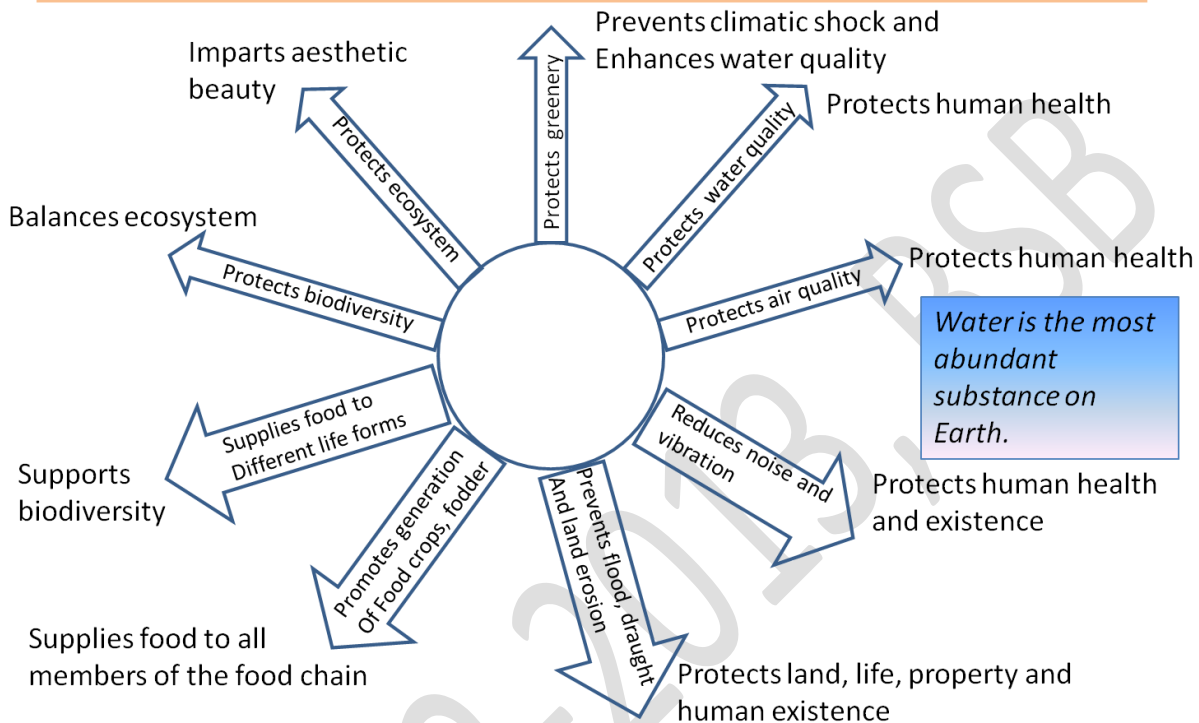# Chapter 6 Water resources

Water resources

Water resources

Ocean covers 71 % of Earth's surface.

Water is found in Glaciers, ice caps, lakes, streams, soils, underground reservoirs and in the bodies of all living organisms.

What are the unique properties of water?

1. *Ice melts in water*
2. *A considerable amount of energy is consumed when ice melts (80 cal) and evolved when it boils (540 cal)*
3. *Water is an excellent solvent for many different kinds of substances and is therefore called an universal solvent*

- *We use water in home, industry, agriculture etc.*
- *These use differ with respect to quality and quantity of the water.*
- *We use all available sources – inland water, groundwater, ocean water*
- *We pollute it, purify it, reuse it over and over again*

- H_2O is the molecular formula of water
- It has a bent shape
- The H-O-H bond angle is 104.5 °.

- Due to this H_2O has dipole.
- H_2O molecules are bonded to each other through H-bonding.

Properties of Water

How does ice remain in the solid state at 0 °C?

- The strong H-bonding between the water molecules result in association of molecules and thus molecular weight and hence melting point, increases. This keeps ice in the solid state up to 0 °C.

What makes ice float on water?

- When crystal structure of ice breaks, the liberated molecules become associated with each other so strongly that they pack together more closely than in ice crystal itself. As a consequence, ice becomes less dense than water and floats on it.
- If it did not happen, a body of water would freeze from the bottom upwards instead of from top downwards, and aquatic life, as we know, would not exist.
- When water vaporizes and becomes steam, the molecules are completely dissociated from each other. i.e. All H-bonds between the water molecules is broken. This requires about 7 times as much energy as it does to melt ice. When these processes are reversed the energy flow also is reversed.

Hydrological cycle

- The sequence of events involving the transfer of water from the atmosphere to the landmasses and oceans and its return to the atmosphere is called hydrological cycle.

Evaporation

- It is the change of state of a liquid into vapour at a temperature below the boiling point of that liquid. It takes place from the surface of all water bodies in hydrosphere.

Condensation

- The water vapour raises and gets cooled to form drops of water around the dust particles present in air. This is how clouds are formed.

Transpiration

- The physiological process by which water is lost in the form of water vapour, from the green aerial parts of the plants.
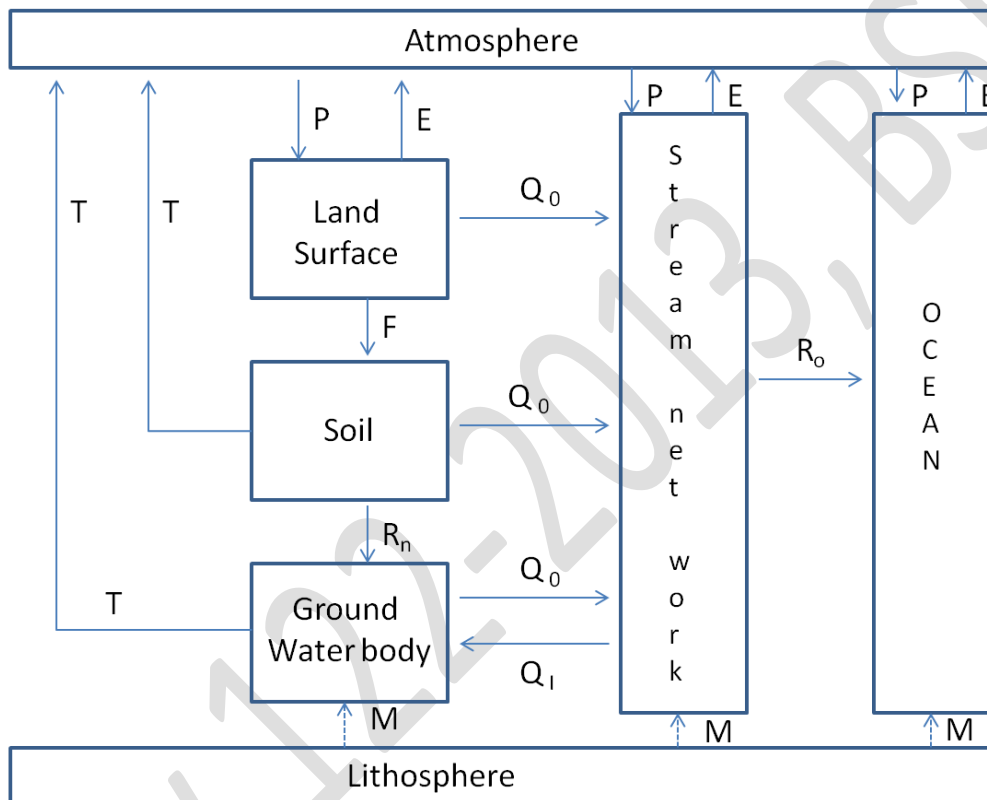
Precipitation

- It is a general term for all forms of atmospheric moisture which descend on to earth in the form of rain, snow, hail and sleet.

