Environmental Science

Course Objective

- This course introduces the students to the environmental consequences of industries, development actions etc. and the methods of minimizing their impact through technology and legal systems.

Modules

This Course is divided into 6 Modules

1. Ecology, biogeochemical cycles
2. Environmental Gradients
3. Water and wastewater treatment
4. Atmospheric Chemistry and noise pollution
5. Solids waste management
6. Health impacts of waste and e-waste

Swachh Bharat Abhiyaan (Clean India Mission)

A ‘Green’ Planet....

....But a 'fragile' planet, handle with care !

Origin

- The word "**Environment**" has come from an old French word **environ** or **environner** to be exact which literally means "**to encircle**" or "**to surround**".

Definition

- The word “**environment**” can be defined as “our life support system which includes air, water, land/soil & all other natural resources present around us”.

Definition

- According to ISO:14001(International Organization for Standardization), **environment** can be defined as, “Surroundings in which an organization operates, including air, water, land, natural resources, flora(plants), fauna(animals), human beings and interrelations”.

Related Terms

- Environmental Science
- Environmental Engineering
- Environmental Management
- Environmental Laws

Environmental Science

- It is the study of human beings impact on the environment and the physical, chemical and biological changes occurring in nature which focuses on pollution.
- It is highly interdisciplinary & it collects information from various fields such as biology, chemistry, geography, agriculture, geology etc.

Environmental Engineering

- It is defined as that branch of engineering which is concerned with protecting the environment from the potentially deleterious or harmful effects of human activities, protecting the human population from the effects of environmental pollution and improving the environmental quality for better human health & well being.

Environmental Management

- It consist of auditing of EIA (Environmental Impact Assessment), Planning, Preparing EIS (Environmental Impact Statement) & pollution management.

Environmental Laws

- It involves the body of statuaries, policies those are made in order to protect the nature from being misused by human beings.
- Some laws are regulative or controlling in nature while some are for preventive measure & some are binding on us.

Sustainable Development (SD)

- It can be defined as "**the ability to meet the needs of present generation without compromising the ability of future generation to meet their needs**" i.e. the balance or proper use of resources, so that our future generation will not face any problem for their survival, after taking care of our own survival needs.

Pillars or Components of SD

- There are **three** pillars or components of Sustainable Development (SD)

  a) Economical Development

  b) Society or community Development

  c) Environmental Protection

Human Dimension in Env. Engg.

- It is also known as **Three factor model** for assessing environmental degradation.
- To estimate or assess the extent of environmental degradation **John Holdern** (a physicist) and **Paul Ehrlich** (a biologist) have given a three factor model.

Human Dimension in Env. Engg.

- According to this model, total environmental Impact (I) of degradation and pollution due to population in a given area depends on three factors i.e. P, A, T.

  P represents Size of population

  A represents Affluence or Per capita Consumption or per person consumption

  T represents Technology used.

Human Dimension in Env. Engg.

- The relationship is, I = PAT
- In the developing countries, **P^3 syndrome** i.e.(Population, Pollution, Poverty) and in the rich developed countries **overuse of natural resources** are the key or important factors leading to environmental degradation.

Building Blocks of Env. Engg.

- Env. Engg. consists of **Basic Engg.** and **Basic Sciences**.
- **Basic Engg.** consists of Civil Engg. and Chemical Engg.
- **Basic Science** consists of Chemistry, Physics, Biology, Economics.

Building Blocks of Env. Engg.(Basic Engg.)

- Civil Engg. consists of -
  - a) Infrastructure,
  - b) Water Resources,
  - c) Water Quality,
  - d) Sanitary Services,
  - e) Hydroinformatics and
  - f) Waste Engg.

Building Blocks of Env. Engg. (Basic Engg.)

- Chemical Engg. consists of –
  a) Chemical Hazardous Waste process Engg.
  b) Transport of chemicals
  c) Air Quality

Building Blocks of Env. Engg. (Basic Science)

- Chemistry consists of –

  a) Water Chemistry

  b) Air Chemistry

  c) Soil Chemistry

Building Blocks of Env. Engg.(Basic Science)

- Physics consists of –

  a) Hydrology & Hydrogeology

  b) Meteorology & Atmospheric Science

  c) Fluid Mechanics

  d) Heat & Mass Transfer

  e) Sound & Noise

  f) Soil Physics

Building Blocks of Env. Engg. .(Basic Science)

- Biology consists of –

  a) Microbiology

  b) Ecology

  c) Agronomy

Building Blocks of Env. Engg. .(Basic Science)

- Economics consists of –

  a) Economics management

  b) Environmental Laws

  c) Politics

  d) Social Sciences

Building Block of Env. Engg.

- Basic engineering
  - Civil
    - Infrastructure
    - Water resources
    - Water quality
    - Sanitary services
    - Hydroinformatics
    - Waste engineering
  - Chemical
    - Chemical hazardous waste
    - Process engineering
    - Transport of chemicals
    - Air quality
- Basic sciences
  - Chemistry
    - Water chemistry
    - Air chemistry
    - Soil chemistry
  - Physics
    - Hydrology and hydrogeology
    - Meteorology and atmospheric science
    - Fluid mechanics
    - Heat and mass transfer
    - Sound and noise
    - Soil physics
  - Biology
    - Microbiology
    - Ecology
    - Agronomy
  - Economics
    - Economics management
    - Environmental law
    - Politics
    - Social science

Environmental Problems

- The major environmental problems that we are facing are –
  a) Water Pollution
  b) Air Pollution
  c) Biodiversity Depletion
  d) Large amount of Waste Production
  e) Food Supply Problems

Causes of Environmental Problems

- Many Environmental Problems presently we are facing are mainly due to –

  a) Over Population

  b) Wasteful use of Resources

  c) Destruction & Degradation of Wildlife Habitats

  d) Depletion & Contamination of Surface Water & Ground Water

Causes of Environmental Problems

e) Depletion of Non-Renewable resources or minerals

f) Deforestation

g) Soil Erosion

h) Loss of Biodiversity

Definition of Pollution

- It is an undesirable change in physical, chemical or biological characteristics of air, water & soil, that may harmfully affect human beings, animals, the plant life, industrial progress, living conditions & cultural assets.

Definition of Pollutant

- It is an undesirable harmful solid, liquid or gaseous substance present in such a concentration in the environment which tends to be injurious for the whole living organisms.

Ecological Concepts

- The word **ecology** was coined by Ernst Haeckel from two Greek words, Oikos & Logos.
- Oikos means House or Living Space & Logos means Study
- Ecology is the branch of Biology concerned with the relations of various species to one another & to their physical surroundings

Ecological Perspective

- Ecological perspective demands a greater understanding of the functioning of living systems & their interactions with the environment.
- It gives a qualitative emphasis on ecological concepts.

Principles of ecology

- Living organisms can't exist with total disregard to their environment.
- All living organisms & their physical environment are interdependent upon each other & also affect each other.

Principles of ecology

- Every living organisms has certain limits of tolerance towards the various factors of environment & only within these limits the organisms can survive.
- The existence of life depends upon flow of energy through food chains & the cycling of nutrients.

Aspects of ecology

- The two important aspects of ecology are –

  a) Autecology or species ecology

  b) Synecology or community ecology

a) Autecology

- It is concerned with the ecology of an individual species & it’s population.

b) Synecology

- It is the study of communities, their composition, their behaviour & the relation to the environment.
- Synecology is further subdivided into three categories –

  i) Population Ecology

  ii) Genetic Ecology

  iii) Taxonomic Ecology

i) Population Ecology

- It relates with individual organisms with different groups of organisms within the ecosystem of different levels & the interrelationship among themselves

ii) Genetic Ecology

- It is also known as Gene Ecology.
- Different organisms have different genes & chromosomes, hence they live in different places.
- The relationship due to the variation in genes among biotic components with their surroundings non-biotic environment is known as Genetic Ecology.

iii) Taxonomic Ecology

- It includes ecology of taxonomic groups such as microbes, vertebrates (with backbone), invertebrates (without backbone) & insects etc.

Ecosystem

- An ecosystem is defined as a natural functional ecological unit comprising of living organisms (i.e. biotic community) & their non-living (i.e. abiotic) environment that interact to form a stable self-supporting system.
- Example: Pond ecosystem, Forest ecosystem etc.

Ecosystem

- The ecosystems are characterized by a diversity of species, but in an ecosystem there must be representatives from the three functional or metabolic groups such as Primary Producers, Consumers & Decomposers.
- The ecosystems can vary in sizes.

Properties of Ecosystem

- An Ecosystem exists independent of specific components i.e. an individual tree may die, but a forest persist.
- The components of an ecosystem are interdependent.
- The nature of ecosystem depends on the species biodiversity of the ecosystem.

Properties of Ecosystem

- The function of ecosystem depends on the energy flow & cycling of chemical elements within the ecosystems.
- The ecosystem can be disturbed by human activities & the most adverse effect of disturbance is the loss of biodiversity.

Types of Ecosystem

1. Natural Ecosystem
2. Artificial or Man-made or Man-engineered Ecosystem

1. Natural Ecosystem

- These ecosystems operate by themselves under natural conditions.
- Depending on the type of habitats, these are further sub-divided into –

  I) Terrestrial Ecosystem

  II) Aquatic Ecosystem

I) Terrestrial Ecosystem

- It includes forest, grassland, desert ecosystems.

II) Aquatic Ecosystem

- These ecosystems found in the aquatic environment.
- It can be divided into two categories –

  a) Fresh water ecosystem

  b) Marine water ecosystem

a) Fresh water ecosystem

- The Fresh water ecosystem can be

  i) Lotic &

  ii) Lentic

  Lotic means (moving or running water)

  e.g. River or Stream ecosystem

  Lentic means (Still or Standing water)

  e.g. Pond, Lake ecosystem

b) Marine water ecosystem

- These include salt water bodies which may be Ocean ecosystem, Sea ecosystem.

2. Artificial ecosystem

- These are maintained artificially by human beings.
- e.g. garden, park.

Incomplete ecosystem

- Abysmal depth of oceans where no light penetrates represent incomplete ecosystem.
- There are no green plants & hence there are no primary production.

Structure or components of ecosystem

- Ecosystem has two major components.

  1. Abiotic & 2. Biotic
- Abiotic can be classified into hydrosphere, atmosphere & lithosphere
- Biotic can be classified into producer, consumer & decomposer.
- Consumer can be primary, secondary, tertiary consumers.

Functions of ecosystem

- Energy flow : It regulates the flow of energy from one level to the other.
- Nutrient cycling : It regulates cycling of nutrients.
- Environmental gradients : The ecosystem fix the limit of tolerance for each organism towards various factors of environment.

Functions of ecosystem

- Food Chain & Food Web : The energy produced by green plants are passed to next levels by a chain of consumers leading to formation of food chain &
- interlinking of food chain will lead to formation of food web.
- Biodiversity : The ecosystem regulates the species diversity to acquire a stable system.

Natural Resources

- The materials those occur in the environment or those are created by the environment & useful for supporting life or promoting the well-being of human beings are termed as natural resources

Natural Resources

- Natural Resources are the naturally occurring substances those are considered valuable in their natural form & their value rest in the amount of material available & the demand for it.

Types of Natural Resources

- There are three types of natural resources –

  1) Renewable or Inexhaustible

     i.e. available in unlimited quantity.

     Ex – Solar energy, wind power etc.

  2) Non-renewable or exhaustible

     i.e. available in limited quantity

     Ex – coal, petrol, diesel etc.

Types of Natural Resources

3) Abstract Natural Resources :

It includes animals, plants & natural landscapes as part of countryside used for recreation & tourism activities.

Ex – Bird watching, sight-seeing

2.Biodiversity

- It doesn’t imply just a collection of species, but is a basic resource which acts as a human life support system.
- Biodiversity plays an important role in biogeochemical cycles.

2.Biodiversity

- Biodiversity has three hierarchical levels i.e.

  i) Genetic Biodiversity

  ii) Species Biodiversity

  iii) Ecosystem Biodiversity

2.Biodiversity

- There can be three kinds of losses of biological resources.

  i) Depletion of a once common species

  ii) Local or global extinction

  iii) Ecosystem disruption.

Levels of organization in Biotic Components

- There are **six** major levels of ecological organization are recognized in the biotic components of the environment.

  1) Individual
  2) Population
  3) Community
  4) Ecosystem
  5) Biomes &
  6) Biosphere

1) Individual

- These are single species.
- Individuals have physiological functions & respond to environmental conditions

2) Population

- Population consists of a group of individuals of the same species living in a particular area at the same time.
- Birth rate, death rate plays an important role in the size of population.

3) Community

- Population of different species living together interact with each other to form a community.
- <u>Niche</u> :-

A suitable or comfortable position in the ecological hierarchy for a species.

Ex- Phytoplankton→Zooplankton→Fish→Whale

Niche of fish in the above ecological hierarchy is three or 3rd position.

4) Ecosystem

- It includes both biotic & abiotic components of an area.
- The major or important feature of this ecological level is the strong interaction between the various biotic & abiotic components present.
- Nutrient cycling & energy flow occur in this ecological level.

5) Biomes

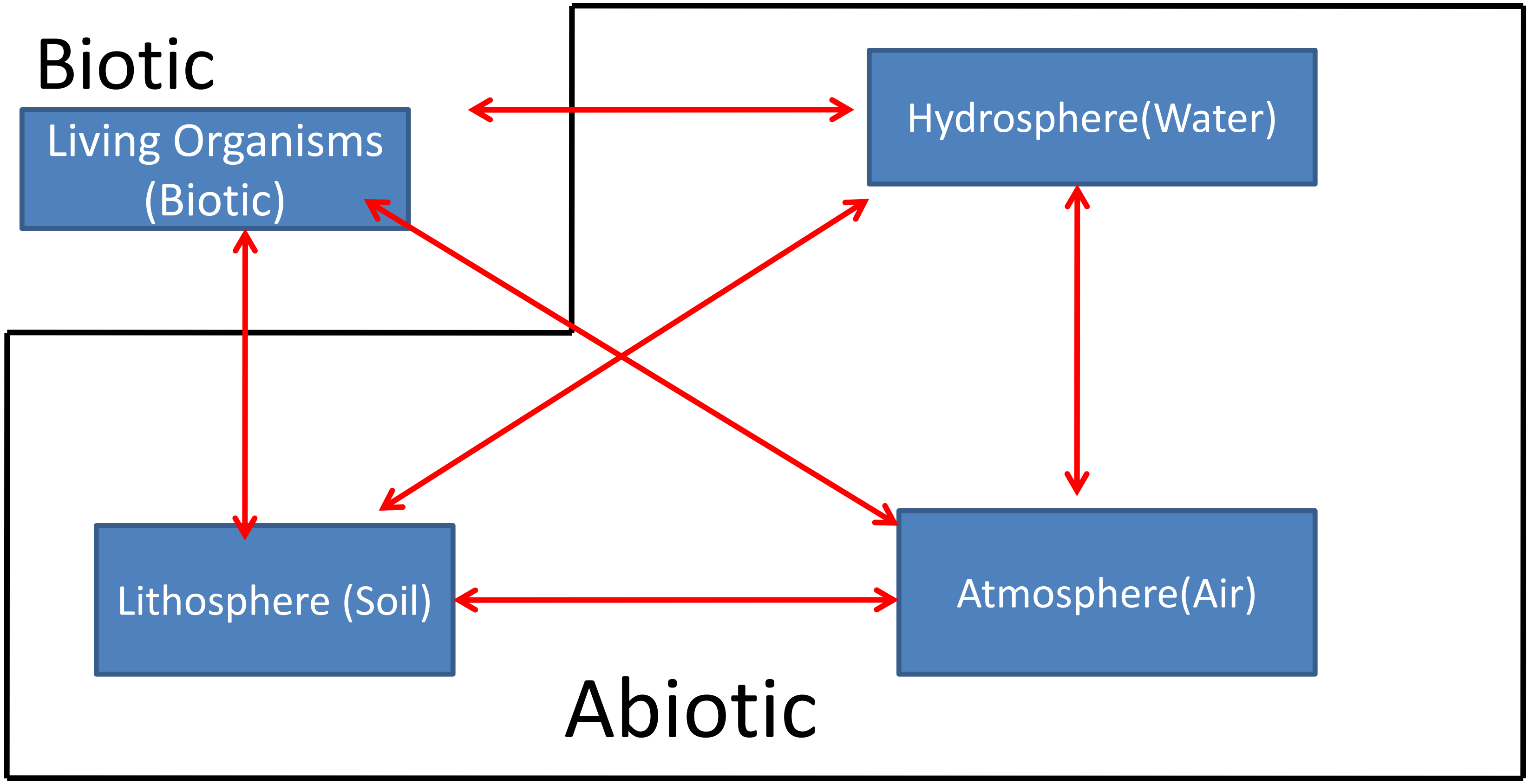
- When environmental conditions are similar in different parts of the country or around the globe, the habitats & communities are also often similar, giving rise to a higher level of biotic organization known as **biomes**.
- Ex- a)**Tropical Rainforest**(High temp.& High rainfall)

  b) **Desert Scrub**(High temp. & low rainfall)

6) Biosphere

- The highest organizational level is the biosphere & it extends from bottom of the sea to the top of the sky where life exists.
- Biogeochemical cycles occur at this ecological level.

Interaction of Biotic and Abiotic components of an ecosystem



Interaction Processes….

- The previous diagram represents dynamic nature of ecosystem due to interactions and interdependence of the various components present.

Ecosystem Process

- In the ecosystem process, the following processes are essential for the survival & maintenance of biotic components.
  1. Energy flow &
  2. Nutrient cycling

1. Energy flow

- On the earth, the ultimate source of energy of life is

  solar radiation.

- There are two sources of energy –

  a) Autotrophic

  b) Heterotrophic

1.(a) Autotrophic

- Autotrophic production of energy is carried out within the ecosystem by green plants in the presence of sunlight using photosynthesis process.

1.(b) Heterotrophic

- Heterotrophic energy source is the one, where the chemical energy is imported as organic matter which is originated from primary production in some other ecosystem.
- This imported organic matter is called **allochthonous**.

Photosynthesis

- $12H_2O + 6CO_2 + 709kcal(\text{from sunlight}) \xrightarrow{\text{Chlorophyll}} C_6H_{12}O_6 + 6O_2 + 6H_2O$

  (Carbohydrate)

- Out of total amount of solar radiation available,

  only 1 to 5% is used in the photosynthesis process.

Photosynthesis

- The organic matter produced by green plants in the Photosynthesis process is called
  Primary Production or (PP)
- PP is affected by various environmental factors like water, light, temperature & soil nutrients.
- PP is of 2 types.
  1) GPP (Gross Primary Production)
  2) NPP (Net Primary Production)

Photosynthesis

- GPP – R(Respiration) = NPP
- GPP is the total amount of chemical energy or biomass stored by plants per unit area per unit time.
- Since plant requires energy for synthesis of organic matter & functioning of plant itself, some of GPP is used in the process of respiration.

Photosynthesis

- NPP is used for plant growth & reproduction.
- NPP is normally 80 to 90% of GPP.
- As various environmental factors affect PP, hence GPP & NPP vary over the globe.
- NPP can be classified into **four** broad groups each with a characteristic productivity range.

Photosynthesis

1. Low range – 0 to 250 gm/m^2 – year
   Ex- Desert, semi-desert
2. Middle range – 250 to 1000 gm/m^2 – year
   Ex- Non-forest communities like shrubland, grassland
3. Normal range – 1000 to 2000 gm/m^2 – year
   Ex- Forest
4. High range – 2000 to 3000 gm/m^2 – year
   Ex- Rainforest

Respiration

- When any organism requires energy, the reverse chemical reaction of photosynthesis occurs, known as **respiration,** where the glucose molecule is broken down in the presence of oxygen to produce CO_2, H_2O & energy for work done & maintenance. The reaction is –

$$C_6H_{12}O_6 + 6O_2 \xrightarrow[\text{enzymes}]{\text{Metabolic}} 6CO_2 + 6H_20 + \text{ energy for work done \& maintenance}$$

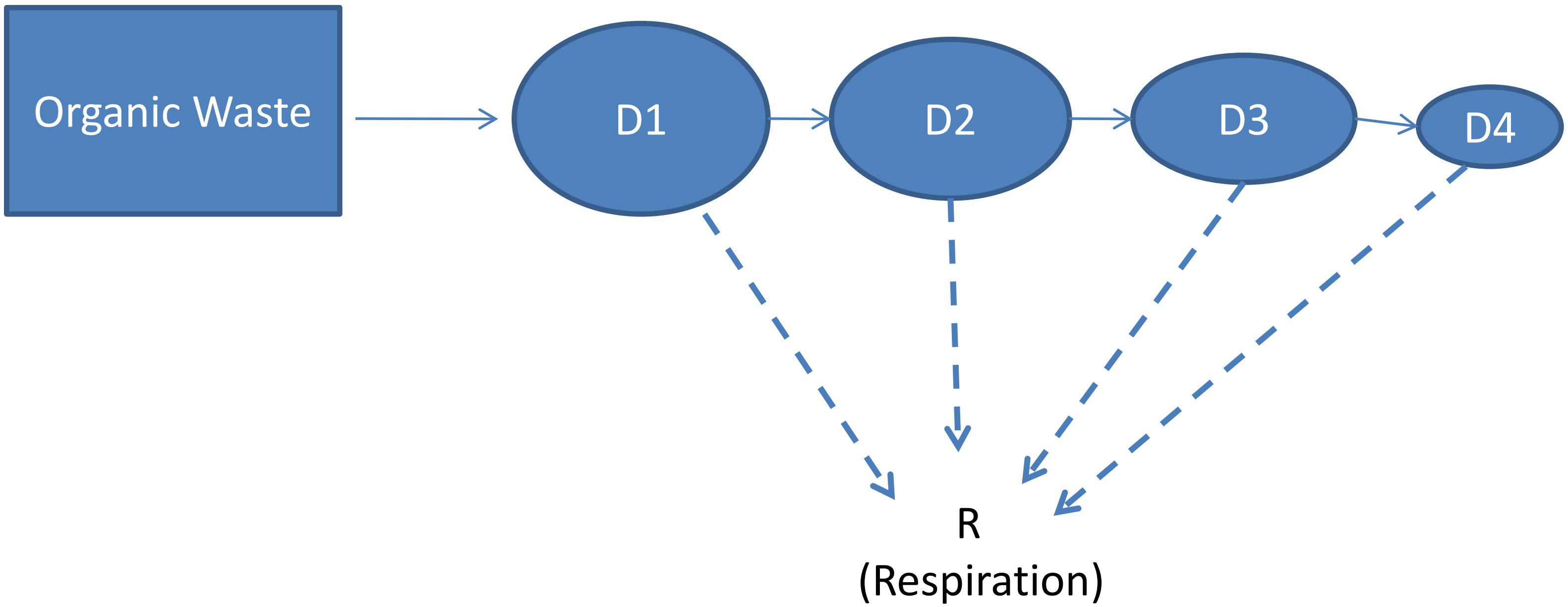
2. Nutrient cycling

- During decomposition, the complex organic molecules in the original detritus or waste are gradually broken down to much simpler constituents & inorganic molecules like nitrates & phosphates, as the material moves through the decomposer or detritus food chain.

