels. It provides for dissolution & removal of PM & gases. An entrainment separator at the top separates humidity from the incoming gas.

WASTE MANAGEMENT →

← * Read from slides * →

NOTE: Vermicomposting is when we use earthworms for composting.