Run-off

- It is the flow back of the precipitation to the oceans through streams. It consists wholly or partly of water contributed by overland flow (surface run-off) and by groundwater flow (base flow).
- Hydrological cycle is fuelled by the solar and planetary forces.

Natural surface	% of solar energy reflected
Fresh snow	90
Old snow	50
Free water surface	5-15
Light coloured rocky surface	40-50
Dense dark vegetation	10-15

Hydrological cycle. P- precipitation; E- evaporation; T-transpiration; Q_0-outflow Q_I – Inflow; F – water infiltrating in to soil; R_n – water infiltrating into ground water body; R_0 – water meeting ocean; M – magmatic water

Movement of water

The streams which receive water from the ground water body are known as *effluent or gaining streams*.

The bodies where water is reserved in liquid form or as ice or snow are known as *stores*. The movement of material between the stores is called *flux*.

The residence time (t) of an element in a store is determined by the equation

t = m (dt/dm)

m = mass of water in the store;

dm/dt = rate of input/output to store

Location	Avg. residence time
Atmosphere	9-10 days
Ocean	
Shallow layer	100-150 yr
Deepest layer	30,000-40,000 yr
Worlds ocean avg.	3000 yr
Continents	
Rivers	2-3 weeks
Lakes	10-100 yrs
Ice caps and glaciers	10,000-15,000 yr
Shallow groundwater	Up to 100s of yr
Deep ground water	Up to 1000s of yr

| Location	Mass (10^{18} gm)
Fresh water	126
Ice	30,000
Oceans	1,42,000

World water budget
- World water budget
  - Rate of flow of water into any of the stores in the hydrological cycle is equal to the rate of flow out of it.
  - Total evaporation from earth surface = total precipitation and *vice-versa*
  - Basic assumption the total amount of water on earth remains same.
  - There may be small amount of consumption by plants during photosynthesis or some amount of water dissociation to O_2 and H_2 in atmosphere. But that is a negligible fraction.

Water resources

- **Surface water**
  - Oceans, lakes, rivers, glaciers, polar ice caps
- **Subsurface water**
  - Ground water, soil moisture of the continents
- **Atmospheric water**
  - Water vapour (gas), rain drop or cloud or fog (liquid), snow or ice (solid)

Distribution of Earth's Water
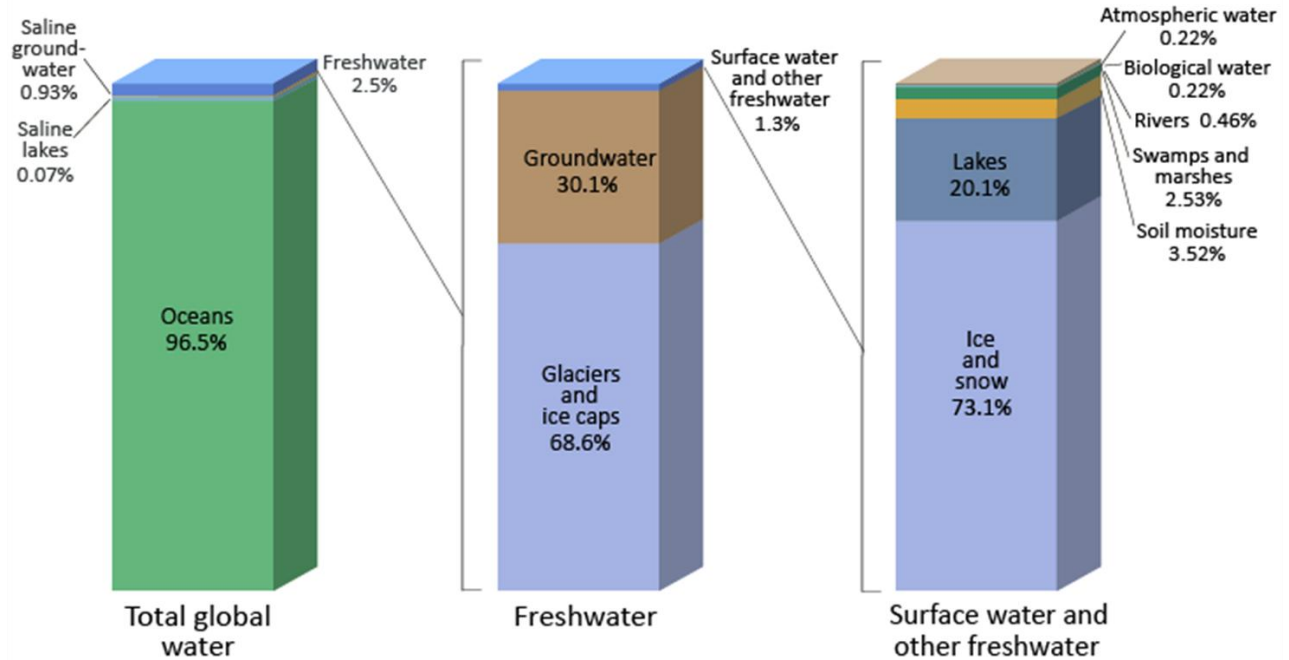
- Ocean covers 362 million km^2 area.
- It is the sink where water finally flows.
- Water streams pick up minerals en-route and deposit it at oceans
- The avg. salt content is 35 %.
- NaCl is present in 90%.
- 57 elements are also present in water.
- **Desalination** requires large amount of energy and means of disposal of salts and salt concentrates are left over as by products.

How can we use ocean water?

- After desalination it can be used. **Desalination**: removal of dissolved constituents that cause salinity. Ex. Distillation, Reverse osmosis, Electro dialysis, Freezing, Solar evaporation

  Oceans are very useful resource food, common salt, construction material, decorating material, electrical energy (tidal energy)

Lakes, ponds and reservoirs represent lentic water (stagnant)

Reservoirs are made by construction of dams across rivers.

Importance of lentic water:

- Domestic and industrial irrigation
- Navigation
- Fish and water fowl habitat
- Flood protection
- Recreation

- Generating hydroelectricity
- Source of water for laundry, bathing, cattle rearing

What are the advantages of dams?