2. Nutrient cycling

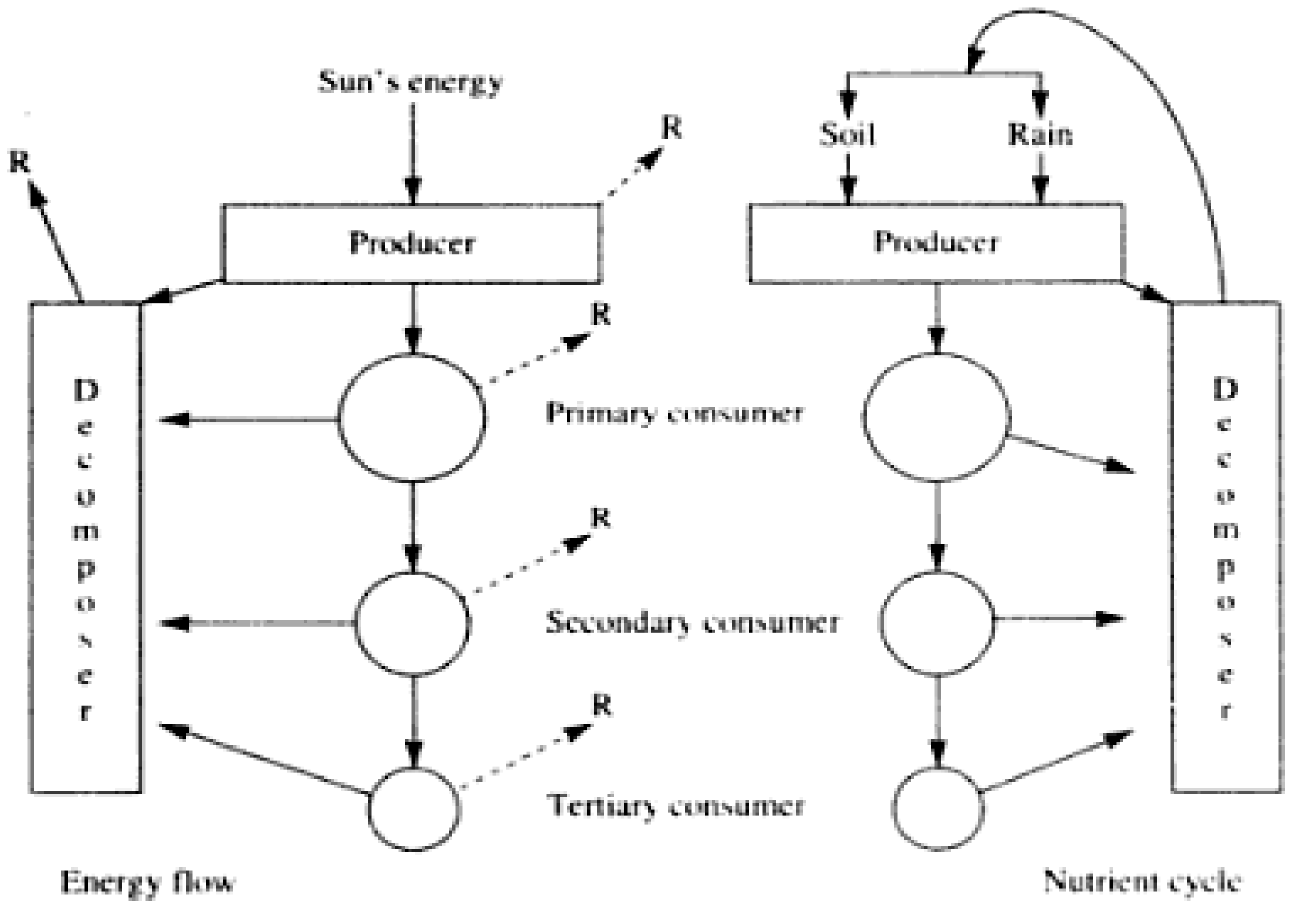
- These are then, enter into the soil or sediment or dissolved in water, where they become the nutrients available for reuse by green plants.
- This whole process of recycling of nutrients within the ecosystem is known as **nutrient cycling.**

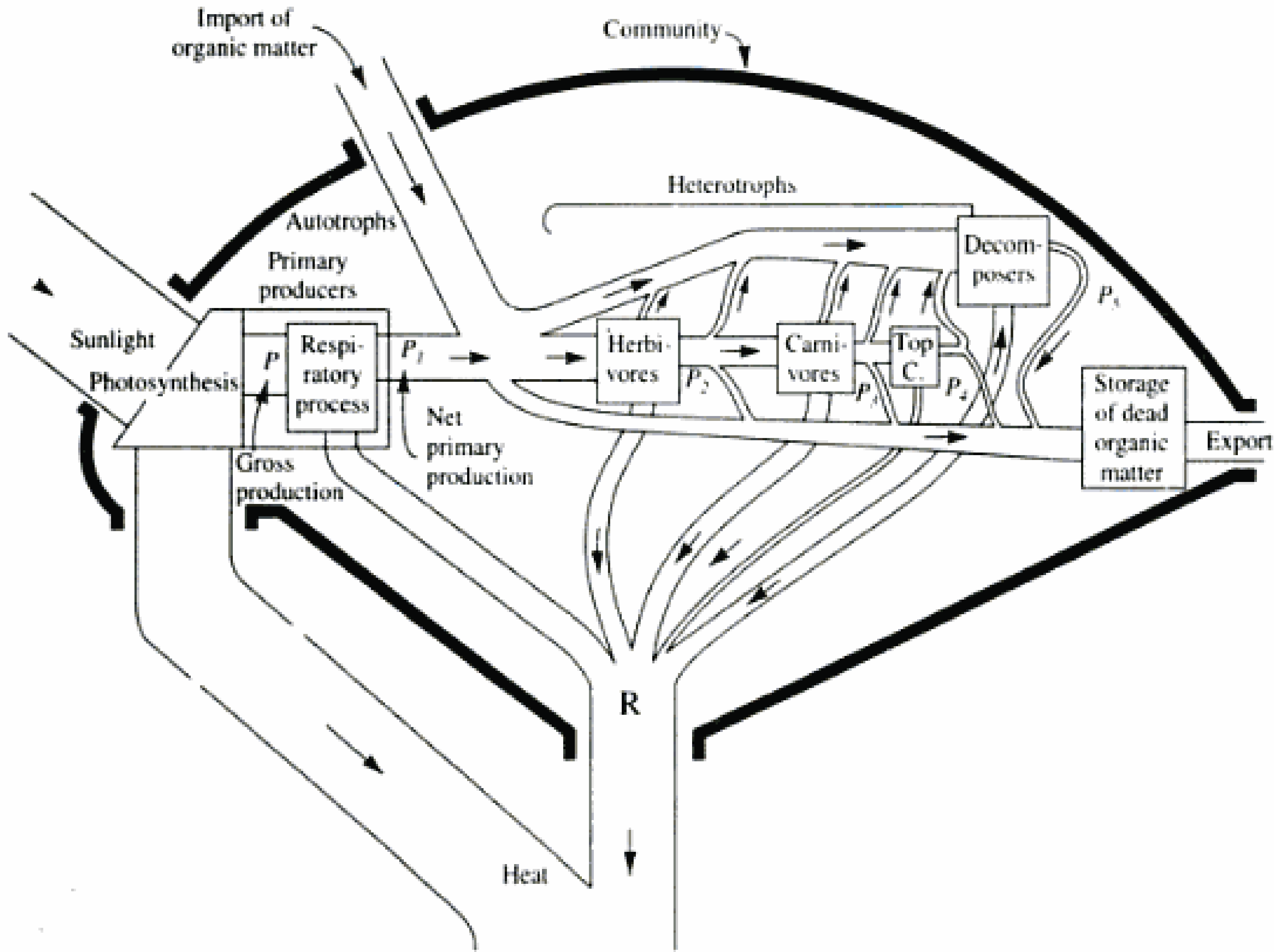
Detritus chain energy flow



(D1 to D4 are different levels in the detritus chain & size of circles indicate the relative amount of energy present in the level.)

Overview of 2 major ecosystem process of energy flow, nutrient cycling





Import of
organic matter
Community
Heterotrophs
Autotrophs
Primary
producers
Decom-
posers
Sunlight
Photosynthesis
P
Respi-
ratory
process
P1
Herbi-
vores
P2
Carni-
vores
P3
Top
C.
P4
P5
Storage
of dead
organic
matter
Export
Net
primary
production
Gross
production
R
Heat

- This diagram represents the **hydraulic analogy of energy flow through an ecosystem**.

  (Pg.- 39, G.Kiely)
- The energy is imagined as being channelled through pipes whose thickness is proportional to the rate of energy flow.
- R = Respiration &

  Top C = Top carnivore

Food Chain

- Chemical energy produced by primary producers & the nutrients used by plants to build plant tissues, are passed up by a chain of consumers leading to formation of food chain, where each link in the chain is provided with energy & nutrients.

Food Chain

- Each consumer population uses the food energy for living & respiration & the remaining energy can then be used to produce new biomass by growth & reproduction, which is called **secondary production** &

  become a potential food & energy source for another species, further up in the food chain.

Food Chain

- Depending on the types of foods, there are **three** types of food chain available.

  a) Predator or Grazing Food Chain

  b) Saprophytic or Detritus Food Chain

  c) Parasitic Food Chain

a) Predator or Grazing Food Chain

- Predator means an animal that naturally preys on others.

  Ex:-

Sunlight ⟶ Grass ⟶ Grasshopper ⟶ Frog ⟶ Snake
↓
Hawk

b) Saprophytic or Detritus Food Chain

- It starts from DOM (Dead Organic Matter) & goes to detritus feeding organisms i.e.

  detrivores i.e.

  bacteria, worms etc. & on to their predators.

  Ex:-

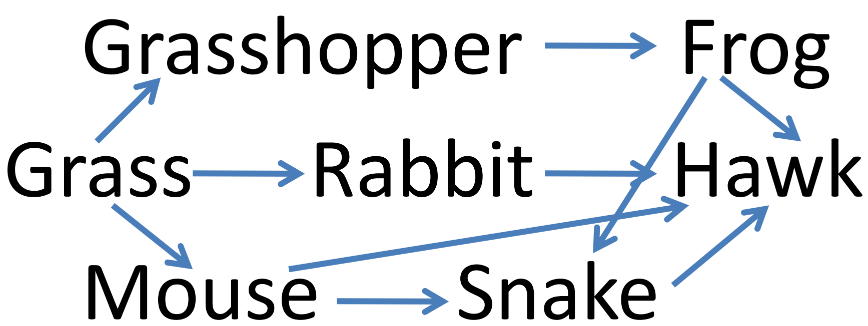
Dead leaves ⟶ Soil mites ⟶ Insects ⟶ Lizard

c) Parasitic Food Chain

- It is a food chain in which parasites live on the host body or within the host body to get energy.
- This food chain also starts from the green plants & animals to parasitic microbes.

Food Web

- In most ecosystems, food chains interlink with each other to produce food web.
- Food web shows the food pattern of energy flow in the ecosystem.



(Terrestrial Food Web)

Trophic Level

- Trophic level or nutritional level or tier gives the feeding status of an organism in an ecosystem.
- It is based on the concept who feeds on whom.
- It is the position an organism occupies in the food chain

Trophic Level

i)First trophic level or primary producer level

Ex: - Green plants

ii)Second trophic level or primary consumer level

Ex: - Herbivores

iii)Third trophic level or secondary consumer level

Ex: - Carnivores

Ecological pyramid

- The graphical representation of tropic levels is called the ecological pyramid.
- The arrangement of organisms in a food chain according to trophic levels forms a pyramid.
- Generally, pyramids are of

  three types.

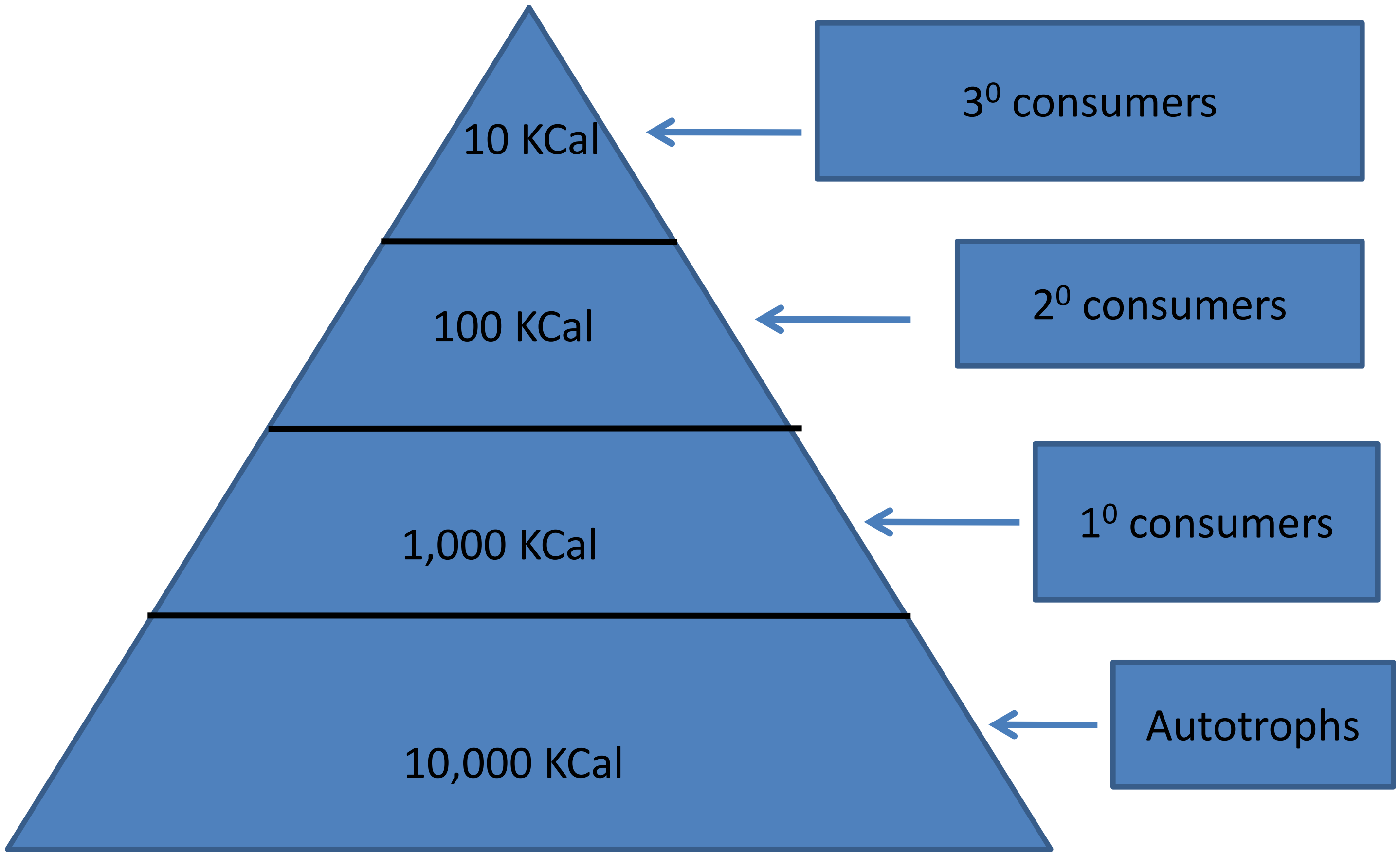
Ecological pyramid

1. Pyramid of energy
2. Pyramid of biomass
3. Pyramid of numbers.

1. Pyramid of energy

- Generally, 10% energy is transferred between adjacent tropic levels & rest 90% of energy is used up in that tropic level giving rise to energy pyramid. This is called **10% rule of ecosystem**.
- It is based on rate of energy flow & productivity at each successive trophic level.
- It decreases from autotrophs to higher tropic level.

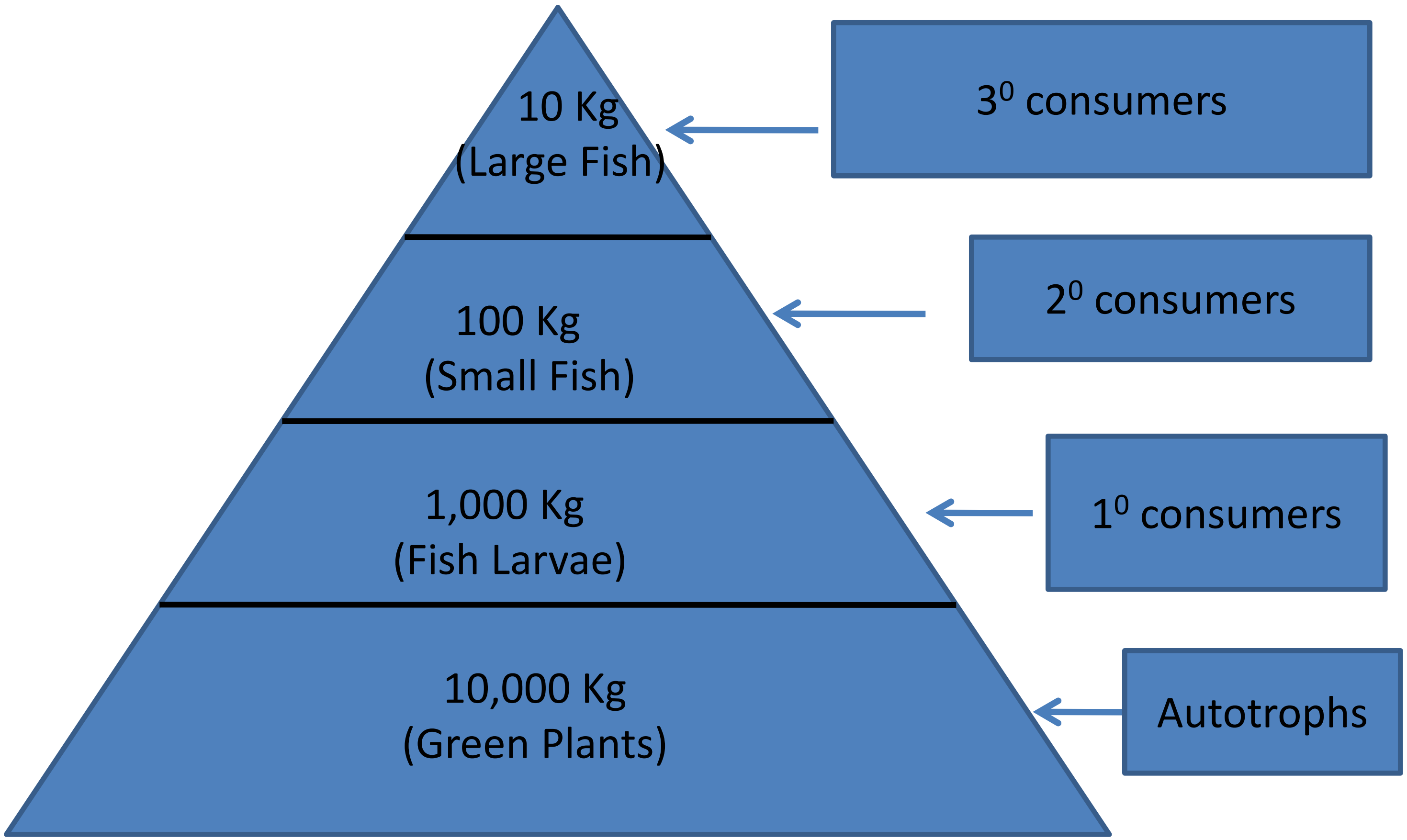
1. Pyramid of energy



2. Pyramid of biomass

- It shows the total mass of the organisms in each tropic level.
- It is based on total dry weight present in the level.
- It decreases from autotrophs to higher trophic level.

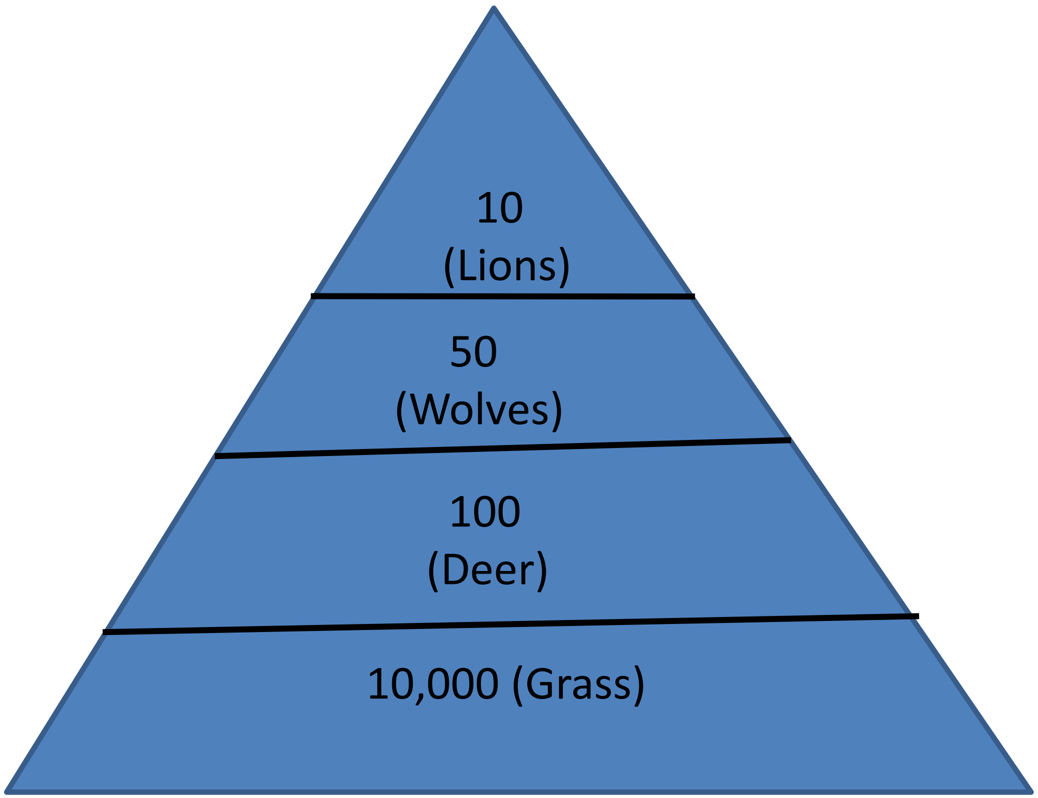
2. Pyramid of biomass



3.Pyramid of Numbers

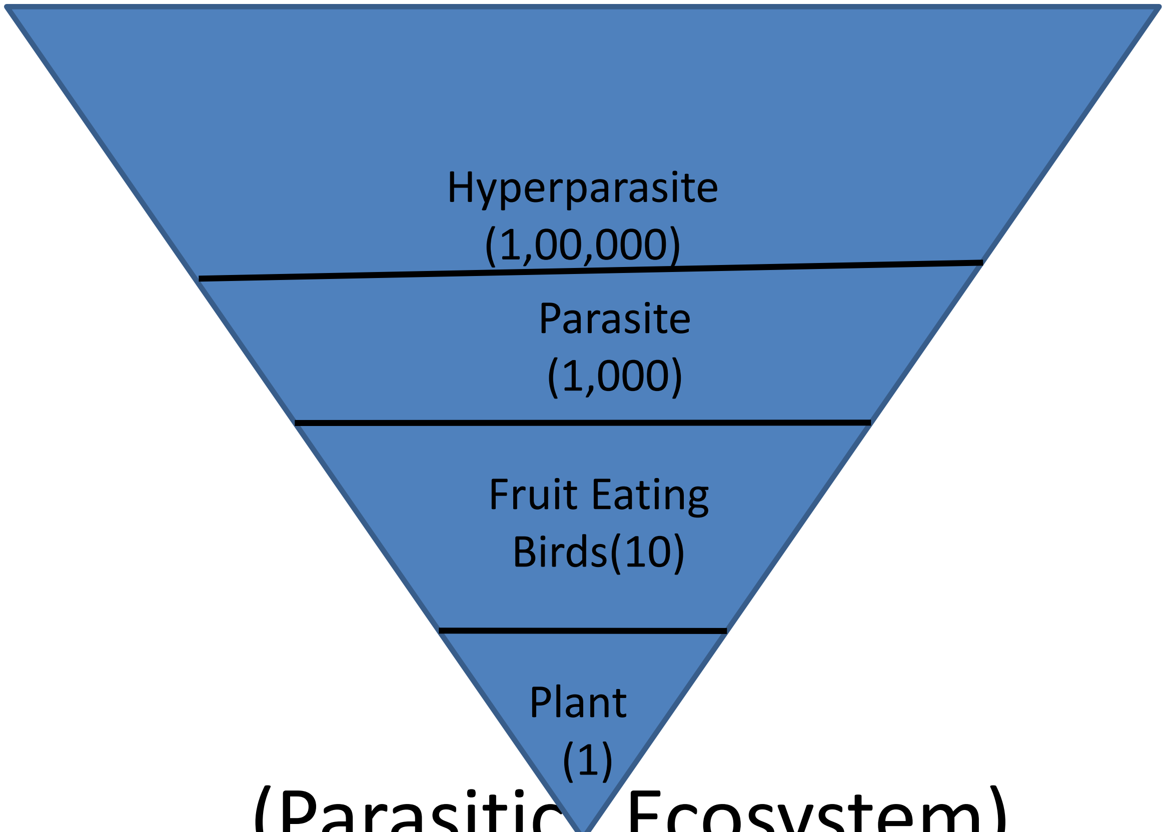
- It shows the number of organisms in each trophic level.
- There may be gradual decrease or increase in the number of individuals.

3.Pyramid of Numbers



(Grassland Ecosystem)

3.Pyramid of Numbers (Inverted Pyramid)



(Parasitic Ecosystem)

Ecological Succession

- In an ecosystem, new species may succeed older species.
- The process of gradual change in the conditions of physical environment, leading to the change in the species structure of an ecological community (i.e. replacement of one species by the other) over space & time, is called **Ecological Succession** or **Ecological Development.**

Biogeochemical Cycles

- Bio means living beings
- Geo means earth extended to air & water, where life exists.
- Chemical means chemical elements which continuously move in the cycles.
- The cyclic pathways through which chemical elements move from environment to the organisms & back to the environment are called bio-geochemical cycles.

Biogeochemical Cycles

- All parts or components of different ecological systems, on a local or global scale are linked with the Biogeochemical Cycles.
- Biogeochemical Cycles can have a number of phases & reservoirs.

  1) Organic Phase

  2) Inorganic Phase

Biogeochemical Cycles

1) <u>Organic Phase</u> :-

In this phase, nutrients pass rapidly through biotic communities using food chain.

2) <u>Inorganic Phase</u> :-

It contains all nutrient elements & are external to food chain.