- It is the most widely used devise for storing water. They also provide a head of water for the generating hydroelectric power. They also increase the depth for navigation. The down stream flow of river can be augmented during dry periods. Construction of dams in upstream regions can check flood in the downstream region during rainy season.

What are the disadvantages of dams?

- Creating a reservoir destroys the land within the reservoir area by **flooding** (this was usually very fertile land).
- Reservoir provides more surface area for **evaporation** and more area for **seepage**. Due to more evaporation more salts gets deposited. When this water is used for irrigation the rate of **salinisation** of the soil increases.
- A reservoir will obstruct the **groundwater drainage** to rivers which will cause a rise in the water level and possibly affect local structure or agricultural lands.
- The raise in water level can **destabilise** the **geodynamic** situation leading to substantial landslips.
- Presence of **loess soil** when saturated with raising water table lead lands to subside.
- Silting is another problem. Slow rate of **sediment settlement** lead to accumulation of grain of sand. This slowly builds the reservoir. This lowers the water level of dams.
- The **hydraulic pressures** generated by the deep reservoirs can change the **seismicity** of the region. If the height of the dram is high then the chances of earthquake are more. (Loess is deposits of silt that have been laid down by wind action)

Reservoir induced seismicity

Location of Dam	Height (m)	Vol. X 10^6 m³	Magnitude
Koyna, India	103	2,780	6.5
Kariba, Zimbabwe	128	1,60,368	5.8
Hoover, USA	221	36,703	5.0
Kremasta, Greece	165	4,750	6.3

What are the disadvantages of dams?

The reservoir, dams act as flood control structures and reduce the damage caused by high floods. Since they change the river flow they increase river bank erosion. It may also damage agriculture that is dependent on high floods.

Rivers

Why rivers are considered to be one of the most important water resources available to man?

- In India rivers contribute 85 % of the total water flow.
- The rivers are spread almost all across the country.
- They are exploited for almost every use.
- They are also used for waste water disposal.

- Waste water disposal on river lead to pollution in many areas.
- Untreated and partially treated sewage disposal lead to many water borne diseases.
- Indian rivers are contaminated by coliform bacteria.
- Over grazing and indiscriminate deforestation in the watershed area of river basin is responsible siltation of dams and few rivers changed their course as well.
- It is also responsible for many floods.

Atmospheric and ground water

- All water in the environment passes through atmosphere in due course of the hydrological cycle
- Atmospheric water is important for determining the environment conditions
- Although atmospheric water is not a direct source of water supply it gives pure water in the form of precipitation
- Atmospheric water also keeps the temperature moderate (for our comfortable living)

What is the **zone of aeration**?

- It is the space between the land surface and water table.
- Here water is present in minute quantities, mostly in smaller openings.
- In the zone of aeration, water is held by soil and rocks by capillarity forces and it will not come into the well.

What is **vadose water**?

- It comprises water fillings voids of capillary dimensions, water in the process of infiltration from the surface towards the zone of saturation and water in the form of vapour occupying the voids.

How is ground water formed?

- When rain falls water enters the soil
    - Water is held by capillarity (to compensate water taken by plants or lost by evaporation)
    - Excess water after above process reach water table
    - Below the water table all the openings are completely full of water.

What is an **aquifer**?

- It is a geological formation or a group of formations or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs

What is an **unconfined aquifer**?

- It is one in which a water table serves as the upper surface of the zone of saturation where the pressure is 1 atm.

What is **confined aquifer**?
- It is one in which a water table serves as the upper surface of the zone of saturation where the pressure is more than atmospheric pressure.

What is an **artesian well**? How it is different from other wells?
- When a confined aquifer is pierced, the water will rise above the base of the confining bed until the column of water is long enough to balance the pressure in the aquifer. When the pressure is very high water flow up without a pump.

What is **fossil water**?
- Deep ground water is called fossil water. It is non-renewable.
- Total quantity of water in aquifer is large. Half of that is present in deep layers. These waters are replaced slowly. These waters were accumulated over 1000s of years.

What are the problem associated with excessive water removal?
- (i) Land subsidence or settling down of ground
- (ii) Saline water intrusion in coastal aquifer
- (iii) Dewatering of shallow aquifers

(i) Land subsidence
- Excess of ground water removal allows sand particle to shift closer to each other thus filling some of the space left by the departed water. This leads to decrease in sediment and the surface subsides.
- This increased flood hazards
- It has caused cracks in buildings, damaged railways, collapse of well tanks
- It is irreversible in case of inelastic compression of clay bed
- It can be stopped by preventing depletion of groundwater

(ii) Saline water intrusion in coastal aquifer
- Generally fresh water from the recharge areas of aquifer flow to sea.
- Overdevelopment can reverse the seaward gradient of groundwater.
- This causes saline marine water to penetrate inland aquifer

(iii) Dewatering of shallow aquifers
- Drying up of shallow wells necessitates change from low technology equipment to high technology pumps.
- Lowering of water table may affect the vegetation and also result in drying up of rivers
- In arid areas, a lowering of the water table below rooting depths may lead to death of vegetation and even desertification

Water resources of India
- By 2025 India needs 1050 km^3 of water (52 for domestic needs, 770 for agriculture and 228 for industrial and other needs)
- Utilisable fresh water 1150 km^3 (groundwater 450, surface water 700)

- Non-uniform distribution of water resources. Ex. Brahmaputra basin covers 6 % of country, has 3 % of population, but has 30 % (334 km^3) of water resource
- Southern and western region has less water than national average
- Most of the river and lakes are polluted
- Ganges, Yamuna are highly polluted
- Ulhas (MH) river polluted with Pb, Cd, Hg, Cu
- In Kerala all 10 major rivers are polluted

Why is India regarded as a water deficient country?
- India has 4 % of world's annual renewable fresh water
- India has world's total land area of 2.5 %. But arable land is 12.5 % (75 % total water used for agriculture)
- India has 16.7 % of world human population and 15 % of world animal population
- With 4 % water India is actually water deficient
- With increasing population demand for water also increases

What steps should be taken to overcome India's water deficit?
- Integrated watershed management is a cost-effective solution
    - Development is not confined to agricultural land
    - Covers the area starting from highest point to the outlet of rivers
    - Contour bunds, gully plugs, percolation tanks constructed over catchment area can help to conserve water for recharging into the ground
    - Afforestation (will increase rain fall)
    - Use of non-conventional energy sources like bio-gas, solar energy
    - Reduction of overgrazing
    - Community participation
    - Reduction in population growth

Why water is regarded as a universal solvent?
- It dissolves mineral salts which consists of + and − ions. Generally +ve ions are metals (Pb, Hg, Cr, Cd, Cu)
- Water is also a good solvent for organic compounds (alcohols, sugars, acids)
- Many materials that are insoluble also dissolve in minute quantities in water
- Even hydrocarbons dissolve (0.05-0.1%)

What are the different ways by which water may get polluted?
- Insoluble particles, if they are small enough, settle at such low rates that they remain indefinitely in water.
- The waste products formed as a result of metabolism of nutrient matter by aquatic life forms may cause pollution.
- Living organisms themselves, if carriers of disease, may be considered as pollutants
- A soluble substance may react with an insoluble contaminant to bring it into solution
- A contaminant may pollute the water by simply floating on it. Floating of lighter substance like oil is a water pollutant.

What are the different types of foreign substances present in water?
1.   Suspended
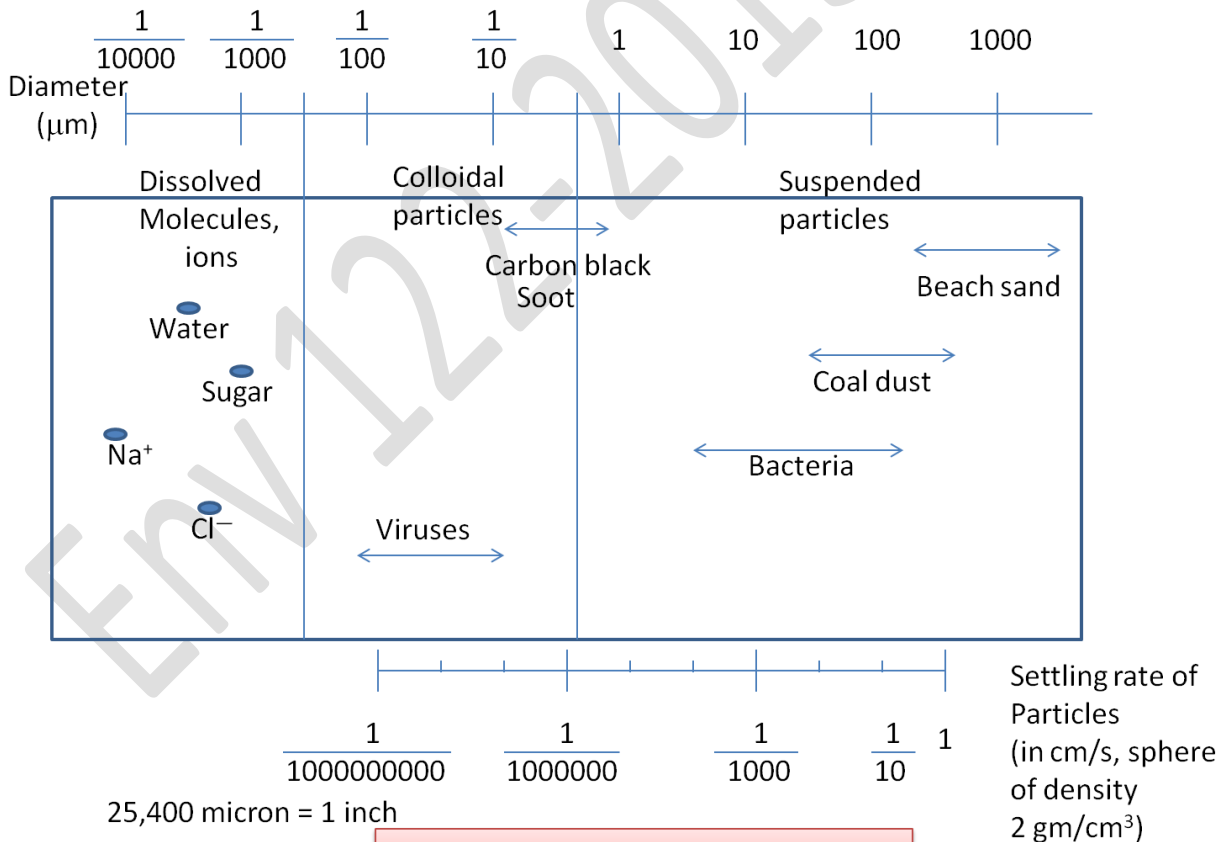2.   Colloidal
3.   Dissolved

Suspended
- Diameter >1 mm.
- Settles down quickly in quiet water
- Can be retained by common filter; large enough to absorb light, Appears murky

Colloidal
- Very small; settling rate is insignificant
- Pass through holes of most filter media; cannot be removed by ordinary filtration
- Appears cloudy, gives colours to water (blue green or red)

Dissolved
- Does not settle out; not retained by filters; does not appear as cloudy
- Less than 1/1000 mm
- When neutral they are called as molecules; when has charge called as ions.

Diameter (µm)	$\frac{1}{10000}$	$\frac{1}{1000}$	$\frac{1}{100}$	$\frac{1}{10}$	1	10	100	1000

Dissolved Molecules, ions   Colloidal particles   Suspended particles

Carbon black Soot   Beach sand

Water   Coal dust

Sugar

Na$^+$ Bacteria

Cl$^-$ Viruses

Settling rate of Particles (in cm/s, sphere of density 2 gm/cm^3)

$\frac{1}{1000000000}$	$\frac{1}{1000000}$	$\frac{1}{1000}$	$\frac{1}{10}$	1

25,400 micron = 1 inch

Spectrum of Particle in water

Impurities in natural water					
Source	Suspended	Colloidal	Dissolved		
Atmosphere	Dusts		Molecules CO_2, SO_2 O_2, N_2	+ve ions H^+	—ve ions HCO_3^-, SO_4^{2-}
Mineral soil and rock	Sand Clays Mineral soil particles		CO_2	Na^+, K^+, Ca^{+2}, Mg^{+2}, Fe^{+2}, Mn^{+2}	Cl^-, F^-, SO_4^{2-}, CO_3^{2-}, HCO_3^-
Living organisms and their decomposition products	Algae Diatoms Bacteria Organic soil (Top soil) Fish and Organisms	Various organic colouring matter	CO_2, O_2, H_2, CH_4 Various organic waste, some of which produce odour and colour	H^+, Na^+, NH_4^+	NO_3^-, Cl^-, HCO_3^-

Productivity in aquatic systems

The productivity of an ecosystem reflects the rate at which its producers photosynthesise

What is an oligotrophic lake? How is it different from eutrophic lake?

- Oligotrophic lake:
    - A clean mountain lake or a pure stream from which a person can drink water
    - Here the productivity is low due to shortage of nutrients for producers
- Eutrophic lake:
    - A lake with high productivity
    - As time passes, nearby mountains or hillsides erode and sediments are washed into fresh water systems
    - These sediments carry nutrients which fertilise the system

What is *cultural eutrophication*?

- In a natural system many 1000s of years may elapse before an oligotrophic water becomes eutrophic. When this slow process is sped up by human activities it is called *cultural eutrophication*.

How do phosphates limit fresh water productivity?

- When P is added as a single dose, the productivity increase is short lived. Because P is continuously removed from the system by deposition in to bottom as sediments. If P is

added continuously (sewage, fertilise run-off, detergent), the productivity of a lake will remain high.