Biogeochemical Cycles

- The various sub-phases of the inorganic phase are –

  a) Sedimentary Phase

  b) Atmospheric Phase

  c) Aquatic Phase or Aquatic Reservoir

Biogeochemical Cycles

a) <u>Sedimentary Phase</u> :-

It involves interactions with the solid earth or rocks & results of geological activities such as weathering.

b) <u>Atmospheric Phase</u> :-

It forms major part of some cycles like 'N' cycle & 'C' cycle & minor parts of some cycles like 'P' Cycle.

Biogeochemical Cycles

c) <u>Aquatic Phase or Aquatic Reservoir</u> :-

It involves plant nutrients.

<u>Types of biological cycles:-</u>

There are two types of biological cycles.

I) Water or Hydrological Cycle

II) Air or Atmospheric Cycle.

Biogeochemical Cycles

II) <u>Air or Atmospheric Cycle</u> :-

It can be classified into –

i) C – Carbon

ii) N – Nitrogen

iii) O – Oxygen

iv) P – Phosphorous

v) S – Sulphur

Hydrological Cycle

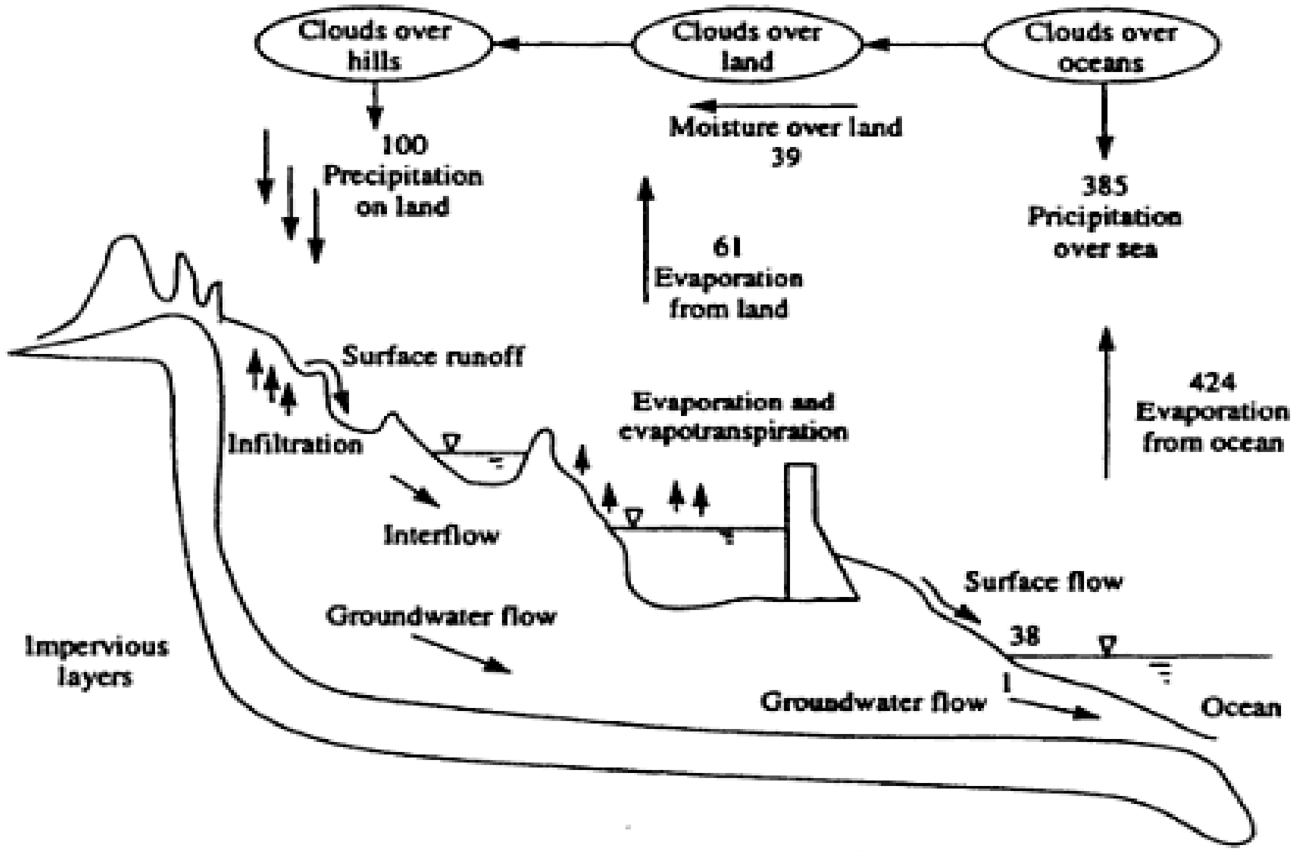


Figure 4.1 Hydrological cycle with global annual average water balance given in units relative to a value of 100 for the rate of precipitation on land (adapted from Chow *et al.*, 1988).

Hydrological Cycle

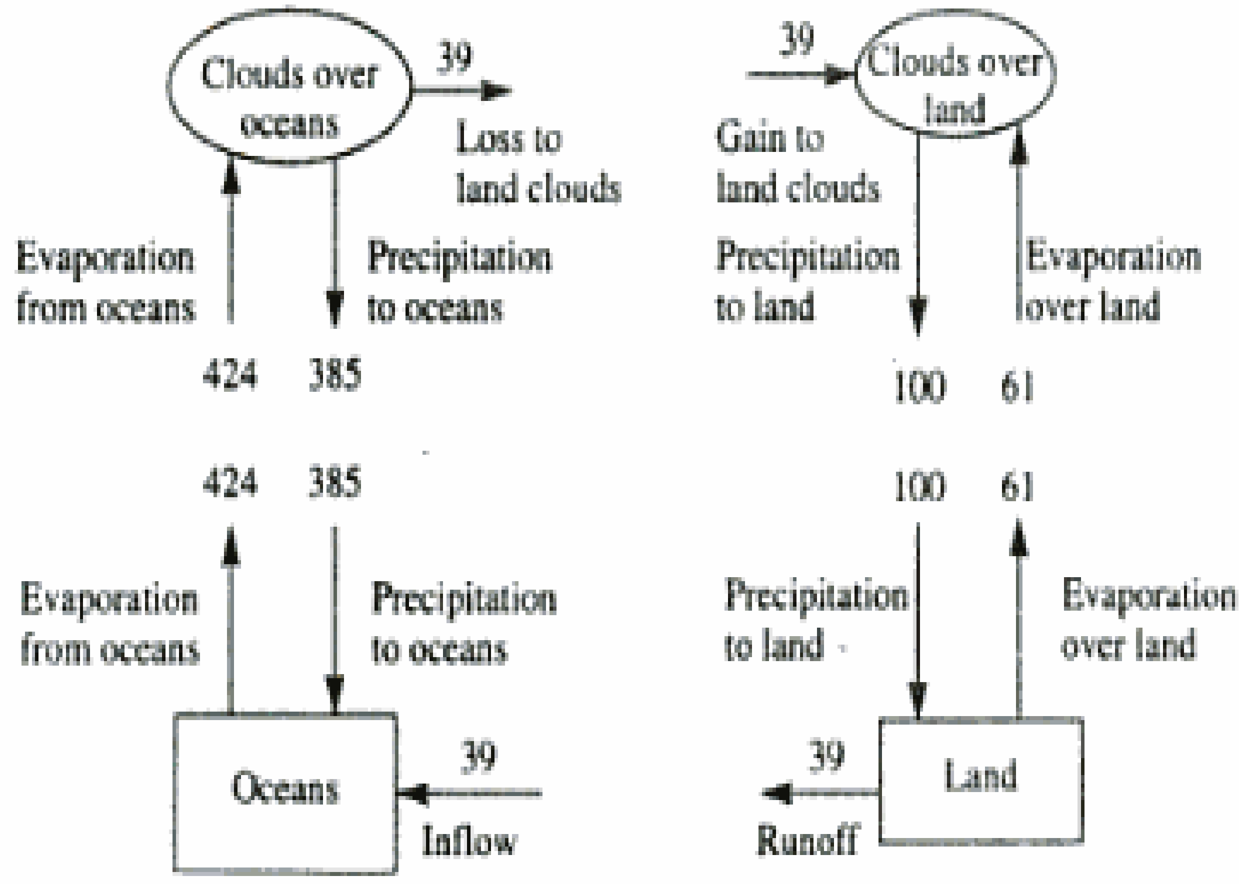


Figure 4.2 Material balance on aspects of the hydrological cycle.

Hydrological Cycle

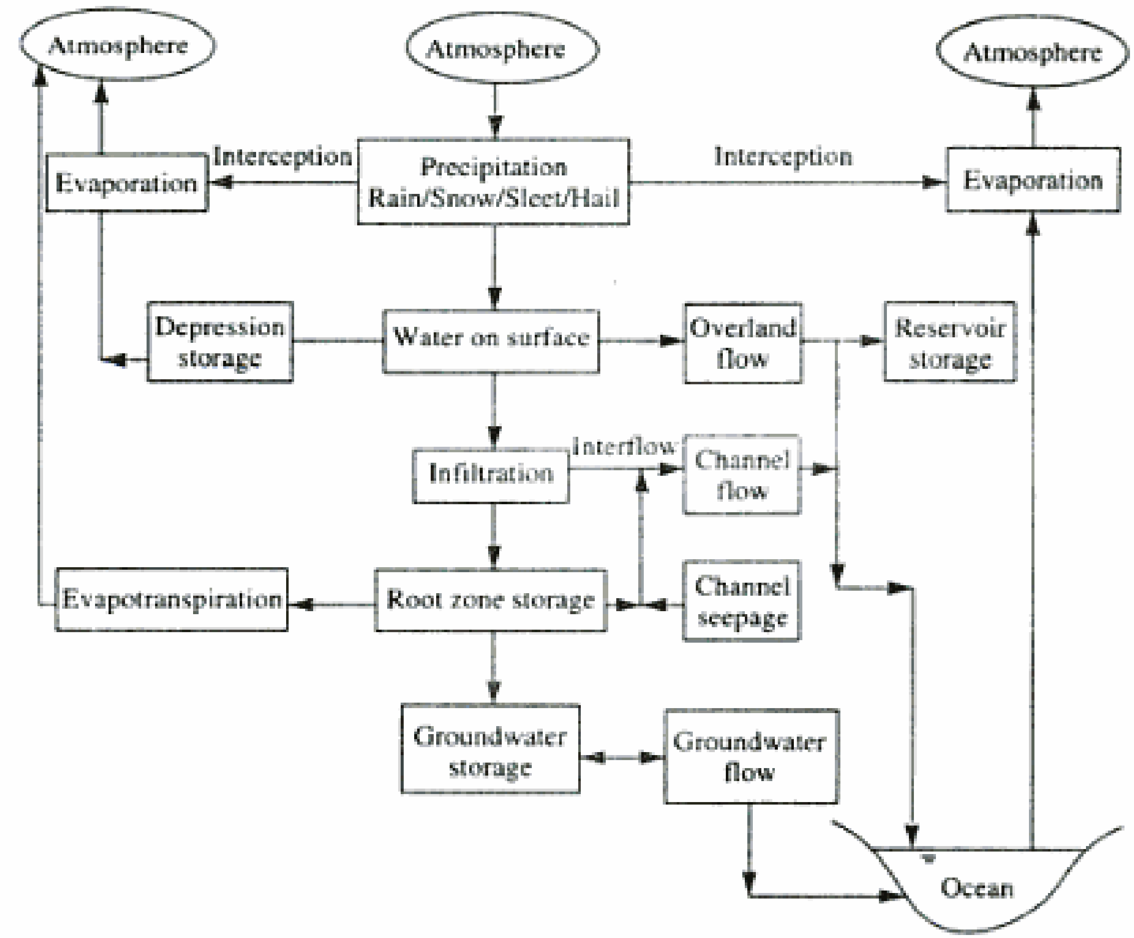


Figure 4.3 Components of the hydrological cycle (adapted from Bedient and Huber, 1988, p. 55, © 1988 by Addison-Wesley

Hydrological Cycle

- Interception:-

  It is the evaporation of water from the outer surface of leaves during & after rainfall.
- Transpiration:-

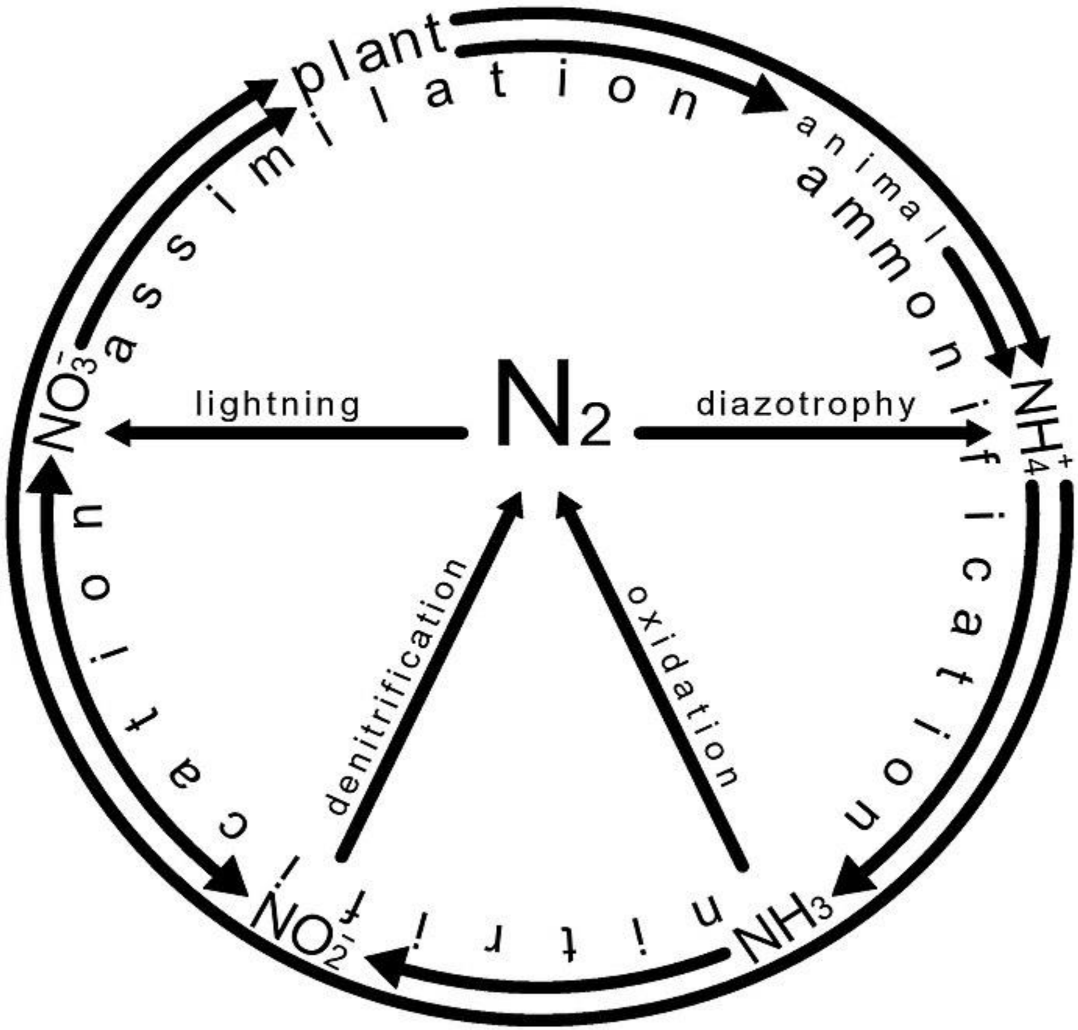
  It is the evaporation of water through foliage.
- Evapotranspiration:-

  It is the combination of Evaporation from water bodies & transpiration from leaves.

Hydrological/Water Equilibrium

- Surface inflow + Sub-surface inflow + Precipitation + Imported water + Decrease in ground water storage = Surface outflow + Sub-surface outflow + Consumptive use + Exported water + Increase in ground water storage
- It has an important impact on agriculture, forestry, irrigation, water supply & hydropower.

The Nitrogen Cycle



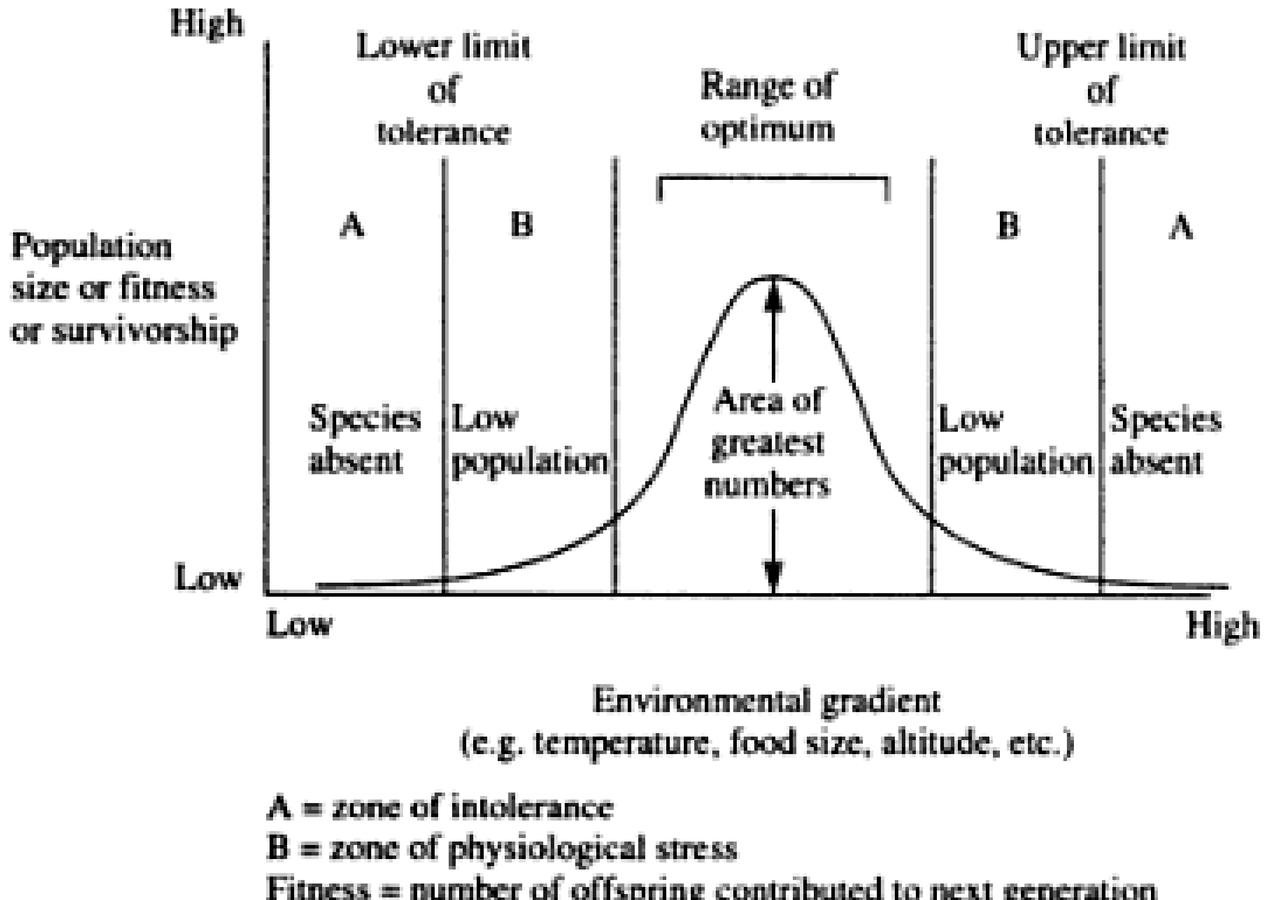
Environmental Gradients

- The environment or environmental factors are not similar over the globe or around the earth, giving rise to Environmental Gradients & due to which different species live in different places.

Environmental Gradients

- The physical, chemical factors like light, temperature & P^H are known as **conditions** & the factors the organism actually uses like food, water, shelter are known as **resources**.
- There is a global gradient change from the equator towards north or south.

Environmental Gradients



2.8 A schematic tolerance curve for a single species population existing on a single environmental gradient.

Environmental Gradients

- This is a normally distributed bell-shaped curve, as the change in environmental conditions are gradual from equator towards north or south.
- But, pollution can make it **skew-shaped**

  i.e. sharp decrease of curve towards left or right from range of optimum.

Environmental Gradients

Limiting Factors:-

The resources in shortage of supply or the conditions over which the species has the smallest range of optimum will limit the species function & is called the limiting factor.

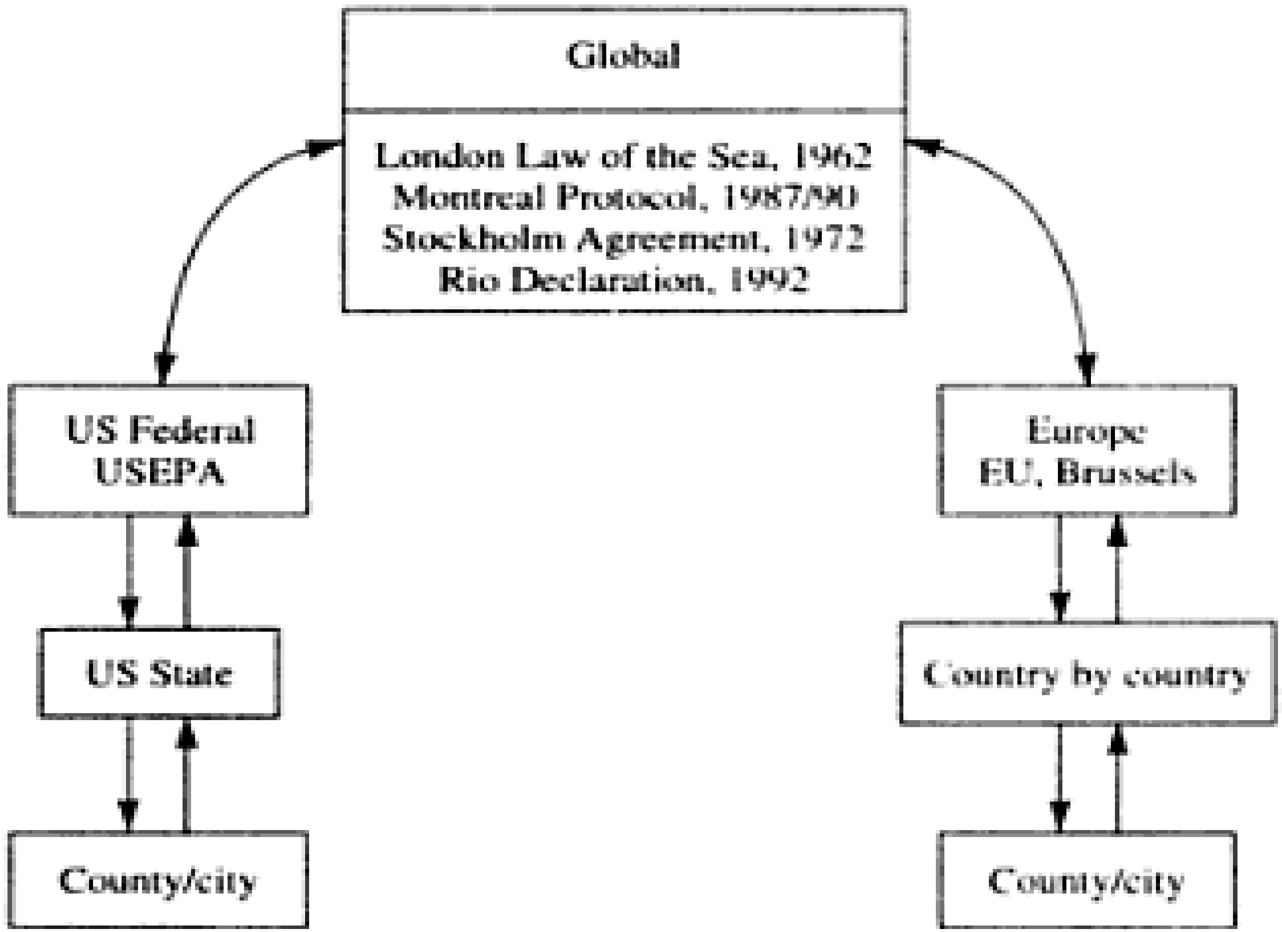
Environmental Gradients

- Ex:- Plant growth is strongly correlated with rain, but in arid region sufficient light is available, but water scarcity is there which is the limiting factor.
- The tolerance of species to different environmental conditions or resources level vary from each other.

Environmental Gradients

- The **favourable** environmental factors to a species provide wide tolerance curve & broad range of optimum known as **Eurytopic** factors.
- The **unfavourable** environmental factors to a species provide narrow tolerance curve & narrow range of optimum known as **Stenotopic** factors.

EU & US Env. Laws or Directives



1.1 Levels of environmental legislation in the European Union and the United States.

EU & US Env. Laws or Directives

- London Law of the sea is for prevention of sea pollution by oil.
- Stockholm Agreement has imposed ban on the ocean dumping wastes.
- Montreal Protocol is for reducing CFCs & other ozone depleting chemicals.
- Rio Declaration has objectives of sustainable development.