What is BOD?

- The amount of oxygen that will be consumed when a biodegradable substance is decomposed in a aquatic system. Unit mg/L.

BOD Values
Domestic sewage 100 mg/L
Food processing 1000 mg/L
Pure water 8.4 mg/L
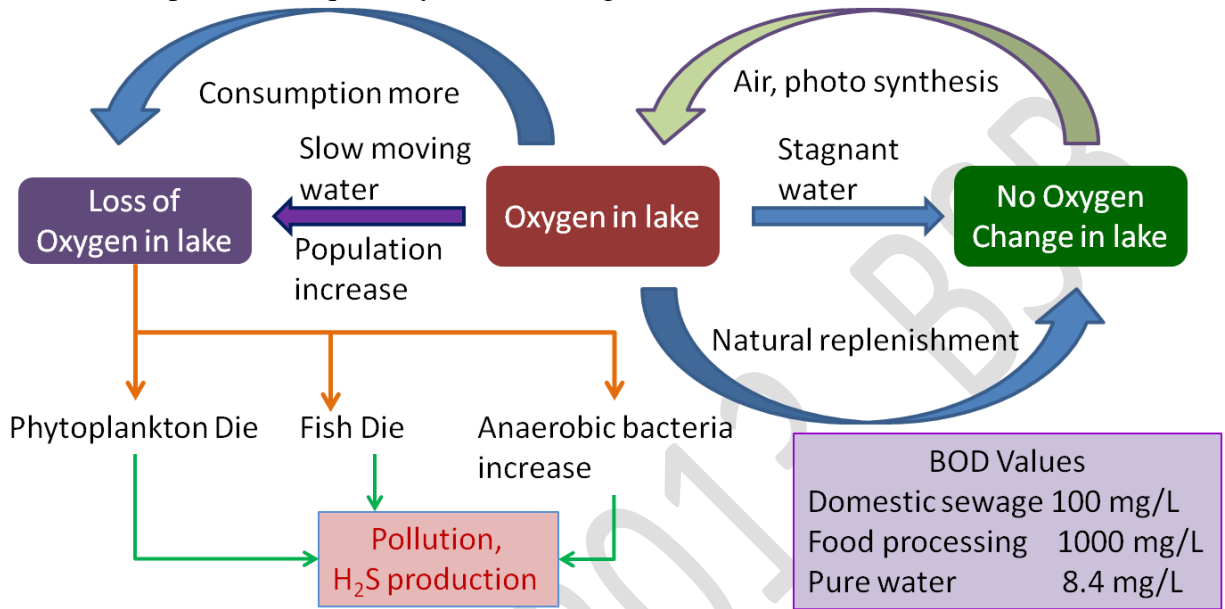
Pollution of river by nutrients

- When sewage is discharged into fresh water stream, the stream becomes polluted. Oxygen does not deplete, but there is a chance for it. BOD increases.

River pollution from sewage discharge
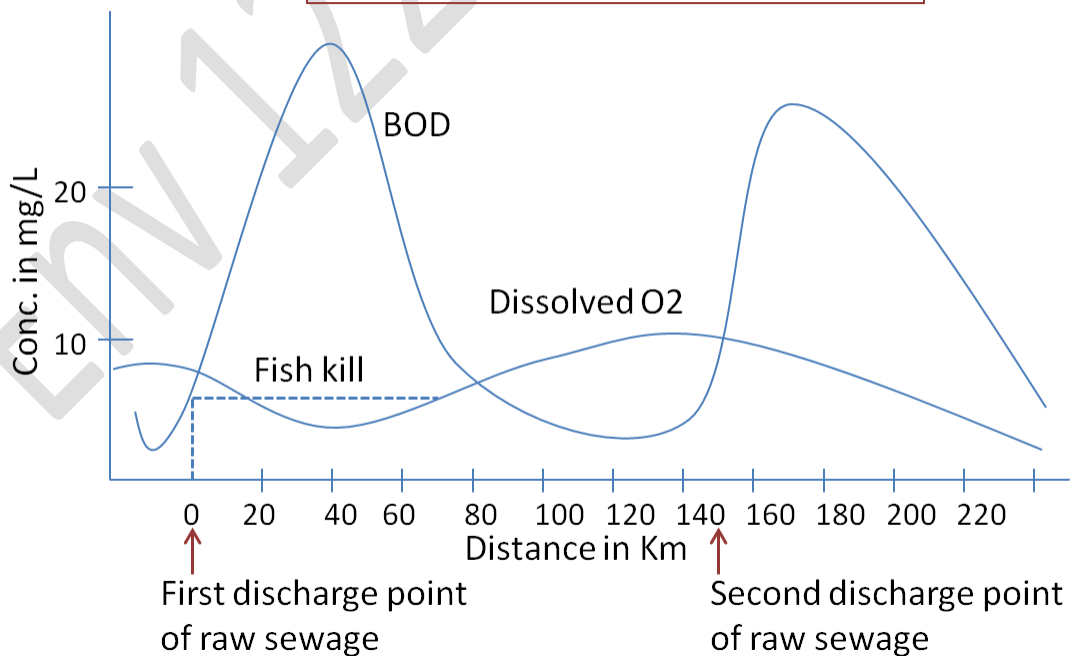
The processes that affect BOD after the immediate discharge of sewage are
1. The bacteria consume sewage resulting in the decrease of sewage, in turn BOD reduces.
2. Bacteria also use dissolved oxygen to consume sewage which reduces the dissolved oxygen concentration .
3. Some of the lost oxygen is being supplied by air and photosynthesis by phytoplankton.

What is the relationship between the BOD and survival of fish population in a river?

When the bacteria consumes sewage at a faster rate, the dissolved oxygen level falls down. This leads to fish kill. Fish does not die due to sewage but the available oxygen for fish survival falls below 4 mg/L. Once all the sewage is consumed by bacteria, the demand for oxygen slows down and the natural ability of the river to recover oxygen happens, then fish begin to survive.

If additional sewage is introduced before full recovery, it becomes detrimental to survival of fish. That leads to putrefaction and fermentation.

How do aquatic life in lakes exist when the lake freezes during the winter?
- Water has maximum density at 4 °C.
- During summer epilimnion (oxygen-rich layer) float above hypolimnion (cold less O_2 rich layer)
- During winter the epilimnion goes to 0 ° C whereas hypolimnion remains at 4 ° C.
- Now hypolimnion behave like one unit. Moreover at less temp. more O_2 dissolves.
- The metabolic rate of all organism reduces in the winter. So they require less O_2 .
- So when the lake freezes in the winter hypolimnion still has enough O_2 and life continues.

What are the effects of oxygen-demanding pollutants on these processes?
- During summer, organic matter serve as nutrients in the epilimnion
- This requires less O_2. Replacement of O_2 by air and photosynthesis help in fixing the depletion of O_2
- When organic matter settles down at the bottom where O_2 is less creates problem
- In a eutrophic lake the bottom part suffers first
- Fish that live there get less O_2 and they die
- Industrial waste pollute river water
- Nature, composition, usage type, raw material used, process etc contribute to pollution

Industrial wastes in water

River Ganges is polluted by
- Chemical, textile, tanning, pulp and paper, petrochemical, rubber industries
- Deforestation in the upper reaches, soil erosion and enhancement of sediment load
- Increase in population (more discharge of sewage)

River Yamuna is polluted by Delhi industrial waste (8 lakh tonne)

River Damodar is polluted by
- Continuous discharge of uncontrolled toxic and hazardous effluents
- Fine metallurgical grade coal are discharged (364864 tonne per day)

- Untreated industrial waste from fertiliser, steel, ceramic industries (1.5 million gallon)

Parameter	Range	Mean	Total Load Million Kg/year
Fe	0.05-12.5	2.4	16.8
Cu	<0.002-0.14	0.57	3.99
Mn	<0.002-2.6	0.05	0.35
Zn	<0.002-0.07	0.04	0.28
Pb	<0.001-0.50	0.098	0.069
Cd	<0.005-0.30	0.067	0.47
Cr	<0.05-1.3	0.28	1.96
Ni	<0.02-0.51	0.103	0.721
Hg	<0.0005-0.005	0.0015	0.010

What lead to Minamata disaster in 1960s?

- A chemical plant in Minamata city Japan, released Hg in its effluent. That affected the Minamata Bay. Since people ate the fish from this area they were exposed to Hg contamination as high as 50 ppm. This lead to irreversible brain damage and death. The inorganic forms of Hg were converted to methyl mercury and got accumulated in organisms leading to biomagnifications in the body of fish.

Children with Congenital Minamata Disease due to intrauterine methylmercury poisoning (Harada 1986).
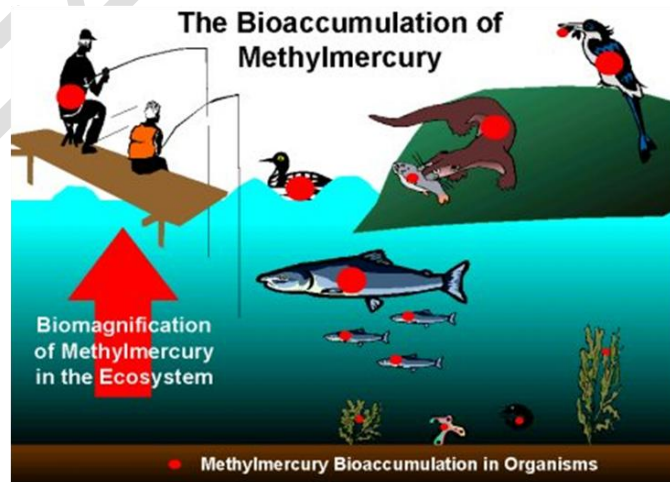
Acid mine drainage

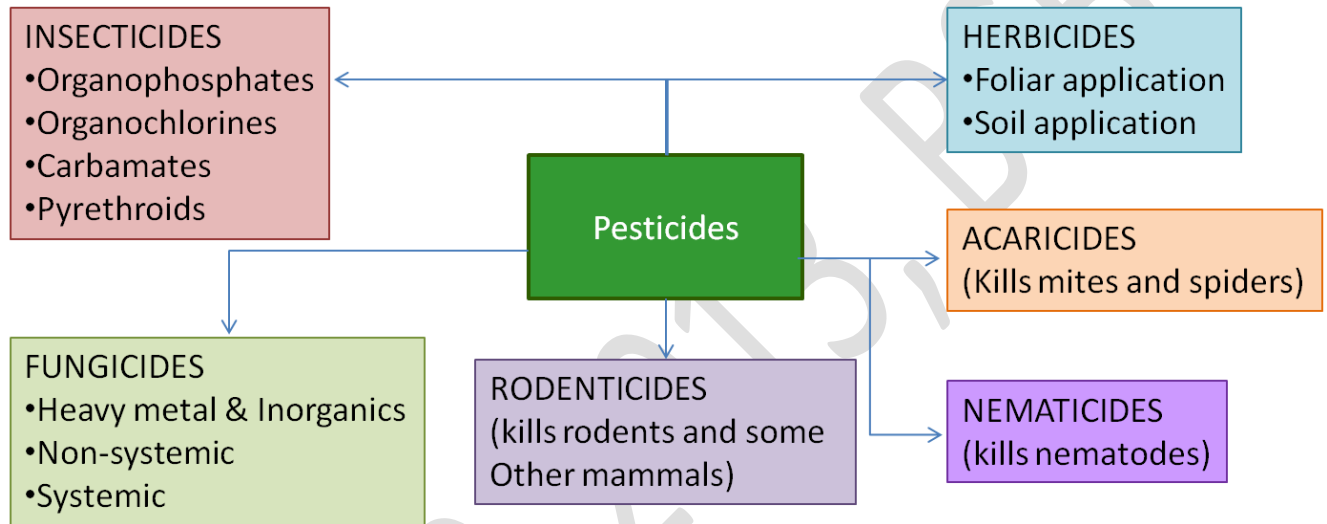How do mining operations pollute the water resources?

- Mining operation results in **acid mine drainage (AMD)**. In the presence of O_2 and H_2O, the bacteria *Thiobacillus ferro-oxidans* converts sulphides to H_2SO_4.
- Thus, the pH of the water becomes acidic and corrosive. This can dissolve metals in high concentration. The discharge of this water will destroy aquatic life; H_2O is non potable.

- The coal seams in Guandong, Guizhon in China have high S content and the pH of AMD is 2 or 3. the contaminants in this water is 10 times the allowed level. This water was responsible for decline of shrimp and fish, and low yield of crops.
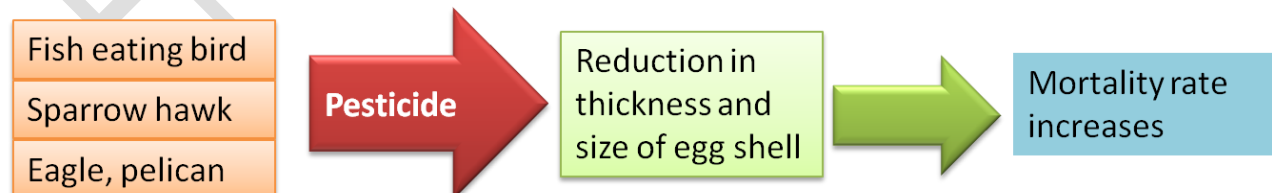
Agricultural wastes in water

This usually originate in the form of run-off from the agricultural fields and animal forms. Modern agriculture uses many chemicals like fertilisers, insecticides, pesticides etc. all these and the organic debris of harvested crop are trapped by run-off water. This pollutes receiving water. The agricultural run-off which is rich in nutrients (N, P) create problem of eutrophication, pesticides cause toxicities to aquatic life.