Regulatory Structure of Indian Env. Laws

- MOEF – Ministry of Environment & Forest, Government of India
- CPCB – Central Pollution Control Board
- SPCB – State Pollution Control Board

Indian Env. Laws

- Water Laws
- Air Laws
- Wildlife & Forest Laws
- General Env. Laws

Water Laws

- The various env. Laws on water are –

  1) The Water(Prevention & Control of Pollution) Act – 1974

  2) The Water(Prevention & Control of Pollution) Act rules – 1975

  3) The Water(Prevention & Control of Pollution) Cess Act – 1977

  4) The Water(Prevention & Control of Pollution) Act, rules & amendments – 1992

Objectives of Water Law

- The objectives are –

  a) Prevention & control of water pollution

  b) Maintaining good quality of water

  c) Establishment of boards for the prevention & control of water pollution.

Air Laws

- The various env. Laws on air are –

  1) The air(Prevention & Control of Pollution) Act – 1981

  2)The air(Prevention & Control of Pollution) Act rules – 1982

  3) Atomic Energy Act – 1982

  4) Motor Vehicles Act – 1988

Objectives of Air Law

- The objectives are –

  a) Prevention & control of air pollution

  b) Maintaining good quality of air

  c) Establishment of boards for the prevention & control of air pollution

Wildlife & Forest Laws

- The various env. Laws for wildlife & forest are-

  1) The wildlife protection act – 1972

  2) The wildlife protection act and amendments – 1991

  3) The forest conservation act – 1980

  4) The national forest policy – 1988

Objectives of Wildlife & Forest Laws

- The Objectives are –

  a) Protection & conservation of wildlife

  b) To preserve biodiversity

  c) To maintain essential ecological processes & life supporting systems.

General Env. Laws

- The various laws in this category are –

  1) The environmental protection act (EPA) – 1986 or Umbrella act

  2) Hazardous waste (management & handling) rules – 1989

  3) Biomedical waste(management & handling) rules – 1998

Objectives of Umbrella act

- Protection & improvement of environment & prevention of hazards to all living creatures.
- Maintenance of harmonious relationship between human beings & their environment.

Soil Chemistry

- The order of 10 most abundant elements in soil & crustal rocks are –
- In soil :

  O > Si > Al > Fe > C > Ca > K > Na > Mg > Ti
- In Crystal rock :

  O > Si > Al > Fe > Ca > Mg = Na > K > Ti > P

Soil Chemistry

- The most common soil minerals are –

  Quartz - SiO_2

  Calcite - $CaCO_3$

  Gypsum - $CaSO_4.2H_2O$

  Gibbsite - $Al(OH)_3$

Soil Chemistry

- Soil Salinity :-

  A soil solution is considered saline, if the electrical conductivity (EC) is greater than 4000 micro-siemens/cm or µs/cm.

  This condition occurs, when evaporation exceeds precipitation.

  If this condition continues then, saltpan will occur.

Soil Chemistry

- General Composition of soil :-

1)Inorganic or Mineral matter–45% (Ca,Mg etc.)

2) Organic matter – 5% (Humus)

3) Soil water – 25%

4) Soil air – 25%

Soil Chemistry

- Types of soil in India :-

  1. Red soil
  2. Black soil
  3. Mountainous soil
  4. Desert soil
  5. Alluvial soil

  (fine grained fertile soil present in river bed)

Soil Chemistry

- The elemental properties of soil in relation to infiltration are –
  1. Bulk Density or Dry Density
  2. Particle Density
  3. Porosity
  4. Water content
  5. Degree of saturation

Soil Chemistry

1. Bulk Density(ρ_b)=M_d/V_t
 = Dry mass of soil/Total volume of soil
2. Particle Density(ρ_m)=M_d/V_d
 = Dry mass of soil/Dry volume of soil
3. Porosity(ϕ)= $(V_a+V_w)/V_s$
 = (Volume of air + Volume of water)/Volume of soil
4. The water content (Θ) = V_w/V_s
 = Volume of water/ Volume of soil

Soil Chemistry

5. Degree of saturation(s):-

It is a measure of wetness.

So, $S = V_w/(V_a+V_w)$

$= (V_w/V_s)/[(V_a+V_w)]/V_s$

$= \Theta/\ \phi$

Soil Chemistry

- Soil Moisture Deficit (SMD) :-

  The Soil Moisture Deficit is the term used when soil moisture is below the Field Capacity (FC) of soil.

- Field Capacity (FC) :-

  It is the maximum % of volumetric soil moisture that a soil sample will hold freely against earth gravity. It varies from 5% for sandy soil to 30% for dry soil.

Atmospheric Chemistry

- Primary Pollutant :-

  The Primary Pollutants are those which are emitted by identifiable manmade sources.

  Ex:- SO_X, NO_X,CO

Atmospheric Chemistry

- Secondary Pollutant :-

  The secondary pollutants are those formed in the atmosphere by chemical or photochemical reactions of primary pollutants.

  Ex:- Acid rain, Photochemical Smog

- Photochemical smog :-

  It is basically the product of HC(Hydrocarbon)+NO_x+Sunlight------> SMOG

Atmospheric Chemistry

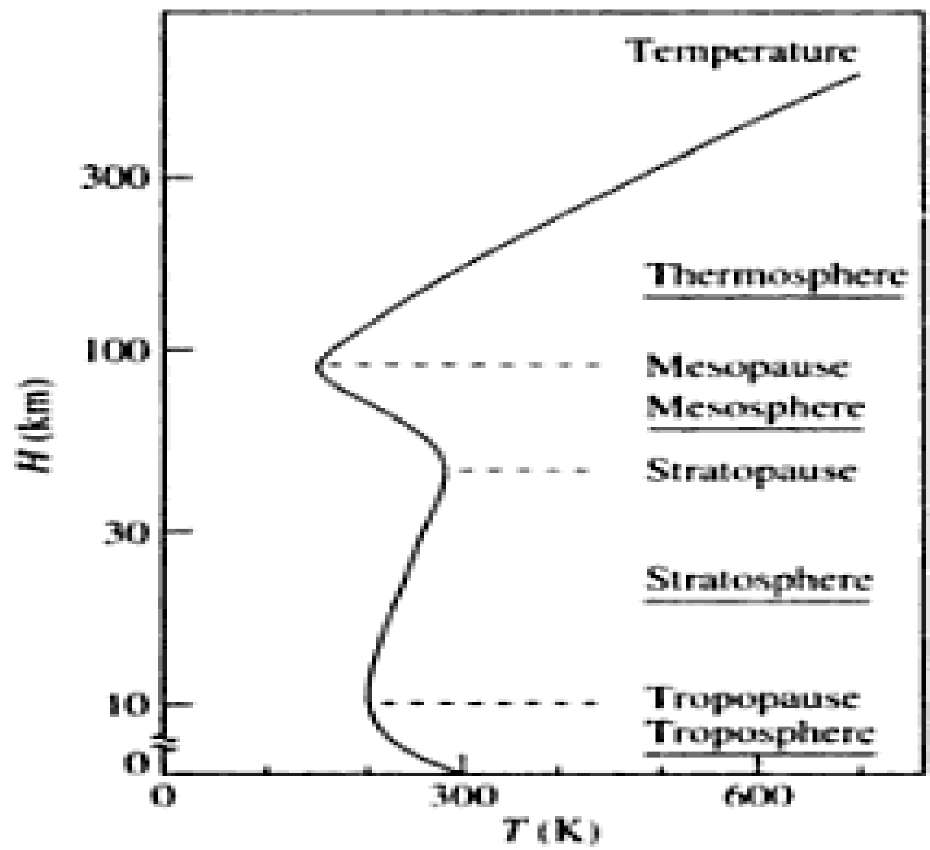


Figure 3.13 Vertical temperature profile of earth's atmospheric regions.

Atmospheric Chemistry

- Troposphere – 0-12 km
- Stratosphere – 12-50 km
- Mesosphere – 50-80 km
- Thermosphere – 80-700 km

Atmospheric Chemistry

- The **Troposphere** is mostly heated by transfer of energy from the earth surface and temperature decreases with altitude or height.
- In **Stratosphere** temperature increases with height due to increased absorption of UV radiation by Ozone Layer.

Atmospheric Chemistry

- In **Mesosphere** temperature decreases with height due to decreasing solar heating.
- In **Thermosphere** temperature increases with height due to absorption of highly energetic solar radiation which causes atmosphere particles in this layer to become electrically charged.

Atmospheric Chemistry

Table 3.11 Average composition of the atmosphere

Gas	Composition by volume (ppm)
N_2	780 900
O_2	209 500
A	9 300
CO_2	300
Ne	18
He	5.2
CH_4	2.2
Kr	1
N_2O	1
H_2	0.5
Xe	0.08
O_3	0.02
NH_3	0.006
NO_2	0.001
NO	0.000 6
SO_2	0.000 2
H_2S	0.000 2

Chemical & Biochemical Reactions

- The relationship between rate of reaction(r), concentration of reactants(c) & reaction order (n) is given by,

$$r=c^n \Rightarrow \log(r) = n \log(c)$$

- Reactions can be -
- Zero order
- First order
- Second order

Zero Order

- In this case, rate of reaction(r) is independent of concentration of reactants(c).
- Half life period ($t_{1/2}$)= $C_0/2k_0$,

  where C_0 is concentration of reactants at t=0

  & k_0 is reaction rate constant

  Ex:- Photochemical reaction between H_2 & Cl_2

  $$H_2(g) + Cl_2(g) \longrightarrow 2HCl(g)$$

First Order

- In this case, rate of reaction(r) is directly proportional to concentration of reactants(c)
- Half life period ($t_{1/2}$) = $\ln 2/k_1$

  $=0.69/k_1$

Ex:- Dissociation of hydrogen peroxide

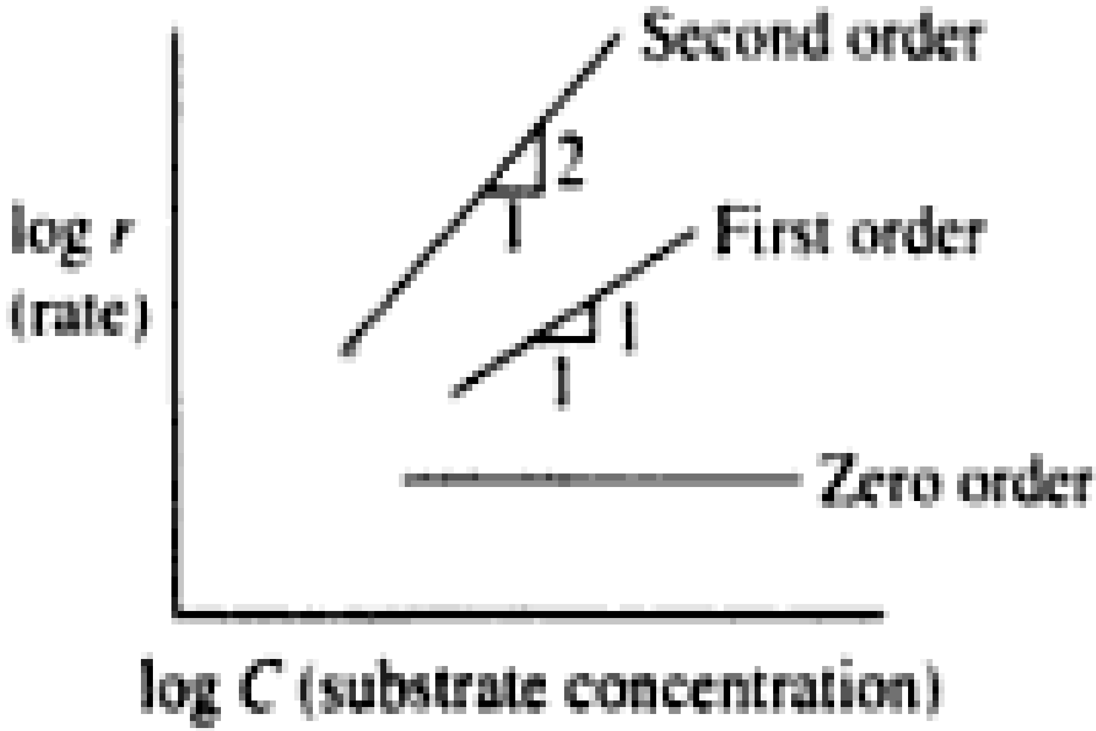
$H_2O_2(l) \longrightarrow H_2O(l)+1/2\ O_2(g)$

Second Order

- In this case, rate of reaction(r) is directly proportional to square of concentration of reactants(c)
- Half life period ($t_{1/2}$) = $1/k_2C_0$
- Ex:- Dissociation of NO_2 to NO (Nitric Oxide)

$$2NO_2(g) \longrightarrow 2NO(g)+O_2(g)$$

Orders of reaction



Material Balance

- Input – output = accumulation
- If there is no accumulation within the process, then input = output

Material Balance

- A comprehensive formulation of the principle of material balance is as follows –

  Accumulation within the system =
  input throughout the system boundaries + generation within the system - output through the system boundaries- consumption within the system

Methodology of Material Balance

- Sketch a figure defining boundary of the process.
- Label the flow of each stream & their composition with symbols.
- Show all know flows & composition on the figure

Methodology of Material Balance

- Select the basis or units for calculation
- Write the material balances which include total balance & component balance
- Solve the equations & check the solutions.

Problem-1

- A wastewater treatment plant with an output of 38,400 m^3/day discharges the liquid effluent with a BOD of 20 mg/L into a river. If the BOD of the river upstream of the discharge point is 0.2 mg/L, at a minimum flow of 20m^3/s, calculate the BOD of the river downstream of the discharge, assuming complete mixing.

Problem-2

- PSS(Primary Sewage Sludge) & SSS(Secondary Sewage Sludge) are thickened(or mixed) together. If the PSS is produced at 100kg/hr at 1% DS(Dry Solid) & SSS is produced at 150kg/hr at 3% DS, determine the DS percentage of the end product.

Problem-3

- Everyday $3780m^3$ of wastewater is treated at a municipal wastewater treatment plant. The influent contains 220mg/L of suspended solids. The treated water has a suspended solid concentration of 5 mg/L. Determine the mass of sludge produced daily from the treatment plant.

Problem-4

- A slurry containing 20% by weight of limestone($CaCO_3$) is processed to separate pure dry limestone from water. If the feed rate is 2000kg/hr, how much $CaCO_3$ is produced per hour.

Reactor Configuration

- In environmental engineering, particularly in water & waste water treatment reactors used are of 3 types –

  i) Batch Reactor(BR)

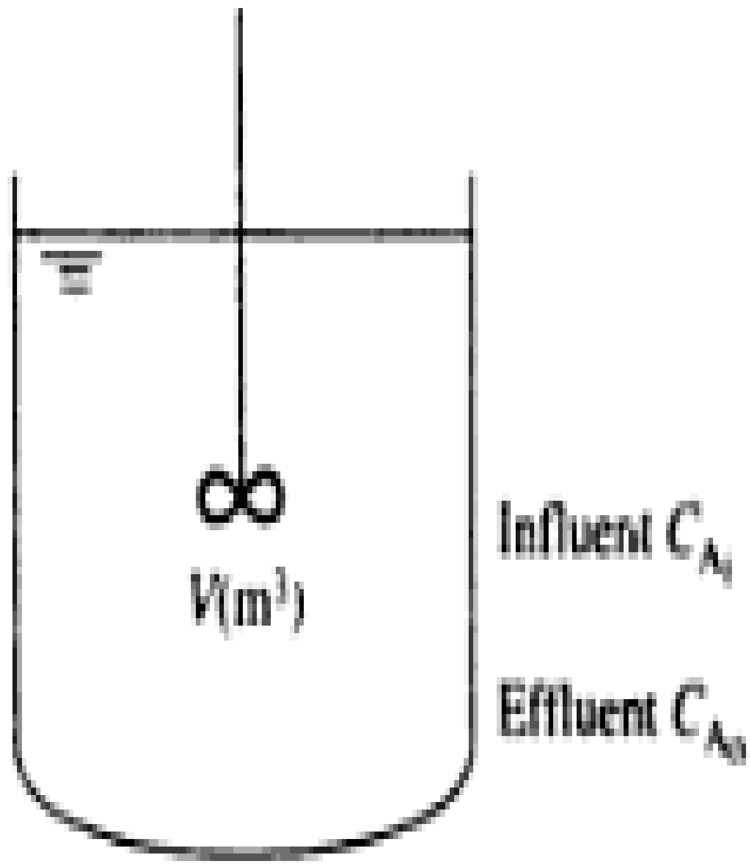
  ii) Continuously Stirred Tank Reactor(CSTR)

  iii) Plug Flow Reactor(PFR)

i) Batch Reactor(BR)

- In this case, the reactants or inputs enter into the reactor, remain for desired time & then discharged.
- Ex:- BOD test

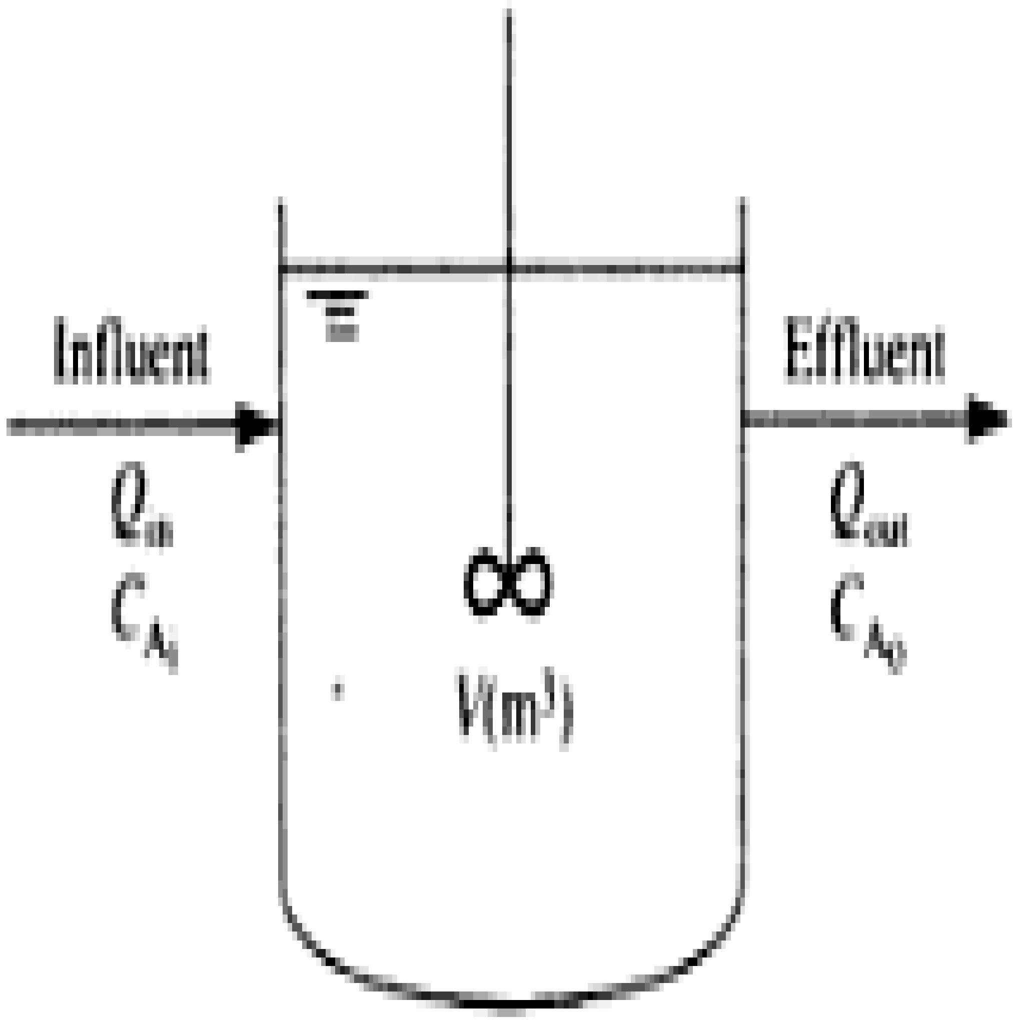
Diagram of BR



ii) Continuously Stirred Tank Reactor(CSTR)

- In this case, reactants continuously enter into the reactor & the products are continuously discharged from a well-mixed vessel.
- Ex:- Waste water treatment

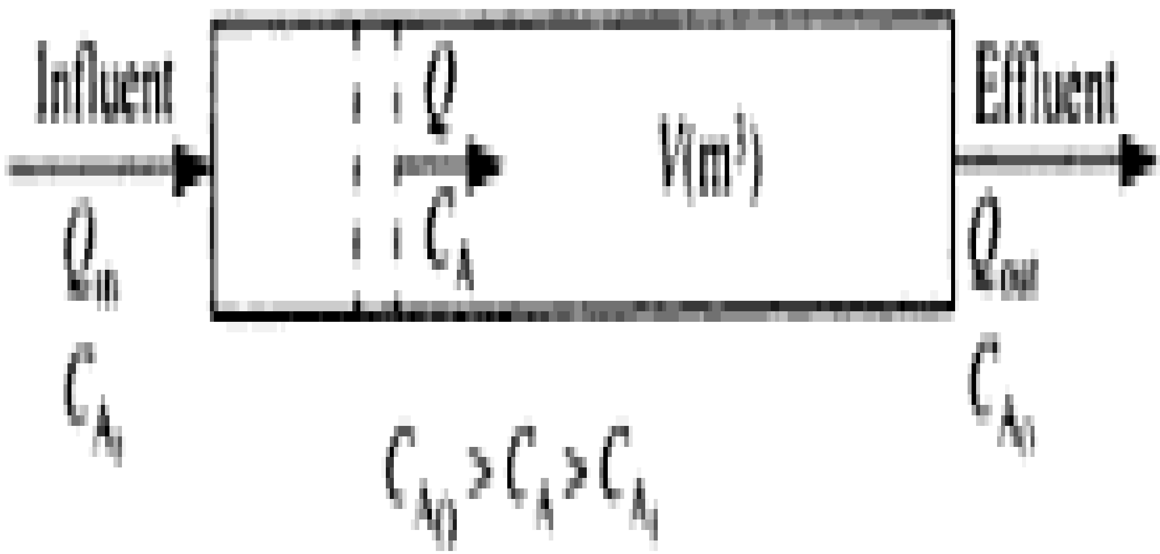
Diagram of CSTR



iii) Plug Flow Reactor(PFR)

- In this case, the reactants or inputs are entered at one end & products are discharged at the other end, after spending a minimum retention time in the system.
- Ex:- mixing of pollutant in river flow

Diagram of PFR



Noise Pollution

- Sounds are mechanical waves of pressure which allow us to hear & listen.
- Sounds can be transmitted through solid, liquid & gas.
- Generally human beings can perceive sound frequencies between 20 Hz & 20 KHz.

Noise Pollution

- Noise is a sound, that is loud, unpleasant, unexpected or undesired.
- Sounds, particularly loud ones, that disturb people or make it difficult to hear wanted sounds, are called noise.
- Noise is a subset of sound.

Sources of Noise Pollution

- Sources can be classified into outside & inside.
- Outside include construction sites, road traffic, airport, factories etc.
- Inside include phones, TV, radio, home appliances etc.
- Main source is urbanization & increasing population.

Sources of Noise Pollution

Source	Sound in dB
Normal conversation	60
Alarm Clock	80
Car horn	120
Jet	130
Gunshot	140
Rocket Launching	180

Effects of Noise Pollution

- Sleep disturbance
- Lack of productivity
- Causes stress & depression
- Hormone imbalance
- Higher heart rate

Noise Control or Attenuation

- Noise has following medium.
- Source→Transmission Path →Receiver
- The acoustic treatment of above three can help in attenuation.

Ways to reduce Noise Pollution

- Wear ear plugs
- Avoid using multiple appliances at a time
- Keep vehicles & machines in proper condition
- Buildings can be designed with suitable noise absorbing material for the walls, windows, and ceilings.
- Social awareness programs should be taken up to educate the public about the causes and effects of noise pollution.

Physical Properties of Sound

- The various physical properties of sound are –
- Amplitude(A)
- Wavelength(λ)
- Time Period(T or P)
- Frequency(f)
- Speed of sound(c)

Physical Properties of Sound

- Amplitude is maximum or minimum pressure
- Wavelength is the distance between successive crest or trough
- Time period is the time gap between successive crest or trough
- Frequency is the number of complete pressure variations or cycles per second.
- Speed of sound in air is 340m/sec.

Noise Criteria

- The various noise criteria can be –
- L_{Aeq} (Equivalent Continuous Level)
- L_{AE} (Sound Exposure Level)
- L_{AN} (Sound Level Exceeded for N% of time)

Indian Standard for ambient noise level

Area code	Area	Daytime	Night time
A	Industrial Area	75dB	70dB
B	Commercial Area	65dB	55dB
C	Residential Area	55dB	45dB
D	Silence Zone	50dB	40dB

The above values are of L_{Aeq}.