INSECTICIDES
•Organophosphates
•Organochlorines
•Carbamates
•Pyrethroids

HERBICIDES
•Foliar application
•Soil application

Pesticides

ACARICIDES
(Kills mites and spiders)

FUNGICIDES
•Heavy metal & Inorganics
•Non-systemic
•Systemic

RODENTICIDES
(kills rodents and some Other mammals)

NEMATICIDES
(kills nematodes)

How do pesticides affect human health?
- Pesticides are highly toxic to animals and plants. Pesticides enter humans as a result of consumption of contaminated food and by inhalation of contaminated air. When they accumulate in human body they cause cancer, leukemia, hypertension, sterility or even death.
- Pesticides not only kill pests they also kills the predators of pest. When the pest escape pesticide will now grow without the fear of the predator. During the course pest may also mutate and now the pesticide will be no longer be effective. Examples include house flies, mosquitoes, cotton boll worm, spider mites. They have overcome the toxic effects of nearly all the chemicals to which they were extensively exposed.

Fish eating bird
Sparrow hawk
Eagle, pelican

Pesticide

Reduction in thickness and size of egg shell

Mortality rate increases

What is synergism?
- It is the phenomenon in which the combined action of two substances produce greater effect than what would be expected by adding the individual effects of the two.

Pollution of groundwater

It is defined as *"groundwater which has been influenced by man to such an extent, that it has a higher concentration of dissolved or suspended constituents than the maximum permissible concentration fixed in national or international standard for potable water"*.

What is the outer limit of polluted groundwater zone?

- The line where the concentration of all pollutants have dropped below the valid limits for drinking water, or, where all water properties have returned to the normal values for respective environment.

Sources and causes of groundwater pollution

1. Municipal source
   a) Sewer leakage
   b) Liquid waste
   c) Solid waste
2. Industrial source
3. Agricultural source
4. Miscellaneous source

Pollution mostly stems from the disposal of wastes on or into ground. Methods of disposal include placing wastes in percolating ponds, in sewage pits/trenches, in dry stream-beds

Sources and causes of groundwater Pollution

1. **Municipal source**
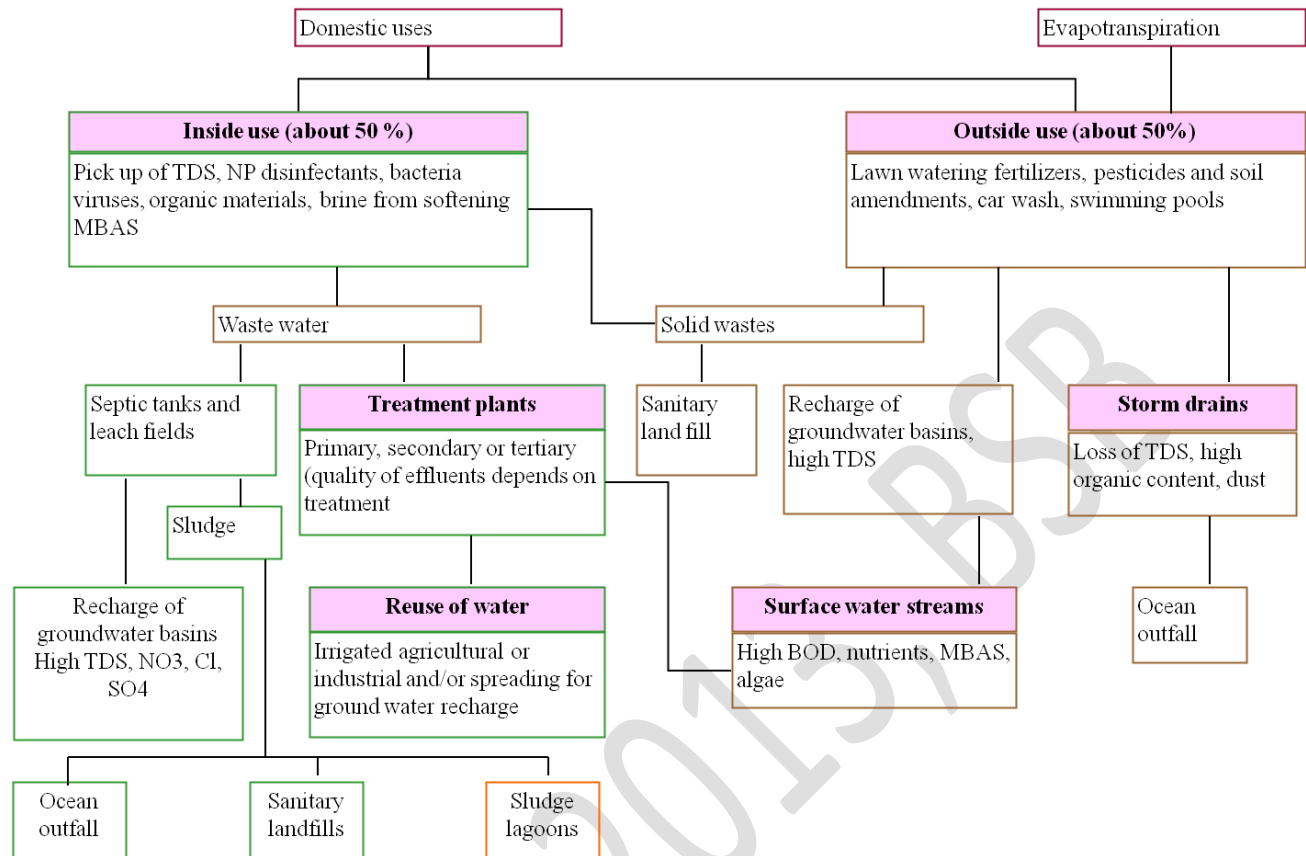   a) **Sewer leakage**
      1. Leakage of sewage into ground water from old sewers
      2. It introduces high concentration of COD, BOD, NO_3, bacteria
      3. Sewage leak from industrial area increases toxic concentration of As, Cu, Fe, Pb, Hg

   b) **Liquid waste**
   - Domestic use, industries or storm run-off produces wastewater
   - Generally treated waster is discharged into surface waters
   - When there is a considerable stress on the aquifer this wastewater introduces bacteria, virus, inorganic or organic chemicals, heavy metals
   - Chlorination of wastewater can also produce additional pollutants

   c) **Solid waste (Why does land disposal of solid waste create groundwater pollution?)**
   - Leachates from landfill can pollute groundwater if water moves through the fill material
   - When landfill receives high rain fall or when the groundwater occurs in an unconfined shallow water table conditions increase pollution
   - Pollutants include BOD, COD, Fe, Mn, Cl^-, NO_3^-
   - Hardness, alkalinity, total dissolved solids (TDS) increases
   - CO_2, CH_4, NH_3, H_2S may reach groundwater through rainwater or seepage water