Inverse Square Law of sound Propagation

- It states that, the sound intensity(I) is inversely proportional to the square of the distance (r) it propagates.
- $I= W/4\pi r^2$ i.e.
- $I \alpha 1/r^2$,
- where, W is Sound power of noise source in watt.

Formula

- The sound power level is measured in decibel(dB) i.e.
- $L_W=10 \log(W/10^{-12})$
- where, L_W is sound power level in dB for 10^{-12} watt & W is sound power of noise source in watt.

Formula

- The sound pressure level is measured in decibel(dB) & is directly proportional to the square of sound pressure i.e.
- $L_P=10\log\{P^2/(P_0)^2\}$
- $= 20 \log (P/P_0)$
- where L_P is sound pressure level in dB,
- P is measured pressure in Pascal &
- P_0 is reference pressure = 20μPa

Problems

- Q.1. The sound from a voice shouting source is 0.001W. What is the sound power level?
- Q.2.If a sound source has a pressure of 2000μPa at 10mtr distance, calculate
- a) Sound Pressure Level in dB
- b) Sound Intensity in Watt/m^2
- c) Sound Power in Watt.

Problems

- Q.3.If two sound sources have equal pressure of 2000μPa, then determine the sound pressure in dB.
- Q.4. An air conditioner generates a noise level of 75dB for five minutes in every hour. If the background noise level is 55dB, then calculate the L_{Aeq}.

Physical Properties of Water

- The various physical properties of water that shows wide variation in magnitude includes –
- Colour
- Turbidity
- Taste & odour
- Temperature
- Solids

Physical Properties of Water

- <u>Colour</u>:-
- It is measured in Hazen's Scale.
- The permissible limit of colour for drinking water is 5mg/L or ppm.

Physical Properties of Water

- <u>Turbidity</u>:-
- It is the measure of cloudiness in water & caused by presence of suspended matter which scatters & absorbs light.
- It is measured in NTU
- (Nephelometric Turbidity Unit)
- The Permissible limit of turbidity for drinking water is 1NTU.

Physical Properties of Water

- Taste & Odour :-
- This may be due to presence of micro-organisms, algae, dissolved minerals, salts etc.
- It is measured in TON
- (Threshold Odour Number)
- The permissible limit of TON for drinking water is 1 to 3.

Physical Properties of Water

- <u>Taste & Odour</u>:-
- TON = (A + B)/ A
  A - Volume of Sample with odour
  B -Volume of Pure Water with no odour Added
- If A was a 100 ml sample and 100 ml of water had to be added to not detect the odour - the TON would be 2.
  TON = (100 + 100)/ 100=200/100=2.

Physical Properties of Water

- Temperature:-
- The temperature of water varies with atmospheric temperature & it is a significant parameter regarding characteristics of water.
- For drinking water the temperature should be 10-25^{0}C.

Physical Properties of Water

- Solids:-
- Solids content of water represents the characteristics of water.
- Solids present in water can be studied as follows-
- a) Total Solids(TS)
- b) Suspended Solids(SS)

Physical Properties of Water

- c) Total Dissolved Solids(TDS)
- = TS – SS
- d) Total Volatile Solids(TVS)
- e) Volatile Suspended Solids(VSS)
- f) Filterable Solids(FS) & Non-Filterable Solids (NFS)

Physical Properties of Water

- NFS = SS
- (Particle Size Range is 10^{0} to 10^{-3} mm)
- FS can be Colloidal
- (Particle Size Range is 10^{-3} to 10^{-6} mm) &
- Dissolved
- (Particle Size Range is 10^{-6} to 10^{-9} mm)

Chemical Properties of Water

- It can be
- Inorganic &
- Organic

Chemical Properties of Water

- Inorganic Chemical properties of water includes –

.   pH

- Alkalinity & Acidity
- Hardness
- Conductivity

Chemical Properties of Water

- Organic Chemical properties of water includes-
- BOD
- (Bio-Chemical Oxygen Demand)
- COD
- (Chemical Oxygen Demand)
- TOC
- (Total Organic Carbon)
- TOD
- (Total Oxygen Demand)

Inorganic Chemical Properties of Water

- pH is
- Potential of Hydrogen or Power of Hydrogen
- pH = - log $[H^+]$ or
- = - log $[H_3O^+]$
- pH range for public water supplies is 6.5 to 8.5.

Problem

- In a water treatment plant, the pH values of incoming & outgoing water are 7.2 & 8.4 respectively. Assuming a linear variation of pH with time, determine the average pH value of water.

Inorganic Chemical Properties of Water

- <u>Alkalinity & Acidity</u> :-
- Alkalinity is also known as ANC or
- (Acid Neutralizing Capacity) &
- Acidity is also known as BNC or
- (Base Neutralizing Capacity)

Inorganic Chemical Properties of Water

- Alkalinity can be of
- three types.
- a) Carbonate Alkalinity
- b) Bicarbonate Alkalinity &
- c) Hydroxide Alkalinity

Inorganic Chemical Properties of Water

- a) Carbonate Alkalinity in
- mg/L as $CaCO_3$ or ppm $CaCO_3$ can be expressed as

Problem

- The Supernatant from anaerobic co-digestion of the MSW food fraction & PSS(Primary Sewage Sludge) has an alkalinity of 4427 mg/L as $CaCO_3$. The P^H is 7.27 at a temperature of 25^0C.Determine the individual alkalinity contribution.

Inorganic Chemical Properties of Water

- <u>Hardness</u>:-
- Hard water has high mineral content.
- Hardness of water are of two types:-
- a) Temporary Hardness or
- Carbonate Hardness
- b) Permanent Hardness or
- Non-Carbonate Hardness

Inorganic Chemical Properties of Water

- a)Temporary Hardness:-
- It is due to carbonate & bicarbonate of Ca^{+2} & Mg^{+2}.
- b)Permanent Hardness:-
- It is due to Chloride & Sulphate of Ca^{+2} & Mg^{+2}.

Inorganic Chemical Properties of Water

- Hardness of water is expressed in mg/L as $CaCO_3$.
- The permissible limit of hardness of drinking water is
- 200 mg/L as $CaCO_3$.

Inorganic Chemical Properties of Water

- Hardness in mg/L as $CaCO_3$
- = [M^{+2}(concentration in mg/L) X 50]/ [equivalent weight of M^{+2}]
- = M^{+2}(Concentration in meq/L) X 50

Problem

- Determine the various hardness of the following water sample.
- Constituent — Concentration (in mg/L)

Constituent	Concentration (in mg/L)
Ca^{+2}	60
Mg^{+2}	29.3
HCO_3^-	366

Inorganic Chemical Properties of Water

- Conductivity or Electrical Conductivity:-
- It is the measure of the ability of an aqueous solution to carry an electric current.

$$ec = \sum_{i=1}^{n} C_i f_i$$

Inorganic Chemical Properties of Water

- where,
- ec is electrical conductivity in μs(siemens)/cm,
- C_i is concentration of ionic species in solution in mg/L &
- f_i is conductivity factor for ionic species.

Organic Chemical Properties of Water

- $BOD_5 = 0.6$ COD
- CBOD or
- Carbonaceous BOD = 0.92 COD

Organic Chemical Properties of Water

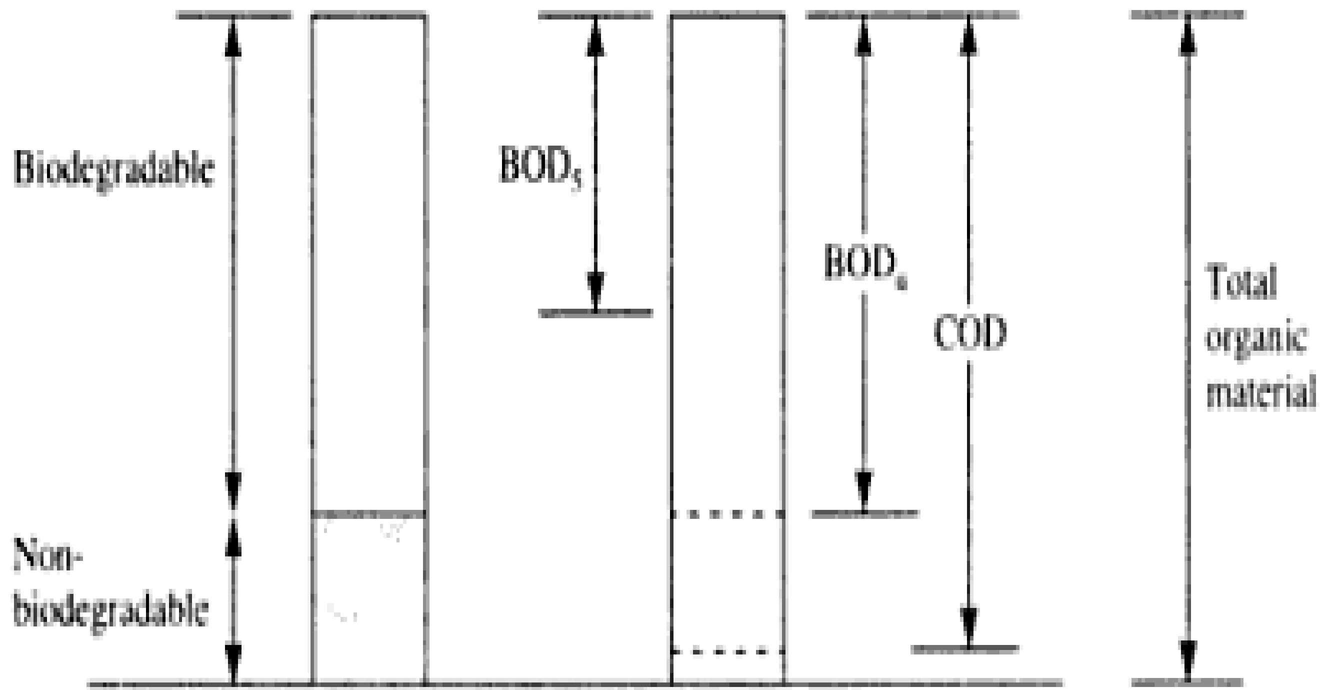


Figure 3.8 Schematic of BOD/COD/T.org matter relationship.

Organic Chemical Properties of Water

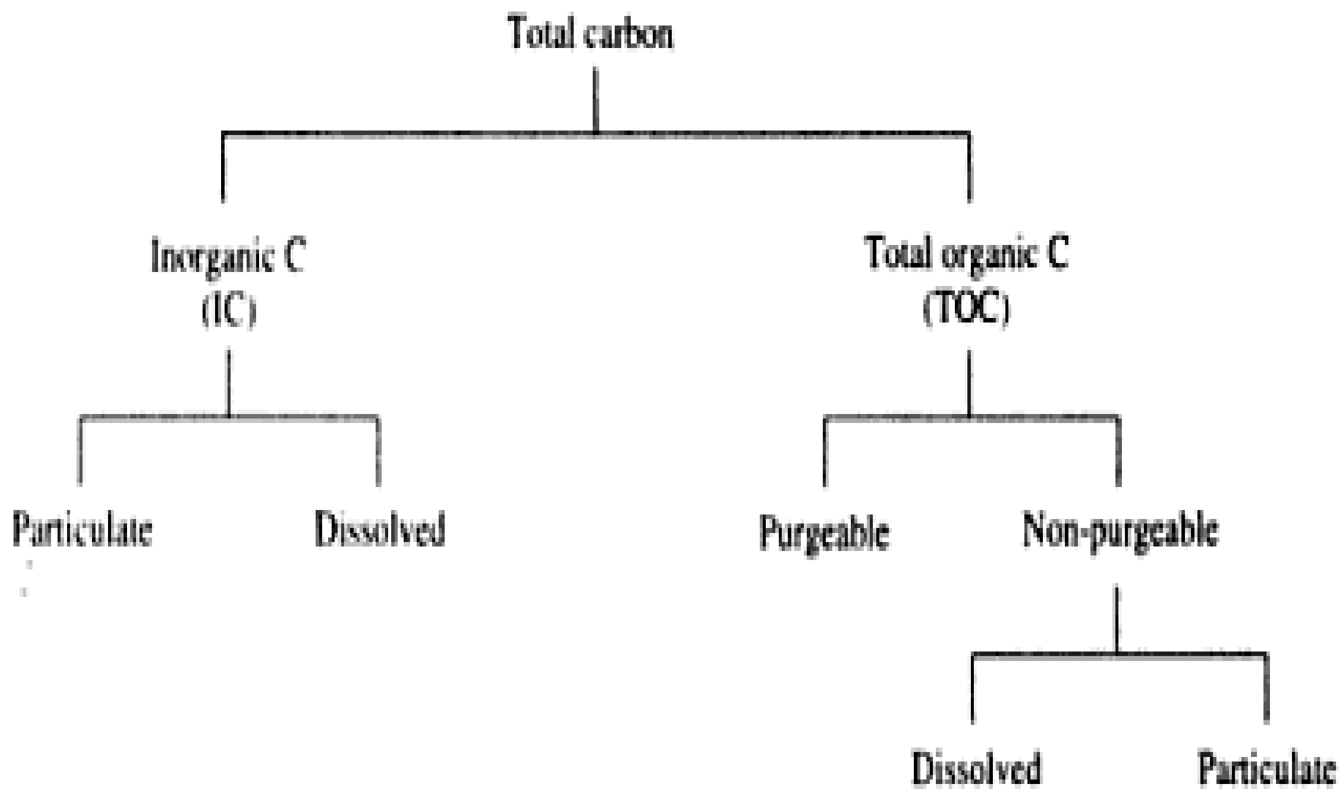


Figure 3.9 Schematic of subdivisions of carbon in water.

Problems

- Q.1. Determine COD & TOC for glucose($C_6H_{12}O_6$)?
- Q.2. If bacteria cells are represented by the chemical formula $C_5H_7O_2N$, then determine the potential carbonaceous BOD, when bacteria cell concentration is 1000mg/L.

Problems

- Q.3. A wastewater is analysed & is shown to contain 100 mg/L of ethylene glycol ($C_2H_6O_2$) & 120 mg/L of phenol(C_6H_6O). Determine COD & TOC.

Problem

- Q. Determine the time required for benzene (C_6H_6) & DDT($C_{14}H_9Cl_5$) to vapourize to half of their original concentration from a wastewater treatment plant holding tank of depth 2mtr. The mass transfer co-efficient (k) for benzene is 0.144mtr/hr & for DDT is 9.34×10^{-3} mtr/hr.

Solubility of gases in water

- The solubility of gases in water is related to the partial pressure of the gas in the atmosphere above the water & is given by **Henry's Law**, which can be expressed as follows:-

Solubility of gases in water

- $$P_g = (K_h)(X_g)$$
- where,
- P_g= Partial pressure of the gas,
- K_h= Henry's Law Constant
- Xg= Equilibrium mole fraction of the dissolved gas in the liquid phase

Concept of Hydrology

- i)Water Balance or Water Budget
- ii)Energy Balance or Energy Budget
- iii)Bowen Ratio
- iv)Hyetograph & Hydrograph
- V)Rainfall-Runoff Relationship or
- Rational formula for determining runoff

Concepts of Hydrology

- i)Water Balance or Water Budget:-
- It gives the quantitative account of hydrological cycle.
- The equation for water balance is based on conservation of mass.

Concept of Hydrology

- The water balance equation is
- $P = R + E \pm \Delta S \pm \Delta G$
- Where, P is Precipitation
- R is Runoff
- E is Evaporation
- ΔS is change in soil moisture status
- ΔG is change in ground water status

Concepts of Hydrology

- ii) Energy Balance or Energy Budget :-
- The equation for Energy Balance or Energy Budget is –
- R_n= LE+H+G+PS+M
- Where,
- R_n is specific flux of net incoming radiation,
- L is Latent Heat of Vapourization

Concepts of Hydrology

- E is Evaporation
- H is Specific flux of heat into the atmosphere
- G is Specific flux of heat into the ground
- PS is Photosynthetic energy fixed by plants
- M is energy for respiration & heat storage

Concepts of Hydrology

- iii) Bowen Ratio :-
- It is an useful parameter for energy budget & represents ratio between heat flux & evaporation rate.
- It can be expressed by –
- $B_O = H/LE$

Concepts of Hydrology

- iv) Hyetograph & Hydrograph :-
- Hyetograph represents rainfall intensity vs time.
- Hydrograph represents runoff or stream discharge vs time.
- If time is unit i.e. 1hr., then hydrograph will be unit hydrograph.

Concepts of Hydrology

- V)<u>Rainfall-Runoff Relationship</u> or
- <u>Rational formula for determining runoff</u> :-
- Q=CIA
- Where,Q is runoff in m^3/sec
- C is locality coefficient
- I is Rainfall Intensity in mm/hr
- A is Catchment Area in square Km

Concepts of Hydrology

- Peak Discharge (Q_P)or Peak Run-off can be expressed as follows:-
- Q_P=0.278 CIA
- Modified Rational Formula given by Wallingford is :-
- Q_P=0.278$C_V C_R$IA
- Where, C_V is volumetric runoff coefficient &
- C_R is Routing Coefficient

Organic content parameter

- When an organic waste is discharged to a stream, the organic content of the effluent or discharge undergoes a biochemical reaction with the help of micro-organisms.
- The BOD = $P(DO_I - DO_F)$
- Where, P is Dilution Ratio,
- DO_I & DO_F are initial & final DO(Dissolved Oxygen) concentration

Organic content parameter

- The Corrected BOD = $P[(DO_I-DO_F)-f(B_I-B_F)]$
- Where, f is the correction factor or seeding factor=1-(1/P),
- B_I & B_F are initial & final DO(Dissolved Oxygen) concentration of seeded diluted water or Blank

Problem

- Q. The results from a BOD test diluted by 100 are given below. Calculate the BOD_S.
- <u>Time (in days)</u> <u>DO(in mg/L)</u>

Time (in days)	DO(in mg/L)
0	7.95
1	3.75
2	3.45
3	2.75
4	2.15
5	1.80

Problem

- Q. The results from a BOD test diluted by 100 are given below. Calculate the Corrected BOD_S.

Time (in days)	DO(in mg/L)	Blank DO(in mg/L)
0	7.95	8.15
1	3.75	8.10
2	3.45	8.05
3	2.75	8.00
4	2.15	7.95
5	1.80	7.90

Organic matter

- The rate of decomposition of organic matter is directly proportional to the amount of organic matter available & it is a first order reaction.
- i.e. $d/dt(L_t) \alpha\ L_t$
- => $d/dt(L_t) = -k_1 x L_t$
- Where, L_t is BOD remaining in mg/L=BOD_r &
- K_1 is deoxygenation rate coefficient

Problem

- Q. If K_1 or deoxygenation rate coefficient is 0.15 per day, then determine the ultimate BOD or BOD_u or L_0.

Temperature effect on K_1

- Temperature has an effect on K_1 & is given by,
- $K_T = (K_{20})x(\theta)^{(T-20)}$
- Where,
- K_T= The deoxygenation rate coefficient at T^0C
- K_{20}=The deoxygenation rate coefficient at 20^0C
- θ= Coefficient= 1.047 for $20^0C < T < 30^0C$ &
- = 1.35 for $4^0C < T < 20^0C$

NBOD

- The Oxygen demand associated with the oxidation of ammonia(NH_3) to nitrate (NO_3^-) is called Nitrogenous BOD or NBOD.
- $$2NH_3 + 3O_2 \xrightarrow{Nitrosomanas} 2NO_2^- + 2H^+ + 2H_2O$$

$$2NO_2^- + O_2 \xrightarrow{Nitrobacter} 2NO_3^-$$

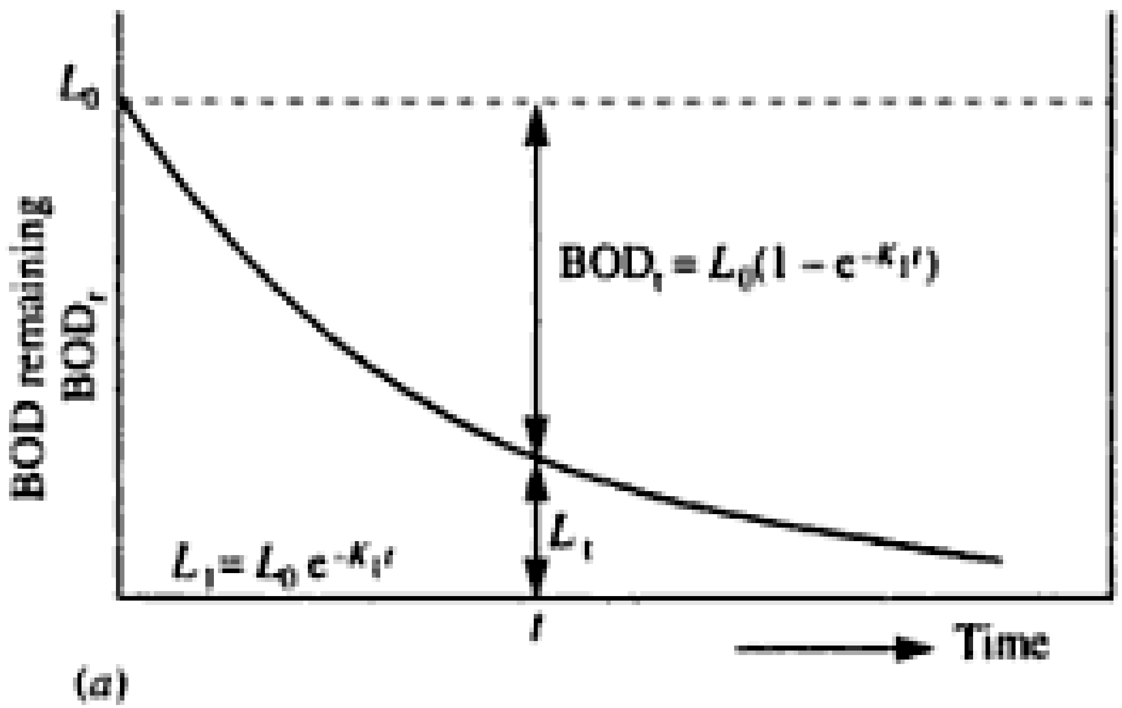
$$So, 2NH_3 + 4O_2 \rightarrow 2NO_3^- + 2H^+ + 2H_2O \,\&$$

$$Finally, NH_3 + 2O_2 \rightarrow NO_3^- + H^+ + H_2O$$

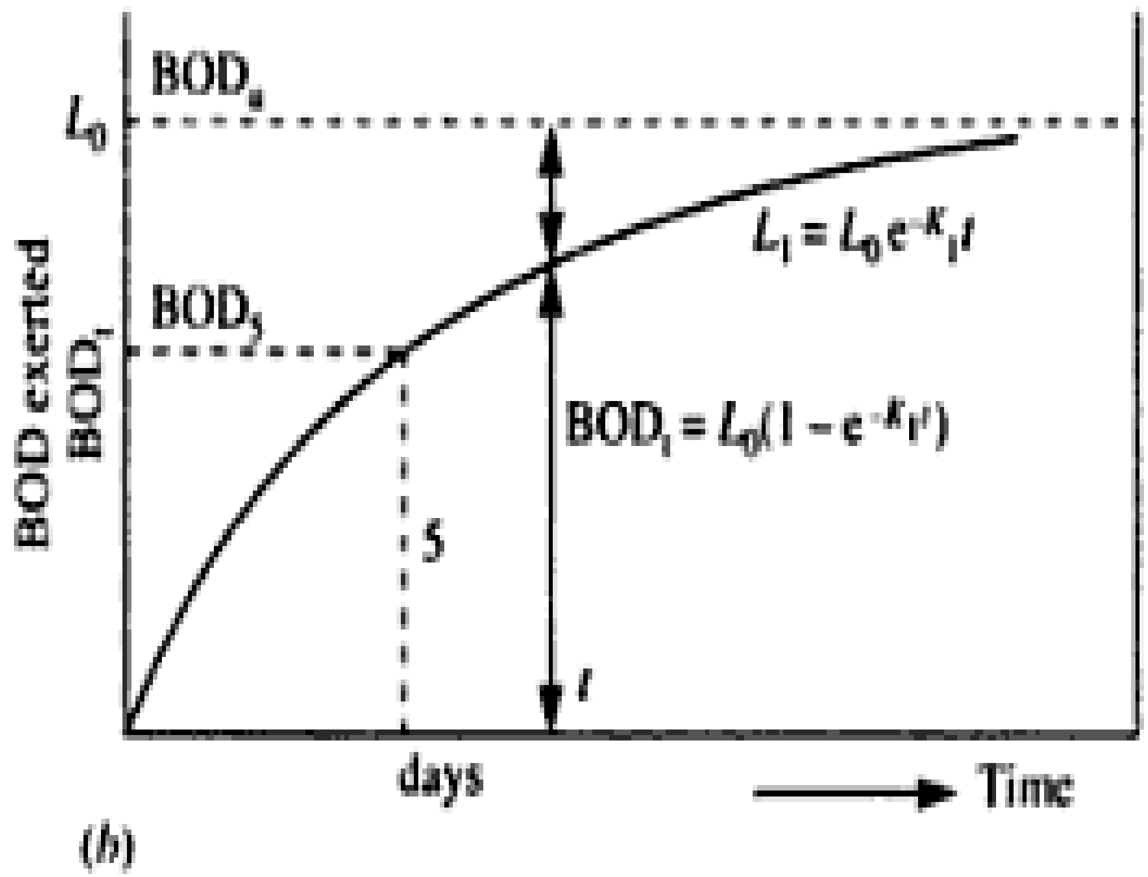
Problem

- Q. Determine the TOD(Total Oxygen Demand) if the sample contains 25 mg/L of N.

BOD remaining(BOD_r) graph



BOD exerted(BOD_t) graph



CBOD & NBOD relationship

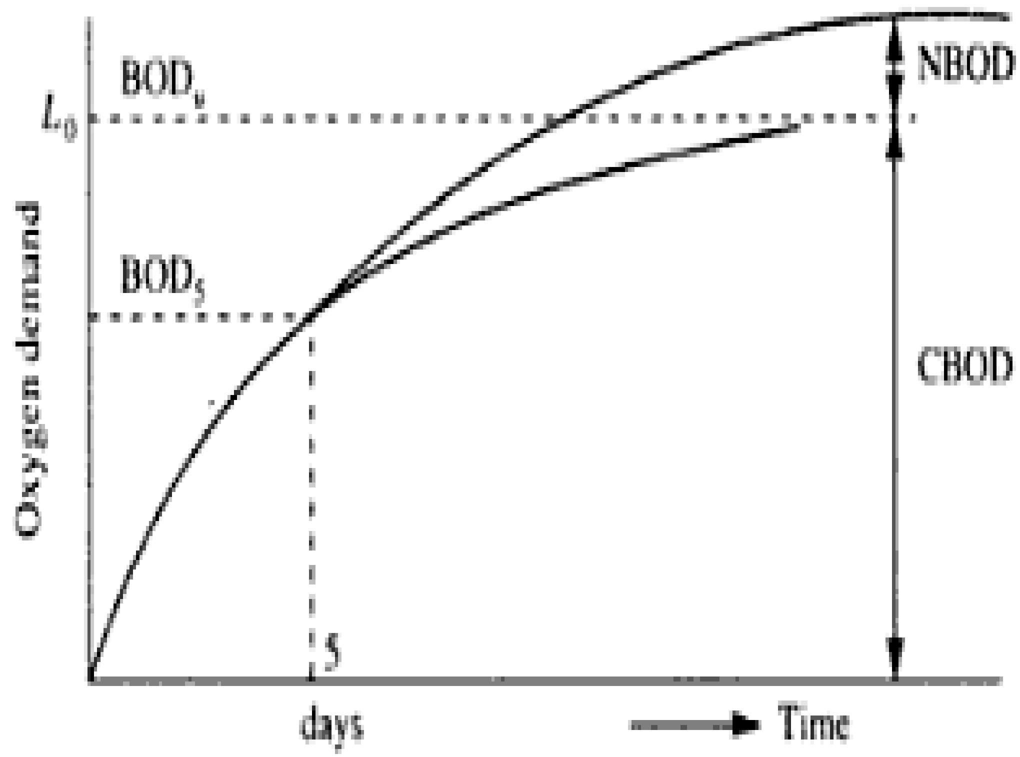


Figure 7.3 Relationship of CBOD and NBOD.

Problem

- Q. 15ml of sample was diluted in 300ml bottle. Initial DO was 8.9 mg/L & final DO after 5days was 4.4mg/L. The corresponding initial & final DO of diluted water was 9.1mg/L & 9.05 mg/L. Find out 5 days BOD at 20^0C.

Problem

- Q. BOD of an sample incubated for one day at 30^0C was found to be 100mg/L. What would be the 5 day BOD at 20^0C. The deoxygenation rate coefficient (K_1) is 0.12 at 20^0C.

Problem

- Determine the two day BOD for a wastewater at 20^0C, while BOD_5 at 20^0C is 250mg/L. The deoxygenation rate coefficient(K_1) value at 20^0C is 0.2 per day. What shall be the BOD after the end of seven days at 25^0C .

Problem

- A BOD test was conducted taking 5% wastewater mixed with 95% aerated water for dilution & the following observations were found out:
- i) DO of the aerated water used for dilution is 3.6 mg/L
- ii) DO of the original wastewater sample is 0.8 mg/L

- iii) DO of the diluted wastewater after incubation at 20^0C for 5 days is 0.7 mg/L
- Calculate the 5 days BOD of the above wastewater sample if the deoxygenation constant is 0.11.

Aquatic Pollution

- The aquatic Pollution can be classified into three broad groups.
- a) Fresh water pollution or
- Surface water pollution
- b) Estuarine pollution
- c) Marine pollution

a)Fresh water pollution

- The pollution of fresh water can be caused by:-
- Wastes from municipality & industries
- Oil from industry wastes & cleaning of vehicles
- Thermal waste from industries & power stations
- Heavy metals etc.

b) Estuarine pollution

- Estuarine means tidal mouth of river or where river mixes with the sea.

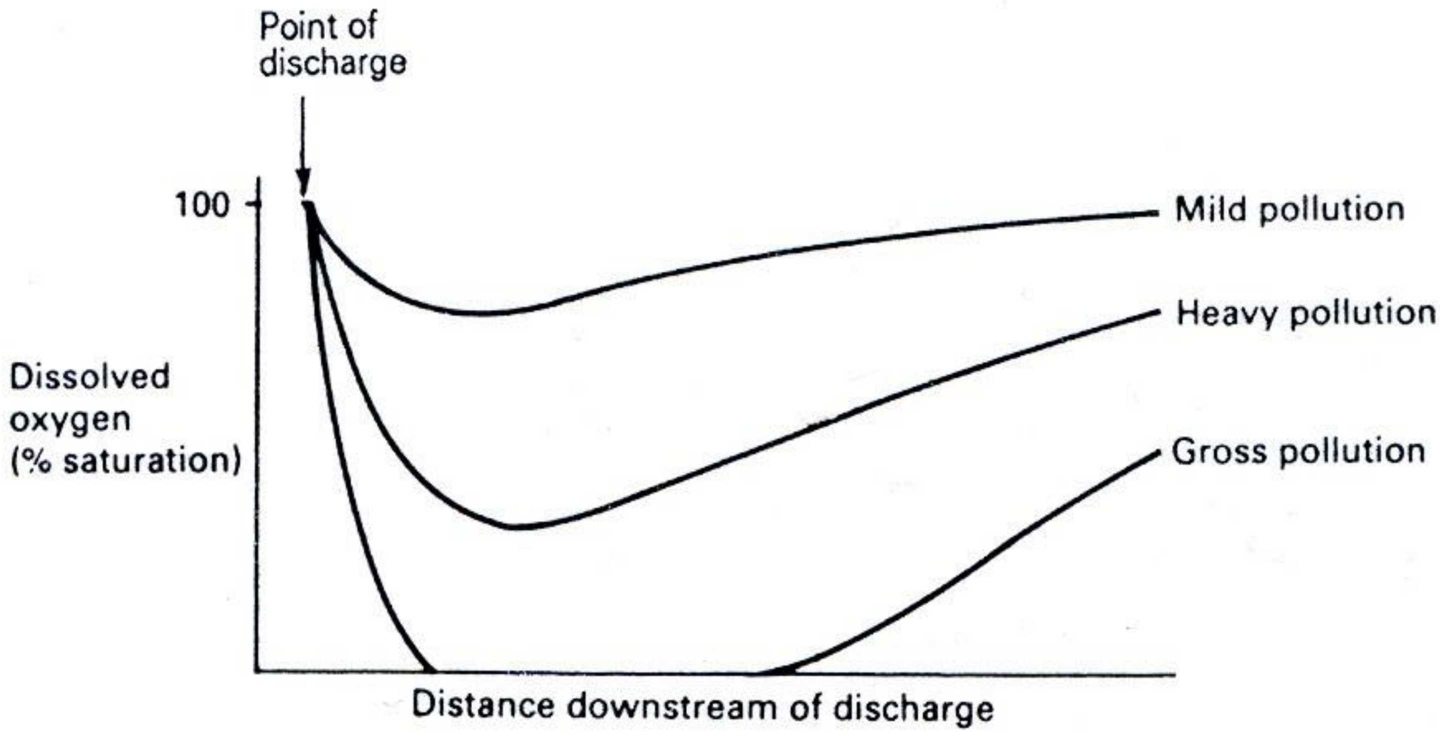
c) Marine pollution

- The main pollutants for Marine pollution are:-
- i) Manmade organic poisons like
-   Pesticides & herbicides
- ii) Radioactivity due to radioactive substances.

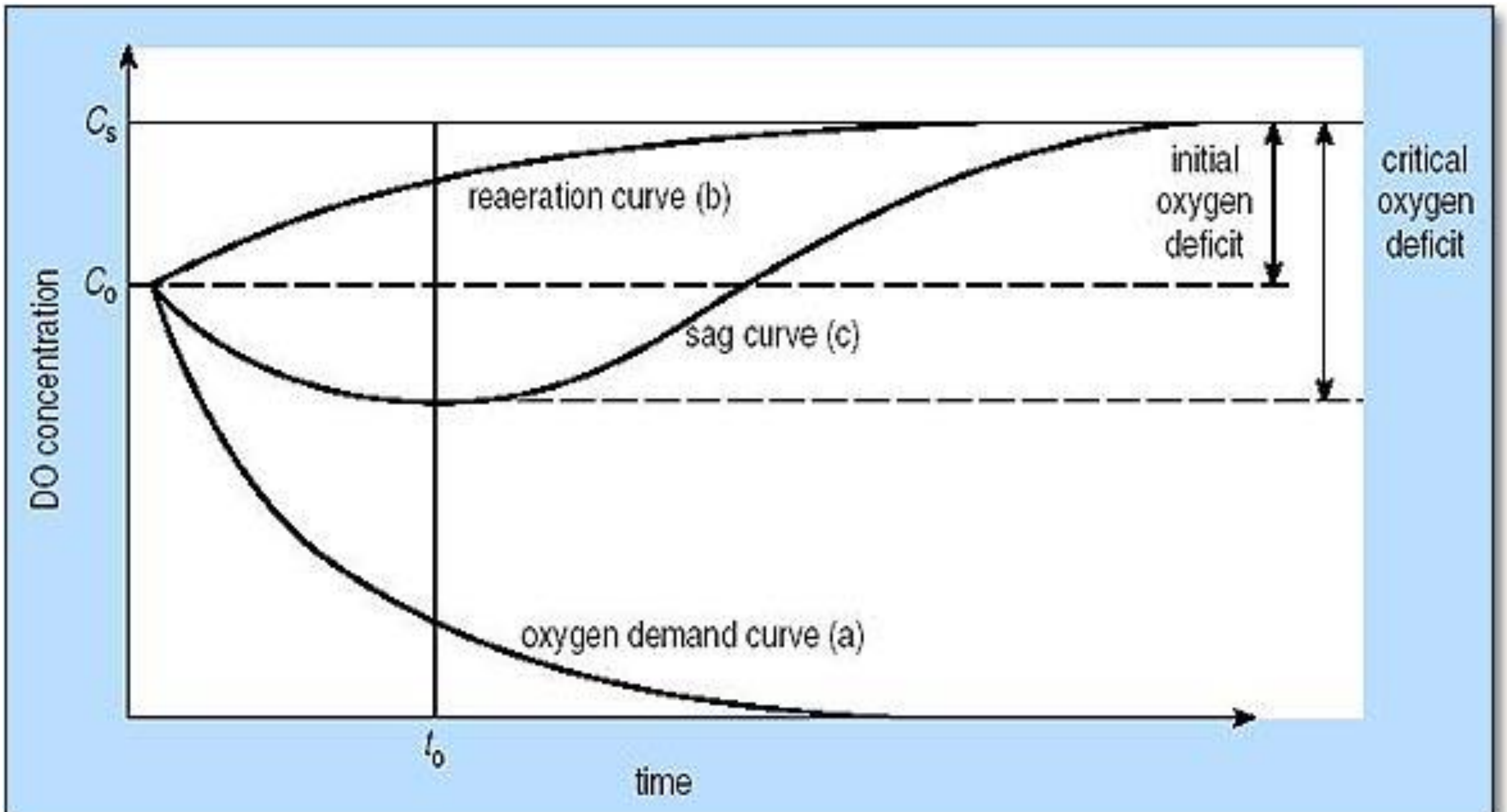
Oxygen Sag Curve

- The longitudinal profile of Oxygen concentration is Known as Oxygen sag curve.

Oxygen Sag Curve



Oxygen Sag Curve



Eutrophication

- It can be defined as the enrichment of water by inorganic plant nutrients like N & P, which results in increase in primary productivity.
- Artificial eutrophication is known as cultural eutrophication which can be achieved by adding fertilizers.

Eutrophication

- The problems arising due to Eutrophication are:-
- Water quality may have unacceptable taste & odour
- Water may be injurious to health
- The household usefulness of water may decrease.

Point & Non-Point Sources of Pollution

- Point Sources are those, which discharge pollutants from specific locations such as chimney, drainpipe of factories etc.
- Point Sources are easier to monitor & regulate.

Point & Non-Point Sources of Pollution

- Non-point sources of pollution are those, which don't have any specific location of discharge.
- As a result, these are difficult to monitor & regulate.
- Ex:- Run-off from paddy fields, Lawns & Gardens.

Oxygen transfer in water bodies

- The oxygen transfer in water bodies is given by Orlob equation i.e.

$$\frac{(C_g - C_0)}{(C_g - C_t)} = e^{K_2 t}$$

Oxygen transfer in water bodies

- Where,
- C_g = Saturation Concentration of oxygen
- C_0 = Initial Concentration of oxygen
- C_t = Concentration of oxygen after time ‘t’
- K_2 = reaeration rate constant

Problem

- If saturation concentration of oxygen in water is 9.2mg/L & the initial concentration of oxygen is 2.1mg/L, then determine the time it takes to become 7.5mg/L , having K_2 value 0.25 per day. What is the time required for C_t to be 5,6,7,8,9 mg/L.

Ground water Quality/Contamination

- The most simple model of decay of a contaminant is to assume the decay to be a first order reaction i.e.
- $r = - Kc$ &
- $C_t = C_0 e^{-Kt}$

Ground water Quality/Contamination

- Where,
- C_t = Concentration at time 't' in mg/L
- C_0 = Initial Concentration in mg/L
- t = time in days
- K = first order decay coefficient

Problem

- Determine the concentration of a contaminant at the downstream well, if the upstream concentration is 80mg/L. Assume decay constant (k) to be 10^{-4} per day & time (t) = 274 years.

Ground Water Recharge

- It is also known as deep percolation
- It is a hydrologic process, where water moves downward from surface to ground.
- Recharge can occur both naturally & artificially.
- Natural way of recharge is occurred through hydrological cycle.

Ground Water Recharge

- Recharge occurs artificially, when rainwater, reclaimed water or recycled water is injected or routed to the subsurface.
- Recharge can help move excess salts that accumulate in the root zone to deeper soil layers or into the deep groundwater system.

Ground Water Flow

- The ground water flow is governed by Darcy’s law which can be expressed as follows:-
- $Q = KiA$
- $= KA(dh/dL)$
- $= KA\{(h_2-h_1)/(L_2-L_1)\}$

Ground Water Flow

- Where,
- Q = horizontal flow in m^3/sec
- K = hydraulic conductivity in m/sec
- i = dh/dL= hydraulic gradient
- A = cross sectional area in square mtr

Ground Water Flow

- h_2- h_1= water head drop
- L_2-L_1 = Length difference over which water head drop occurs
- q = Q/A
- = Specific discharge or
- discharge per unit area

Problem

- Determine the daily flow capacity and transmissivity of an aquifer, if it's height, width, length are 15mtr, 800mtr & 2km respectively. The water head change over the length 2km is 3mtr. The hydraulic conductivity(K) value is $6x10^{-7}$ m/sec.

Problem

- Determine the hydraulic conductivity(K) for an unconfined aquifer which is 10mtr thick, if a well delivers 360m^3/day. Observation well(1) is situated at 20mtr from pumping well & record a draw down of 6mtr. Observation well(2) is situated at 600mtr from pumping well & draw down is 3mtr. The original water table is recorded at 12mtr.

Water Table

- A water table is the underground depth, at which point the ground is totally saturated by water.
- The water table may vary due to seasonal changes in precipitation, evapotranspiration & topography etc.

Aquifer

- An aquifer is a body of saturated rock through which water can easily move.
- An aquifer is an underground layer of water bearing permeable rock from which ground water can be extracted using a water well.
- Aquifer can be of two types:-
- a) Unconfined aquifer
- b) Confined aquifer

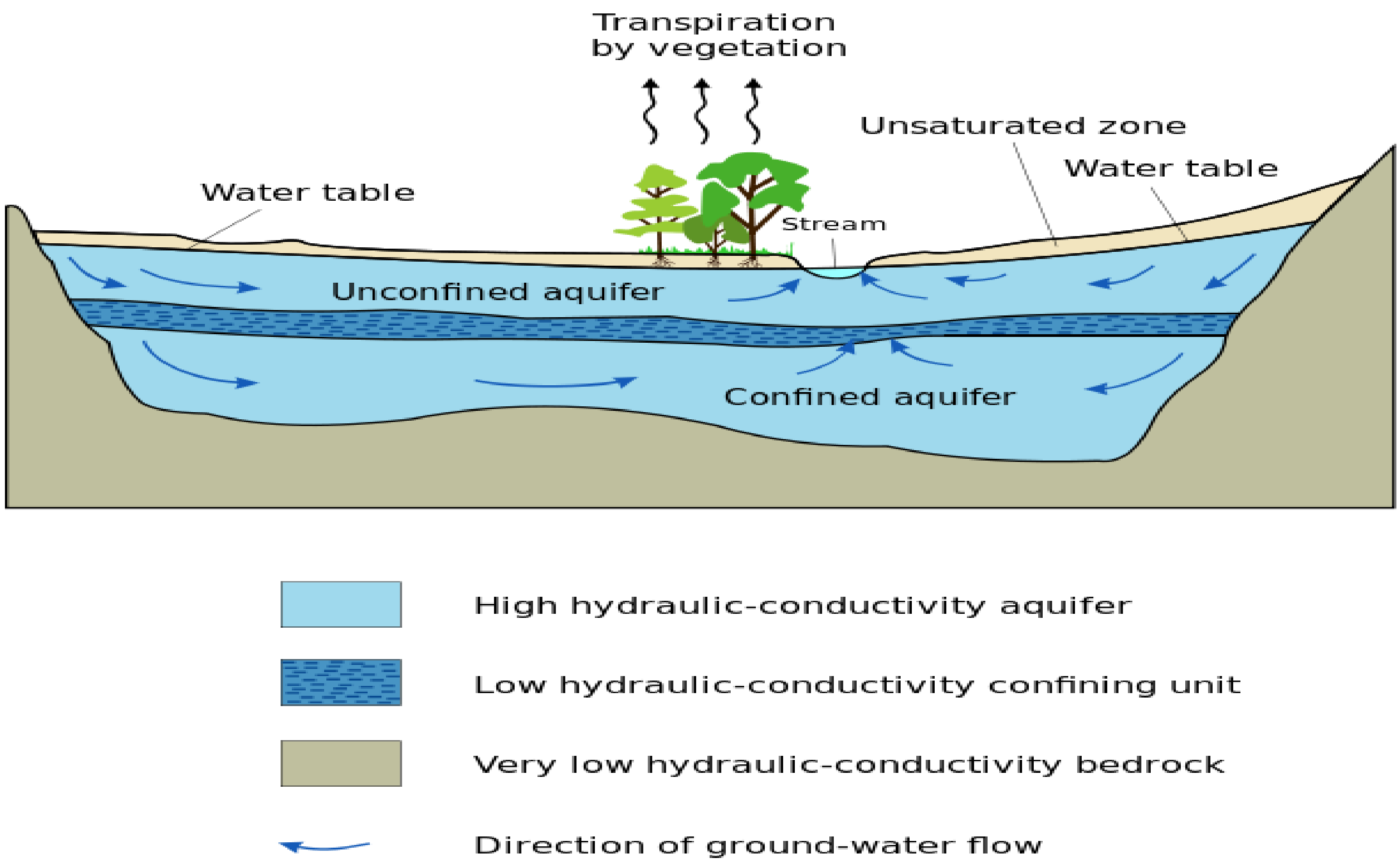
Unconfined aquifer

- An unconfined aquifer is the one which is open to receive water from the ground surface & whose water table surface is free to fluctuate up & down, depending on the recharge & discharge rate.
- These are extremely susceptible to contamination.

Confined aquifer

- These type of aquifers have rock layer with less permeability or confining bed of rock above them due to which water can't enter freely into these type of aquifers from the ground surface.
- These are less susceptible to contamination.

Figure



Transpiration by vegetation
Unsaturated zone
Water table
Water table
Stream
Unconfined aquifer
Confined aquifer
High hydraulic-conductivity aquifer
Low hydraulic-conductivity confining unit
Very low hydraulic-conductivity bedrock
Direction of ground-water flow

Water Treatment

- The objectives of water treatment are :-
- A) To produce Water which is safe for human consumption
- B) To produce Water at a reasonable cost
- C) To reduce water impurities to acceptable levels

Organoleptic Parameters

- Organoleptic Parameters are those parameters which can be sensed or felt by human organs.
- Ex:- Colour, Taste & Odour etc.

Classes of Water treatment

Class	Description	Source
A	No Treatment	Borehole water
B	Disinfection only	Borehole water
C	Standard water Treatment	River,Reservoir
D	Advanced/Special water Treatment	Industrial water

Monitoring Frequency

- The water quality parameters are required to be monitored depending on the source & quality of raw water.
- The three categories are:-
- A) Minimum monitoring(C1)
- B) Current monitoring(C2)
- C) Periodic Monitoring(C3)

Water Treatment Processes

- The treatment processes of water can be classified into three stages :-
- A) Pretreatment processes
- B) Standard or Conventional processes
- C) Special or Advanced processes

A) Pretreatment processes

- Some treatment processes are required prior to standard water treatment processes which may include :-
- i) Screening
- ii) Storage
- iii) Aeration
- iv) Chemical pre-treatment

A) Pretreatment processes

- i) Screening:-
- Different types of screens are used in this process. Those are can be :-
- a)Coarse Screen
- b)Fine Screen
- c)Micro Screen

A) Pretreatment processes

- a) <u>Coarse Screen</u>:-
- These screens contain typically inclined bars of 25mm dia & 100mm spacing, preventing large floating matters from entering the treatment plant

A) Pretreatment processes

- b) Fine Screen:-
- If storage is not provided, then fine screens are fitted after the coarse screens.
- If there is storage, then fine screens are placed at the outlet of the storage tanks.
- Fine screens are typically mesh with openings about 6mm dia or square

A) Pretreatment processes

- C) Micro Screen:-
- In micro screens, mesh openings range from 20 to 40 μm.
- These type of screens are used only for relatively uncontaminated water.

A) Pretreatment processes

- ii) Storage:-
- Storage tanks balance the flows going to the treatment plant.
- Storage capacity should be equivalent to 7 to 10 days of the average water demand.
- The period of storage shouldn't be long, so as not to encourage the growth of unwanted organisms

A) Pretreatment processes

- iii) Aeration:-
- Aeration is the supply of oxygen from the atmosphere to water to effect beneficial changes in the quality of water.
- It is a common treatment process for groundwater

A) Pretreatment processes

- Aeration is generally used for the following:-
- a) To release excess H_2S gas which may cause undesirable taste & odour.
- b) To release excess CO_2 which may have corrosive properties
- c) To increase oxygen content of water.

A) Pretreatment processes

- iv) <u>Chemical pre-treatment</u>:-
- The chemical pre-treatment to remove undesirable properties of water like algae or excess colour is a more expensive process than chemical post-treatment.
- In pre-treatment, greater amount of chemicals are required to effect the same result as some of the chemicals are absorbed by turbidity of water.

A) Pretreatment processes

- The two Chemical pre-treatment processes which are generally used are:-
- a) Pre-Chlorination
- b) Activated Carbon

A) Pretreatment processes

- a) Pre-chlorination:-
- It is used on low turbidity water with a high coliform count. The chlorine is injected into the water stream & it oxidizes & precipitates iron & manganese. It also kill pathogens & reduces colour. The chlorine dose used is 5mg/L. Pre-chlorination also reduces NH_3 in both surface water & ground water supplies.

A) Pretreatment processes

- b) <u>Activated Carbon</u>:-
- The activated Carbon is used for:-
- i) Removal of Photosynthetic Algae
- ii) Improvement of colour & odour
- iii) Removal of organic compounds

A) Pretreatment processes

- Activated Carbon can be used either as PAC (Powdered Activated Carbon) or as GAC (Granular Activated Carbon).
- Generally for water treatment PAC is used, but GAC is used where taste & odour of water have an industrial base.
- PAC has lower cost & efficiency than GAC.
- Doses may vary from 3 to 20 mg/L.