Domestic uses — **Evapotranspiration**

Inside use (about 50 %)
Pick up of TDS, NP disinfectants, bacteria viruses, organic materials, brine from softening MBAS

Outside use (about 50%)
Lawn watering fertilizers, pesticides and soil amendments, car wash, swimming pools

Waste water — Solid wastes

Septic tanks and leach fields

Treatment plants
Primary, secondary or tertiary (quality of effluents depends on treatment

Sanitary land fill

Recharge of groundwater basins, high TDS

Storm drains
Loss of TDS, high organic content, dust

Sludge

Recharge of groundwater basins High TDS, NO3, Cl, SO4

Reuse of water
Irrigated agricultural or industrial and/or spreading for ground water recharge

Surface water streams
High BOD, nutrients, MBAS, algae

Ocean outfall

Ocean outfall — Sanitary landfills — Sludge lagoons

2. **Industrial sources**
- The major uses of water in industrial plants are for cooling, sanitation, manufacturing and processing
- Groundwater pollution occurs when the industrial waste water is discharged into pits, ponds. This leads to water migration to water table. Some times deep injection of hazardous waste into saline water below fresh water aquifer also leads to pollution.
- The groundwater can be polluted from leakage of underground storage tanks and pipe (mainly fuels or chemical storage, radioactive waste)
- Mining activity (coal, phosphate, uranium, iron, copper, zinc)

How do industries contribute to the degradation of groundwater?
- Solid materials that are stockpiled near industrial plants cause leaching of toxic materials due to precipitation into the soil.
- Some times solid wastes are dumped besides the river banks. When they are washed into the river (rainfall) it may cause pollution.

Brine is saline waste water produced during production of oil, gas. Industries inject brine deep into oil/gas formations that is below the fresh water aquifer. When the oil wells are abandoned or unplugged they allow saline to mix with aquifer (pollution).

3. **Agricultural sources**

- Irrigation increases salinity of return water 3-10 times than the applied water. This occur due to addition of salts (fertiliser)
- Fertilisers and pesticides leach through soil and pollute water table

4. **Miscellaneous sources**

- Spills, surface discharges, septic tanks, saline water intrusion
- Connate water can contaminate aquifer due to over pumping of groundwater

Connate water

- The water trapped in the geological formations during sedimentation and remains out of contact with the atmosphere for a long time (millions of years)
- This type of water is found in oil fields and is saline

Purifying process of Polluted groundwater

How is polluted ground water purified?

- Pollution can be reduced or removed in concentration with time and increase in the distance travelled. The self purification process consists of
    1. Microbial decomposition
    2. Chemical precipitation and co-precipitation
    3. Sorption
    4. Exchange of gases
    5. Mechanical filtration
    6. Dilution
    7. Radioactive decay

Flow/movement of groundwater

- **Porous aquifer**
    - Composed of sand and gravel
    - Groundwater flows in small interstices
    - The velocity of the flow is 1 m/day to few m/day
- **Fissured rocks**
    - Groundwater movement restricted to fissures and cracks
    - The velocity of the flow is 0.3 m/day to 26 m/day

    1. Microbial decomposition (How micro-organisms purify ground water?)
- Biochemical degradation of organic and inorganic pollutants are carried out by micro-organisms. When the pollution level increases, the degradation process also increases due to availability of more nutrients to micro-organisms. The motile and immotile organisms form microbial slimes on the surface of the ground particles. Now the bacteria and virus that accompany the waste can not survive. The bacteria is also removed by silt and clay.

    2. Chemical precipitation and co-precipitation
- No free dissolved oxygen zone is called "reduction zone"
- What do you understand by E_h or redox potential?
- E_h is an indication of oxidation reduction states of systems
- It is a measure of the tendency of a system to under go change (oxidation/reduction)

- It is measured in volts or mV
- When E_h is +ve strong oxidising conditions exist
- Reduction zone with negative E_h is favourable for eliminating heavy metal ions
- Downstream from the reduction zone are transition and oxidation zones
- Here hydroxides of Fe and Mn are precipitated
- Cu, Pb, Zn, As, W, V, F^- and PO_4^{-3} are co-precipitated

3. Sorption

Why does sorption serve as a major mechanism for reducing groundwater pollution?

- clay, metallic oxides, hydroxides, organic matter serve as sorption material
- Most pollutants can be sorped under favourable conditions (except Cl^-, NO_3^-, SO_4^{-2})
- Sorption depends on type of pollutant, physical and chemical properties of solution and the subsurface material

4. Exchange of gases

How does gaseous exchange influence groundwater pollution?

- The decomposition of pollutants in groundwater is significantly influenced by the supply of O_2 from the soil, air and sewage water
- Volatile pollutants and decomposition products like CH_4, CO_2, H_2S, N_2 will escape into the soil air and to the atmosphere thus removing considerable amount of contaminants
- Poorly permeable strata above the aquifer (clay and silt) reduce the O_2 supply. This disturbs the escape of gaseous pollutants and the decomposition products

5. Mechanical filtration and Dilution

How do the process of mechanical filtration and dilution help in purifying groundwater?

- Suspended particles can be removed by filtration
- Filtration can remove Fe, Mn particulates, precipitate from chemical reactions
- Filtration can also remove suspended bacteria and virus present in ground water
- When fresh water or seepage water mixes with polluted groundwater, dilution of pollution takes place
- It depends on the rate of recharge of water and its physical/chemical properties
- Dilution is the most important process for pollutants

6. Radioactive decay

- Radioactive decay will have a decontaminating effect when short-lived radioisotope are decayed by long stay of contaminated water in the aquifer as a result of retarding factors such as slow groundwater velocities and long flow distances.

It is important to know the hydrogeological criteria before selecting sites for disposal of waste materials

- There should be large distance between water table and soil surface
- There should be good sorption capacity, presence of clay and silt, low groundwater velocity

Pollution of the oceans

How do domestic and industrial activities contribute to the pollution of ocean water?

- Domestic sewage constitutes largest amount of waste (18,240 MLD)
- The waste are converted using large amount of O_2 from sea
- This leads to loss of O_2 in sea water and sea flora and fauna are affected greatly
- Discharge of industrial waste pollutes sea water
- The quantity of industrial mass generated by industries are 0.67×10^9 m^3
- Many small and medium industries discharge untreated effluents
- The industrial effluents contain metals like Hg, Cd, Pb, As etc.

Oil spills damage the ocean water to a large extent

- Immediately after the spill oil spread on the sea surface (depends on wind speed)
- Lighter fraction evaporates within 24 hr (40%)
- Solar UV radiation removes another 10%
- Heavier fraction broken down by oil degrading bacteria
- Oil oxidised by dissolved O_2 in sea water at a rate of 1 mg oil per 3 mg of O_2
- Barely 1% of spilled oil get dispersed, suspended or dissolved in water