B) Standard or Conventional processes

- It includes:-
- i) Sedimentation
- ii) Coagulation
- iii) Flocculation
- iv) Filtration &
- V) Disinfection

B) Standard or Conventional processes

- i) <u>Sedimentation</u>:-
- The heavier large particles settle down by the force of gravity at the bottom of the sedimentation tank, which is called Sedimentation.
- Stoke's law for settling velocity is the deciding equation for sedimentation.

B) Standard or Conventional processes

- Stoke's law can be represented by:-
- $V_S=(g/18\mu)(\rho_s- \rho_w)d^2$
- Where, V_S is settling velocity
- g is acceleration due to gravity
- μ is dynamic viscosity
- d is diameter of settling particle
- ρ_s is density of particle settling
- ρ_w is density of water

B) Standard or Conventional processes

- ii) <u>Coagulation</u>:-
- The lighter smaller particles don't settle down by the force of gravity.
- To make them settle down, some amount of coagulants are added to the water, which is called Coagulation.

B) Standard or Conventional processes

- Some examples of coagulants are:-
- Alum i.e. aluminium sulphate
- Ferric Chloride
- Ferric Sulphate
- Ferrous Sulphate

B) Standard or Conventional processes

- iii) <u>Flocculation</u>:-
- When coagulants are added to the water, the lighter smaller particles coagulate or combine with each other forming bigger particles, known as floc & the process is called flocculation.

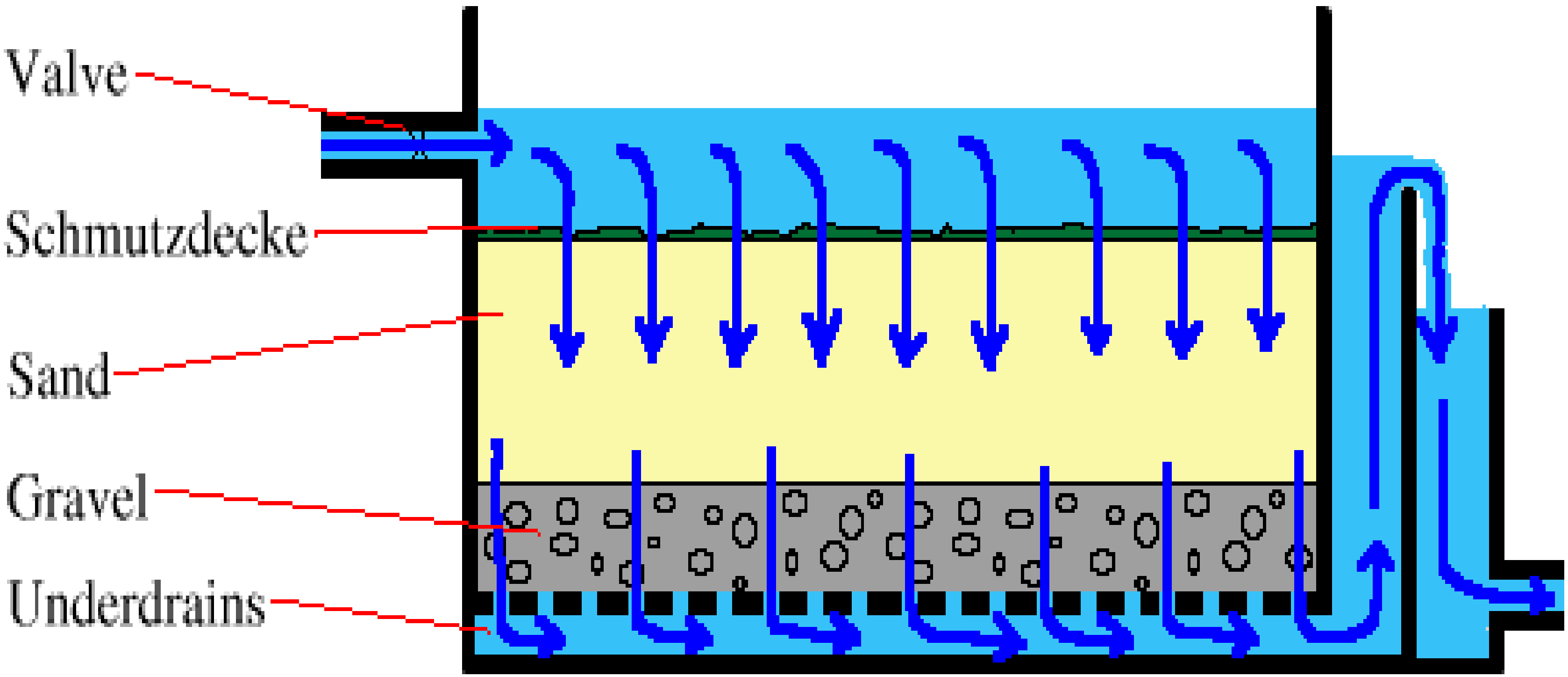
B) Standard or Conventional processes

- iv) Filtration:-
- It is the process of passing water through a porous medium, with the expectation that the filtrate water has better quality than the incoming water.

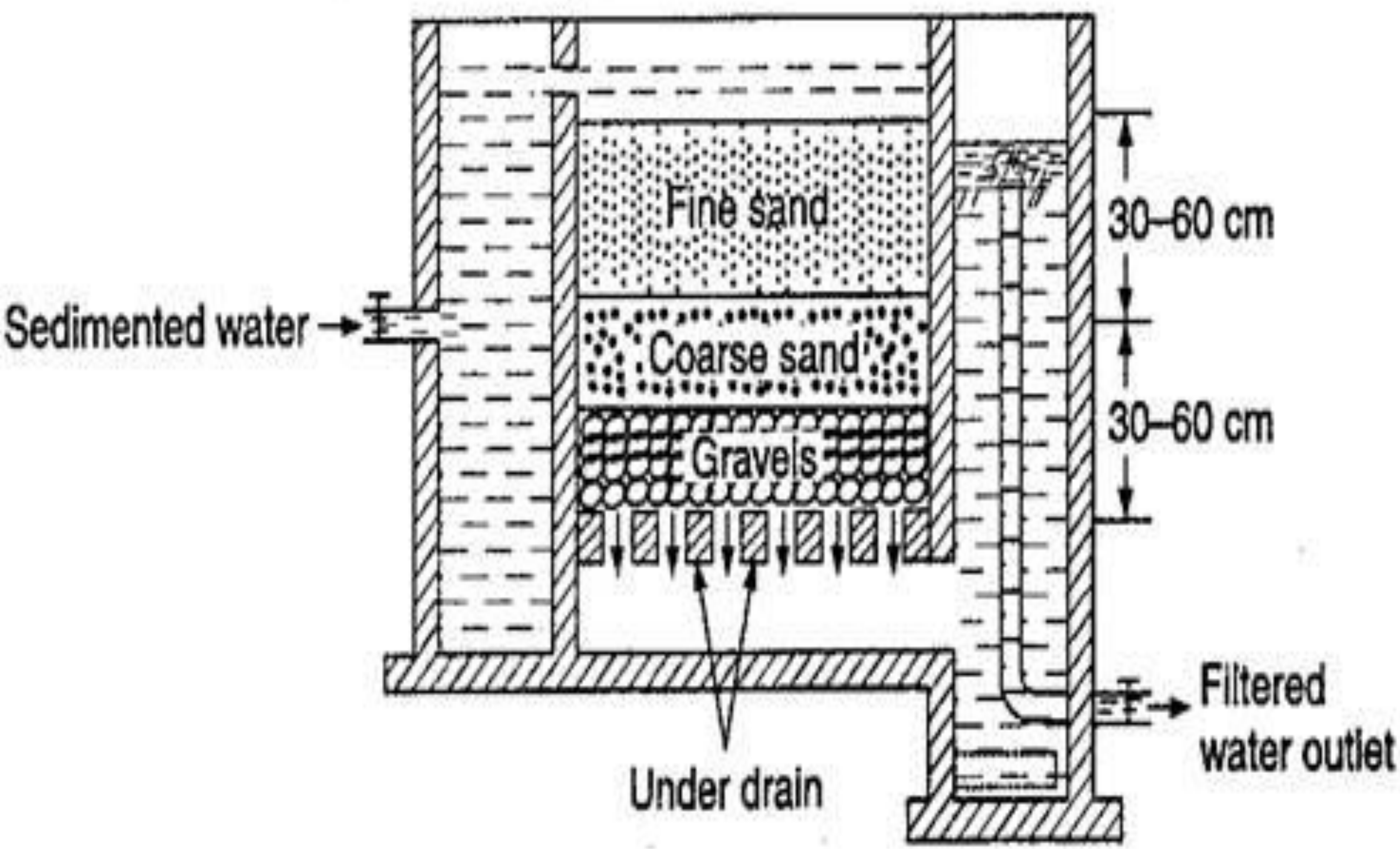
B) Standard or Conventional processes

- Generally, two types of filters are used
- a)<u>Rapid gravity filter</u>:-
- Here rate of filtration is high i.e. 5 to 20m/hr.
- b) <u>Slow sand filter</u>:-
- Here rate of filtration is slow i.e. 0.1 to 0.2m/hr.

Slow Sand Filter



Rapid Gravity Filter



Terminology

- Sand particles range in diameter from 0.0625 mm to 2 mm. An individual particle in this range size is termed a *sand grain*. Sand grains are between gravel (with particles ranging from 2 mm up to 64 mm) and silt (particles smaller than 0.0625 mm down to 0.004 mm)

Terminology

- ISO (International Organization for Standardization)14688 grades sands as fine, medium and coarse with ranges 0.063 mm to 0.2 mm, 0.2 mm to 0.63 mm, 0.63 mm to 2.0 mm respectively.

Comparision

Criteria	Rapid sand filters	Slow sand filters
Improvement of water quality	With pre-treated raw water, a filtrate quality is possible that has less than 1 NTU, 90% removal of coliforms, 50 – 90% removal of Cryptosporidium and Giardia cysts, 10% removal of colour, 5% removal of Total Organic Content (WEDC, 1999 [ref 02]). As a single process, rapid sand filtration was ranked third most effective of all treatment processes, given a range of pathogenic, chemical and aesthetic factors.	With raw water, a filtrate quality is possible that has less than 1 NTU, 95% removal of coliforms, 99% removal of Cryptosporidium and Giardia cysts, 75% removal of colour, 10% removal of Total Organic Content (WEDC, 1999 [ref 02]). As a single process, slow sand filtration was ranked second most effective of all treatment processes, given a range of pathogenic, chemical and aesthetic factors.
Rate of flow	A flow of between 4 – 21 m/h can be expected from a rapid sand filter, which is somewhere between 20 and 50 times faster than the range of slow sand filtration.	Flow rates are usually around 0.1 m/h but can increase up to 0.4 m/h. Check out Flow Rates for more information.
Filter media	Rapid sand filters are made using graded sand, sometimes with an additional coarser layer of material on top of the sand to increase the flow rate (for example, anthracite), in which case they become known as dual-media filters. The effective size for rapid filters is usually greater than 0.55mm with a Uniformity Coefficient of less than 1.5.	Slow sand filters on the other hand, should ideally have an effective size of between 0.15 – 0.35mm, and a Uniformity Coefficient of between 1.5 – 3, but preferably less than 2.
Penetration of solid matter	Penetration of suspended matter into the sand bed is deeper for rapid sand filters, which are usually cleaned by backwashing.	Solids only tend to penetrate slow sand filter beds by between 0.5 and 2 cm by comparison, allowing more manual methods to be employed for cleaning.
Pre-treatment	Pre-treatment is usually necessary for rapid sand filtration. Such treatment could include coagulation and flocculation, followed by sedimentation.	No pre-treatment is usually necessary for raw waters with turbidities of less than 50 NTU. Huisman and Wood (1974 [ref 03]) suggest that the best filtration occurs when turbidity is less than 10 NTU. Note that coagulation and flocculation are not appropriate pre-treatments for slow sand filters because floc carryover is possible, which rapidly blocks the sand bed.

Terminology

- In order to select the correct grain size it is necessary to measure the Effective Size (or D10) and Uniformity Coefficient (or K). Both are used in defining filter media, in this case to know whether a type of media is or is not suitable for slow sand filtration.

Terminology

- The effective size of a given sample of sand is the particle size (in millimetres) where 10% of the particles in that sample (by weight) are smaller, while 90% are larger. Usually this is denoted as the D10.

Terminology

- The size distribution is represented by the Uniformity Coefficient, which enables you to see how well graded your sand sample is (that is, whether there is a whole different range of sizes, or whether most of the sample is only one size). This is done by taking the D60 and dividing by the D10.

B) Standard or Conventional processes

- V) <u>Disinfection</u>:-
- By disinfection, pathogens & micro-organisms are killed, thereby making water more pure.
- The requirements of a good disinfectant are-
- a) It should be toxic to micro-organisms.
- b) It should have a fast rate of kill.

B) Standard or Conventional processes

- c) It should be persistent enough to prevent regrowth of organisms in the distribution system.
- d) It shouldn’t produce undesirable compounds.
- e) It should be safe to handle.
- f) It should be of reasonable cost.

B) Standard or Conventional processes

- Chick's law:-
- The rate of destruction of micro-organisms is often a first order chemical reaction as given by Chick's law i.e.

$$\frac{d}{dt}(N_t)\alpha(N_t) \Rightarrow \frac{d}{dt}\left(N_t\right) = -k(N_t)$$

$$So, N_t = N_0 e^{-kt}$$

B) Standard or Conventional processes

- Where,
- N_t = Number of organisms at time ‘t’
- N_0 = Number of organisms at time ‘t’= 0
- K = Rate constant depends on types of micro-organisms present & types of disinfectants used

B) Standard or Conventional processes

- The various examples of disinfectants are:-
- a) Chlorine dioxide
- b) Chlorine
- c) Chloramines
- d) UV radiation

Chlorine demand & Breakpoint Chlorination

- When chlorine is added to water, the chlorine at first oxidizes inorganic compounds & some amount of chlorine will be consumed by organic matter present in water. Then some amount of chlorine will be used for formation & subsequent destruction of chloramines.

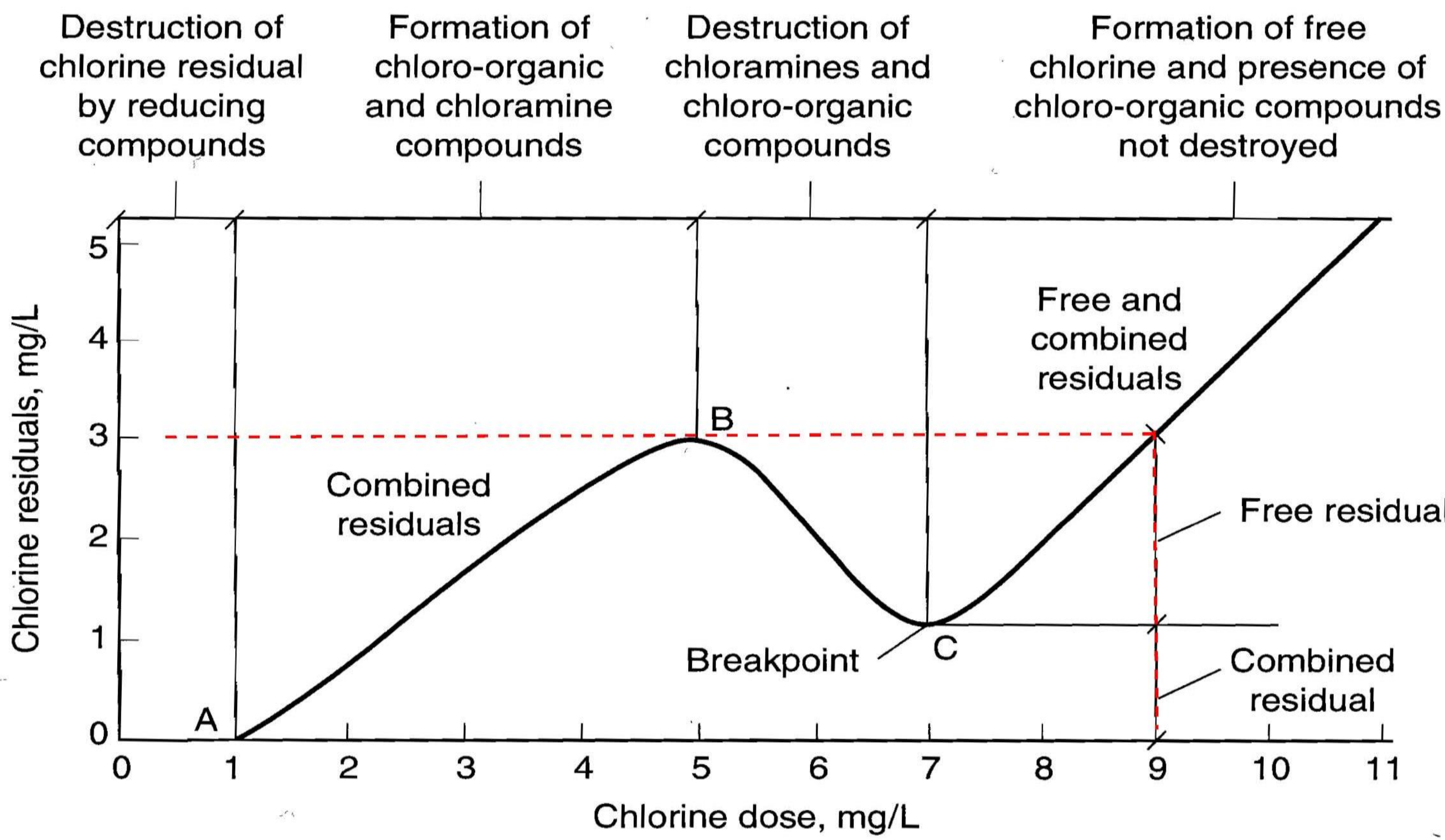
Chlorine demand & Breakpoint Chlorination

- The amount of chlorine required to fulfill the above consumption requirements are called chlorine demand.
- The point at which the chlorine demand is satisfied is called the breakpoint chlorination.

Chlorine demand & Breakpoint Chlorination

- The excess dose of chlorine after breakpoint, is available for disinfection which appears as residual chlorine.
- A residual chlorine of minimum 0.5mg/L is maintained in disinfection practices.

Chlorine demand & Breakpoint Chlorination



C) Special or Advanced processes

- The purposes of advanced water treatment processes are:-
- i) To take water treated by standard water treatment processes & to improve it to an exceptionally high quality water as often required by particular industries like food industry & pharmaceuticals etc.

C) Special or Advanced processes

- ii) To treat water containing specific chemical or microbiological contaminants, so that they can be brought to an acceptable standard.

C) Special or Advanced processes

- The various advanced water treatment processes are:-
- i) Iron(Fe) & Manganese(Mn) removal
- ii) Ion exchange
- iii) Chemical Oxidation
- iv) Membrane processes like Reverse Osmosis & electrodialysis.

C) Special or Advanced processes

- i) <u>Iron(Fe) & Manganese(Mn) removal</u>:-
- The acceptable limit of Iron as Fe and Manganese as Mn in drinking water are 0.3 & 0.1 mg/L respectively.
- By aeration the Fe^{+2} ions are oxidized to Fe^{+3} & precipitates out as $Fe(OH)_3$, which can be removed by filtration.

$$2Fe^{+2} + 0.5O_2 + (x+2)H_2O \rightarrow Fe_2O_3xH_2O + 2H^+ \rightarrow Fe(OH)_3$$

C) Special or Advanced processes

- Mn^{+2} can be removed by oxidizing Mn^{+2} to Mn^{+4} & then precipitating out.

$$3Mn^{+2} + 2KMnO_4 + 2H_2O \rightarrow 5MnO_2 + 4H^{+} + 2K^{+}$$

C) Special or Advanced processes

- ii) <u>Ion Exchange</u>:- Ion exchange processes are reversible & the direction of reaction in this case depends on the concentration & levels of the saturation of the sodium resin.
- Ex:-Water softening process

C) Special or Advanced processes

The reactions can be -

$$Mg^{+2} + Na_2R \rightarrow MgR + 2Na^{+}$$

$$Ca^{+2} + Na_2R \rightarrow CaR + 2Na^{+}$$

C) Special or Advanced processes

- Na_2R is Exchangeable Na Resin &
- R is complex base like Zeolite.
- Zeolites are the aluminosilicate members.
- Ex. of Zeolite is $Na_2Al_2Si_3O_{10}\cdot 2H_2O$, the formula for natrolite.

C) Special or Advanced processes

- iii) Chemical Oxidation:-
- It is the resultant reaction when two or more chemical species are added with each other with the purpose of increasing the oxidation state of one by reducing the other.
- Ex:- Fe^{+2} is oxidised by HOCl (Hypochlorous acid)

C) Special or Advanced processes

- The ferrous ion increased in oxidation state from +2 to +3 & chlorine reduced from Cl^+ to Cl^-.
- The reaction can be –
- $2Fe^{+2} + HOCl + 5H_2O \longrightarrow 2Fe(OH)_3 + Cl^- + 5H^+$

C) Special or Advanced processes

- iv) Membrane processes like Reverse Osmosis & electrodialysis:-
- Reverse Osmosis(RO):- It is a solubilization diffusion technique, that makes use of a semipermeable membrane which acts as a barrier to dissolved salts & inorganic molecules.

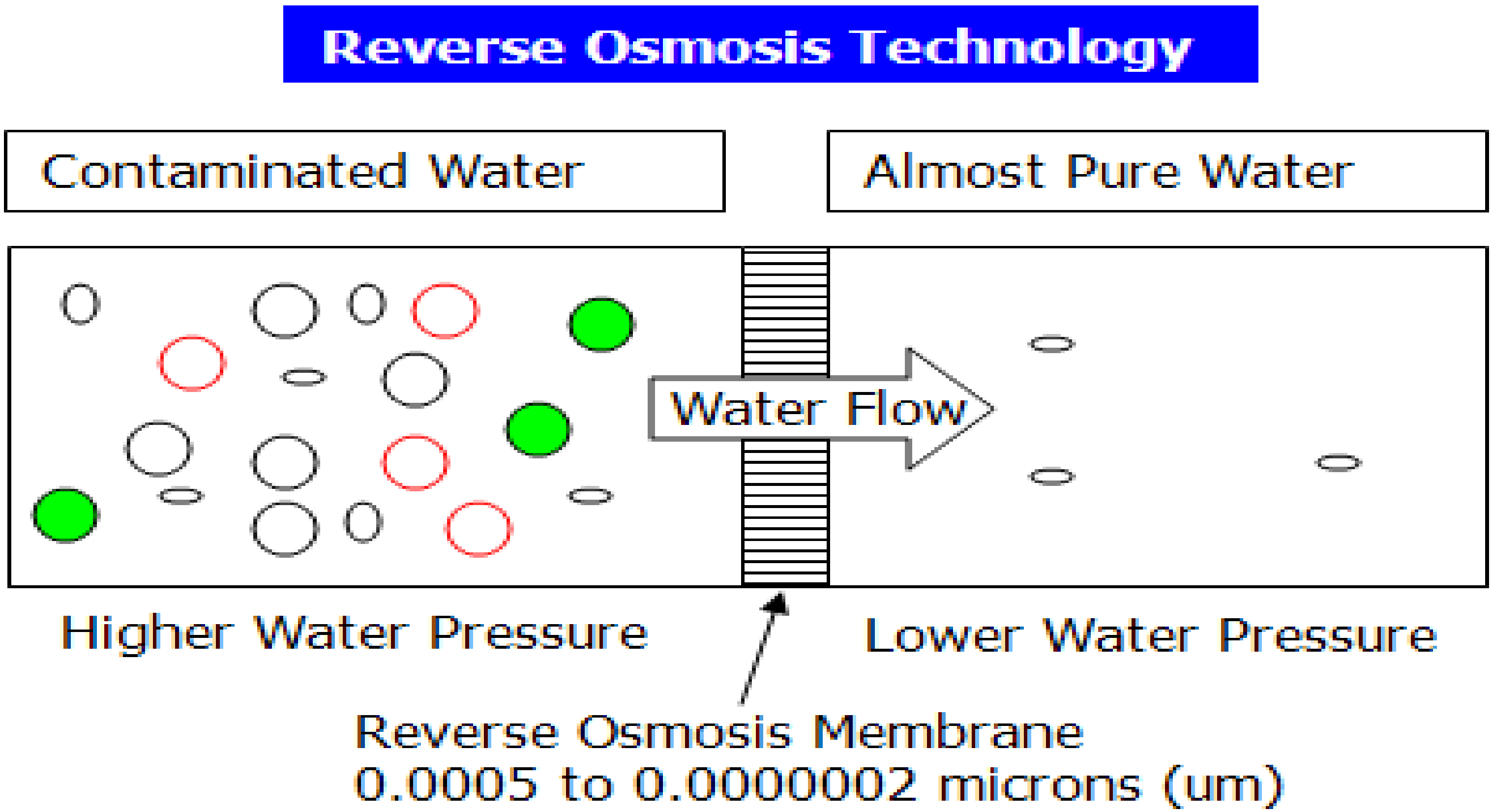
C) Special or Advanced processes

- **Reverse osmosis** (**RO**) is a water purification technology that uses a semipermeable membrane. This membrane technology is not properly a filtration method.
- In reverse osmosis, an applied pressure is used to overcome osmotic pressure, which is the minimum pressure which needs to be applied to a solution to prevent the inward flow of water across a semipermeable membrane

C) Special or Advanced processes

- Reverse osmosis can remove many types of molecules and ions from solutions, and is used in both industrial processes and the production of potable water. The result is that the solute is retained on the pressurized side of the membrane and the pure solvent is allowed to pass to the other side.

Diagram



Reverse Osmosis Technology
Contaminated Water
Almost Pure Water
Water Flow
Higher Water Pressure
Lower Water Pressure
Reverse Osmosis Membrane
0.0005 to 0.0000002 microns (um)

C) Special or Advanced processes

- Electrodialysis(ED):- It is an electrically charged membrane process, where the ions are transferred through a membrane from a less concentrated solution to a more concentrated solution.

Flow Diagram

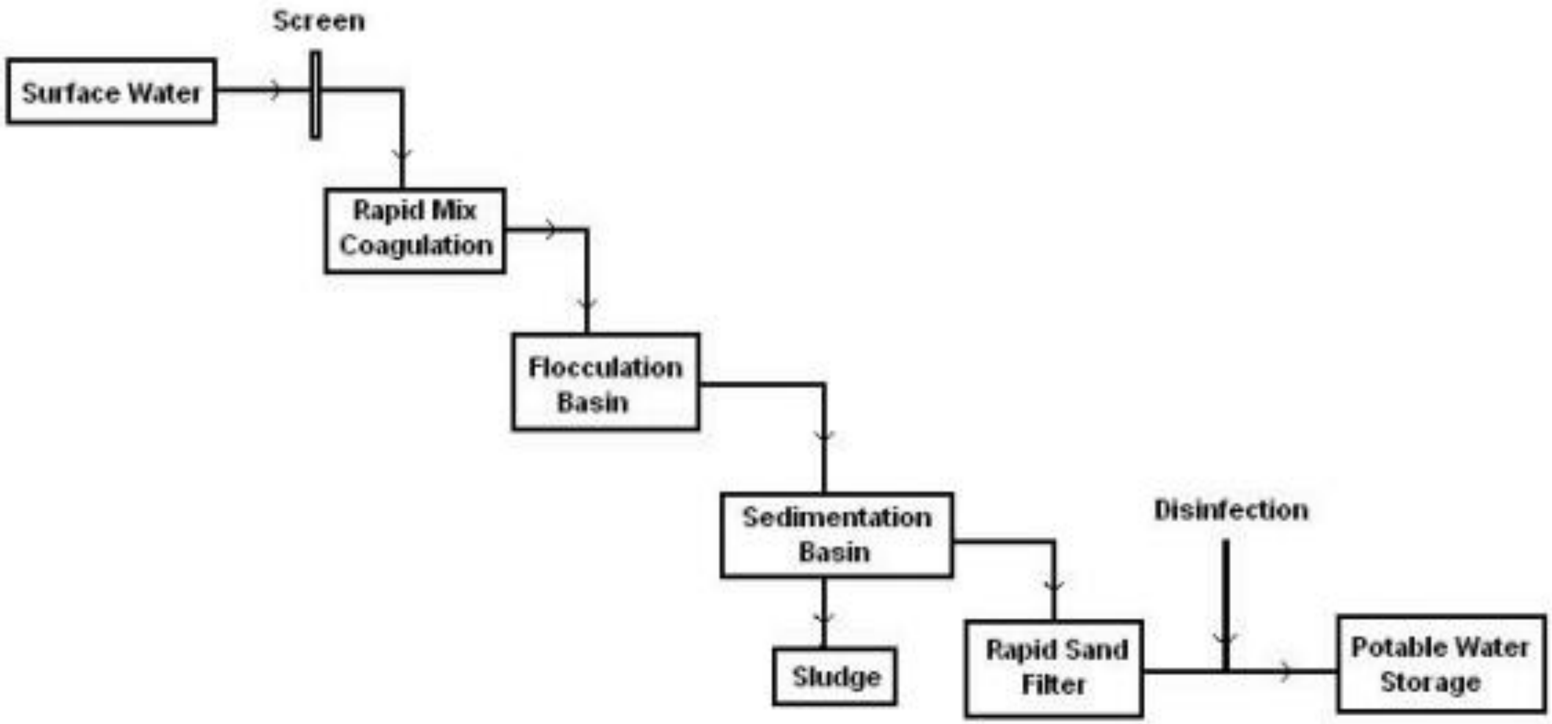
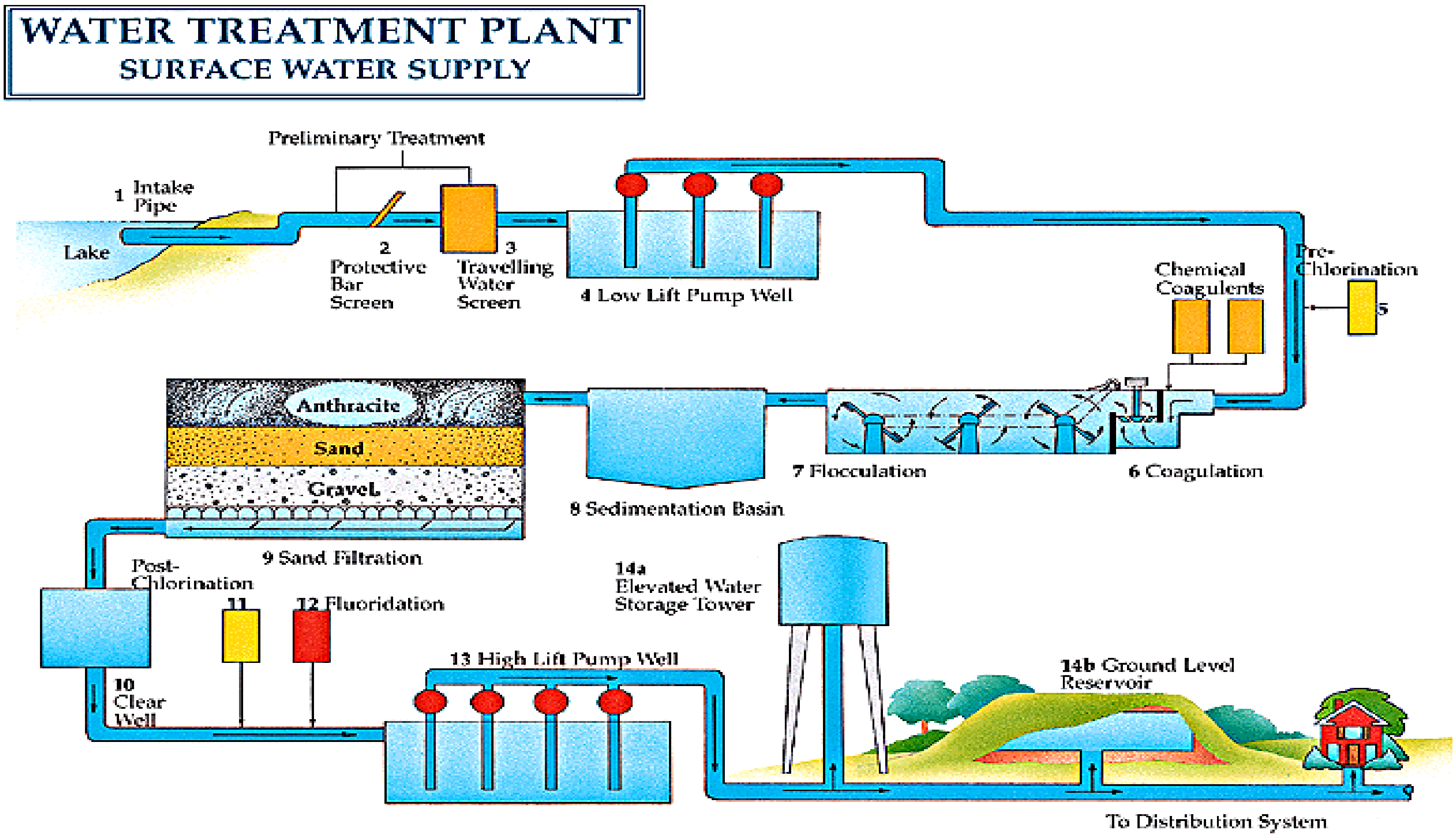


Figure 1 Flow diagram of a conventional potable water treatment plant.

Water treatment plant



Air Pollution

- Criteria Pollutants:-
- The criteria pollutants as defined by USA, EC(European Community) & WHO includes CO,NO_2,SO_2,Pb,PM-10(Particulate Matter of dia less than 10μm)
- These are generally found in urban environment.

Air Pollution

- Non-Criteria Pollutants:-
- The non-criteria air pollutants are those for which emission limits from industry are set or fixed.
- These are more poisonous & hazardous w.r.t. criteria pollutants
- Ex:- Benzene(C_6H_6),Carbon disulphide(CS_2), Arsenic, Asbestos

Air Pollution

- Acid Deposition:-
- Rainwater has pH approximately 5.7 & rainwater having pH less than this will be treated as acid rain, which will be a reason for acid deposition on the earth.
- Hydrocarbon(HC),SO_X,NO_X emitted from industries & vehicles are the main source of acid deposition.

Air Pollution

- GHG(Green House Gases):-
- A GHG absorbs & emits radiation within the thermal infrared range having wavelength between 700nm to 1mm i.e.
- 700×10^{-9} m to 10^{-3}m
- The major GHGs in order of their contribution are CO_2>CFCs>CH_4>N_2O(Nitrous Oxide)

Air Pollution

- <u>Air Pollution Meteorology</u>:-
- The meteorological factors are –
- Wind speed & direction
- Temperature & humidity
- Turbulence
- Atmospheric Stability
- Topographic effects on meteorology

Air Pollution

- <u>Scales</u>:-
- Air pollution emission can be measured in 3 scales-
- a) Microscale
- b) Mesoscale
- c) Macroscale

Air Pollution

- a) <u>Microscale</u>:-
- It is of the order of 1km & duration is minutes to hours.
- Ex:- Chimney gases

Air Pollution

- b) Mesoscale:-
- It is of the order of 100km & duration is hours to days.
- Ex:- Mountain valley wind

Air Pollution

- c) Macroscale:-
- It is of the order of 1000km & duration is days to weeks.
- Ex:- wind over oceans & continents

Air Pollution

- <u>Wind Speed</u>:-
- Wind speed at any height(z) can be determined using power law relationship i.e.
- $U_Z = U_{10}(Z/Z_{10})^P$

Air Pollution

- Where,
- U_Z is wind speed at height Z mtr
- U_{10} is wind speed at 10mtr height
- Z is height in mtr
- Z_{10} is 10 mtr height
- P is exponent, depends on terrain & stability class

Air Pollution

- Q. Use power law velocity profile equation to determine U_{20},U_{50},U_{100},U_{200} if U_{10} is 5m/sec & p is 0.2.

Air Pollution

- Lapse Rate:-
- In the lower troposphere, the temperature usually decreases with altitude.
- The rate of temperature change or gradient is known as the lapse rate.
- Lapse rate can be ambient or adiabatic.

Air Pollution

- Ambient Lapse Rate (ALR) or
- Environmental Lapse Rate(ELR):-
- The temperature change or gradient with respect to rising altitude is known as ambient lapse rate & it varies from day to day & day to night.
- This is the actual change of temperature with altitude for the stationary atmosphere.

Air Pollution

- Adiabatic Lapse Rate:-
- The temperature change of a parcel of air against rising altitude under adiabatic condition (i.e. occurring without the addition or loss of heat) is called the adiabatic lapse rate.

Air Pollution

- Adiabatic Lapse Rate can be of two types-
- i) Dry Adiabatic Lapse Rate(DALR)
- ii) Moist adiabatic lapse rate (MALR) or
- Saturated adiabatic lapse rate(SALR)

Air Pollution

- For dry air i.e. DALR value is 0.98^0C per 100mtr or approximately 1^0C per 100mtr
  or 10^0C per KM height
- For moist air i.e. MALR value is 0.55^0C per 100mtr or approximately 0.6^0C per 100mtr
  or 6^0C per KM height.

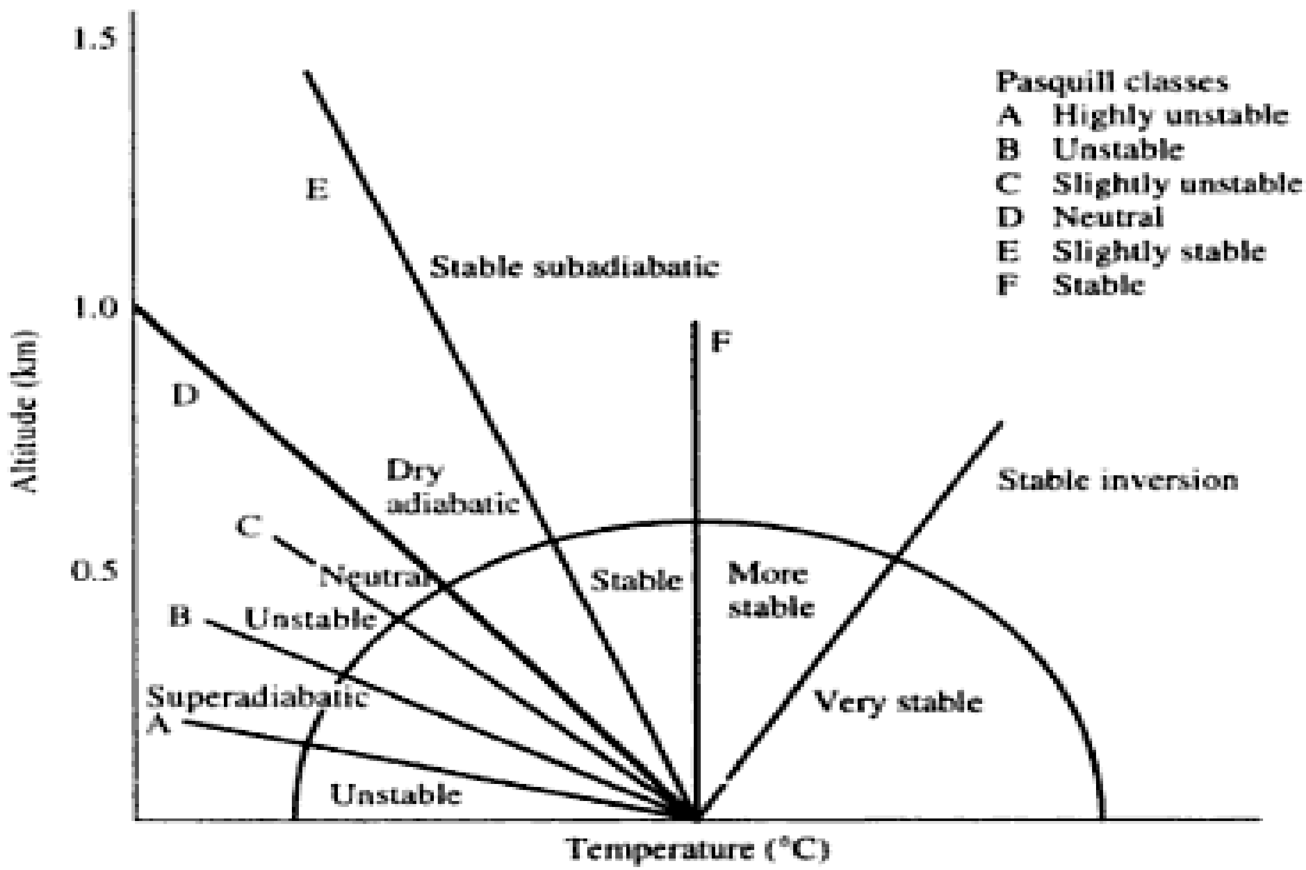
Air Pollution

- A neutrally stable atmosphere occurs when ALR(Ambient)=DALR i.e. rate of cooling with rising altitude is nearly 1^0C per 100mtr.
- A stable atmosphere occurs when ALR < DALR i.e. rate of cooling with rising altitude is less than 1^0C per 100mtr.

Air Pollution

- An unstable atmosphere occurs when ALR > DALR i.e. rate of cooling with rising altitude is greater than 1^0C per 100mtr.
- A stable inversion condition occurs, when the temperature increases with altitude.

Stability Classes



.14 Pasquill–Gifford stability classes—vertical temperature profile.

Stability Classes

- The previous figure represents the relationship of the variety of possible ambient lapse rate(ALR) to the dry adiabatic lapse rate(DALR) as corresponding to the Pasquill-Gifford stability classes.

Air Pollution

- Atmospheric Dispersion:-
- For determining atmospheric dispersion, generally 5 models are used like –
- Gaussian model
- Numerical model
- Statistical model
- Empirical model
- Physical model

Air Pollution

- Out of the above models, Gaussian model is generally used.
- The various assumptions of Gaussian model are –
- i) There is no variation in wind speed & direction between the source & receptor.

Air Pollution

- ii) All discharges remain in the atmosphere.
- iii) Dispersion doesn't occur in the downward direction.
- iv) Emission rates are assumed constant & continuous.

Industrial Air Emission Control

- There are three general options in air emission control:-
- i) Waste minimization
- ii) Recovery & Recycling
- iii) Destruction or Disposal

Industrial Air Emission Control

- Special Methods:-
- There are three special methods of air emission control:-
- i) FGD(Flue Gas Desulphurization)
- ii) NO_X removal
- iii) Fugitive emission

Industrial Air Emission Control

- i) <u>FGD</u>:-
- FGD systems are of two types.
- a) It generates a residue which must be disposed off.
- b) It converts SO_2 & SO_3 to a marketable product.

Industrial Air Emission Control

- The chemistry of FGD systems are –
- $SO_2 + CaO \rightarrow CaSO_3$
- $2CaSO_3 + O_2 \rightarrow 2CaSO_4$
- $CaCO_3 + SO_2 \rightarrow CaSO_3 + CO_2$

Industrial Air Emission Control

- ii) $\underline{NO_X \text{ removal}}$:-
- The term NO_X implies two major oxides of nitrogen i.e.
- NO(Nitric Oxide) &
- NO_2(Nitrogen Dioxide)

Industrial Air Emission Control

- The simplest, most widely used model of NO_X formation is the Zeldovich mechanism, which may be expressed as follows –
- $N_2 + O = NO + N$
- $O_2 + N = NO + O$
- $OH + N = NO + H$

Industrial Air Emission Control

- Methods of NO_X reduction:- (T-16.5,P-777,G.kiely)
- Methods:-
- a)Flue gas recirculation
- b)Low NO_X burner
- c)Staged burners
- d)Selective catalytic reduction(SCR)
- e)Selective non-catalytic reduction(SNCR)

Industrial Air Emission Control

- iii) <u>Fugitive Emission</u>:-
- Fugitive emissions are industrial emissions from both point & non-point sources. These sources may be considered the equipments & methods associated with the transferring, conveying, loading, unloading, storage, packaging & processing of materials.

Industrial Air Emission Control

- Control of fugitive emissions depend on compounds involved, quantities involved & the equipment being used.

Equipment Selection & Design

- The Equipment Selection & Design is made on the basis of the types of compounds which are required to be removed.
- Generally, compounds can be of three types –
- a) Volatile Organic Compounds(VOCs)
- b) Inorganic Compounds
- c) Particulate matter

Equipment Selection & Design

- The major types of equipments which are used are –
- i) Incinerators
- ii) Absorbers
- iii) Adsorbers
- iv) Condensers
- v) Filters

Equipment Selection & Design

- vi) Scrubbers or wet collectors:-
- It is an apparatus using water or solution for purifying gases or vapours
- vii) Various particle collection devices like ESP(Electrostatic Precipitator)
- viii) Impingement separators:-
- By density difference, it separates solids from gases

Equipment Selection & Design

- ESP:- An **electrostatic precipitator** (ESP) is a highly efficient filtration device that removes fine particles, like dust and smoke, from a flowing gas using the force of an induced electrostatic charge minimally impeding the flow of gases through the unit.

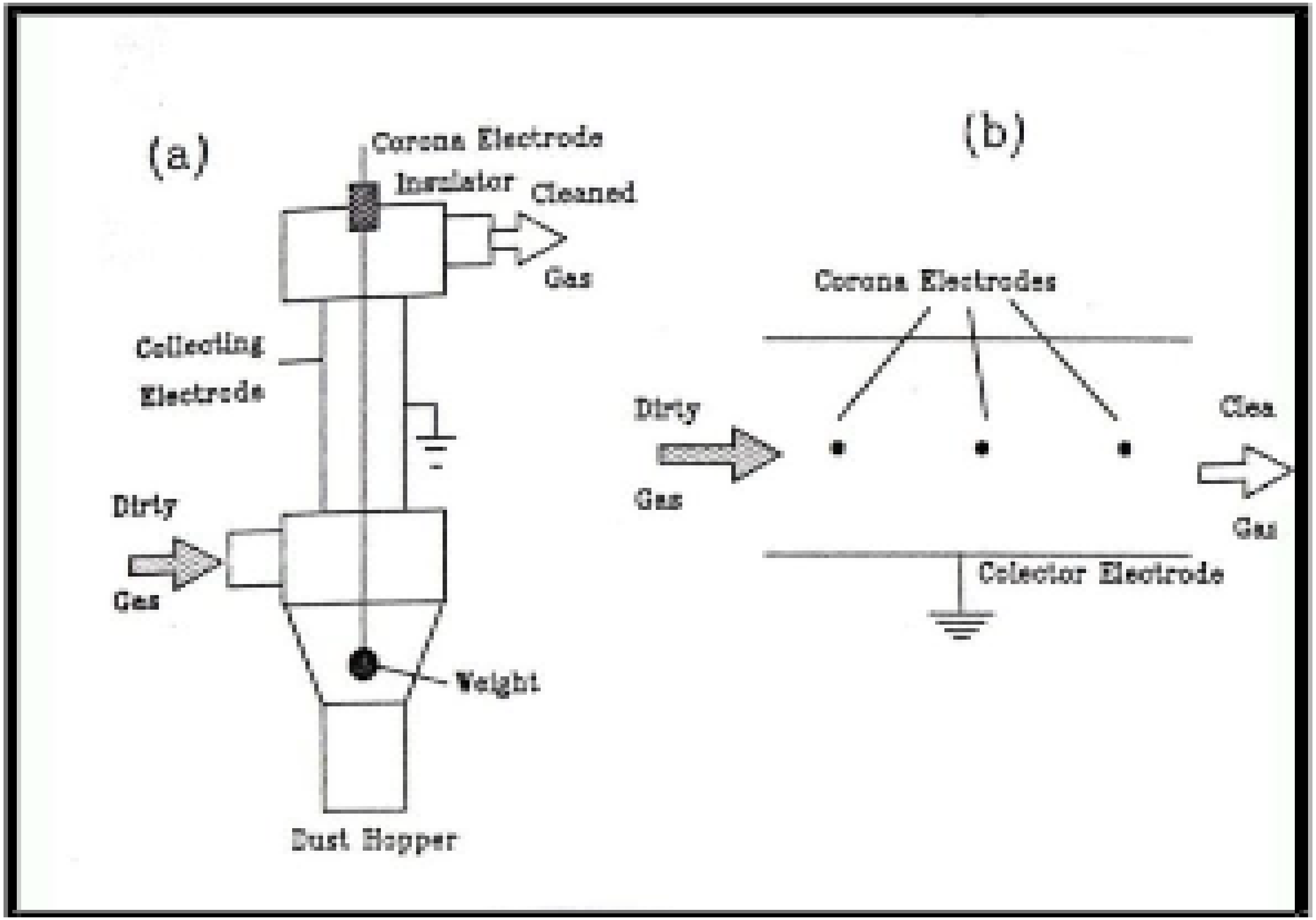
Equipment Selection & Design

- **<u>Basic Working Principle of ESP:-</u>**
- In high- voltage electrostatic field, affected by the electric field force, gas ionization takes place. There are tremendous amount of electrons and ions existing in the ionized gas. After the dust particles are combined with these electrons and ions, they will be polarized, most of them are negatively polarized. Under the action of the field force, negatively charged particles migrates towards the positive electrode and in turn release electrons and attach to the positive electrode.

Equipment Selection & Design

- When the particles agglomerate and the layers reaches a certain thickness on the plate, rapping system will start to work and the particles will be dislodged from the collecting plate by vibration and falling into the hopper. That ends the collection process.

Diagram



(a)
Corona Electrode
Insulator
Cleaned
Gas
Collecting
Electrode
Dirty
Gas
Weight
Dust Hopper
(b)
Corona Electrodes
Dirty
Gas
Clea
Gas
Colector Electrode

Equipment Selection & Design

- The efficiency of an ESP with plate collector is given by Anderson-Deutsch equation which can be expressed as follows:-
- Efficiency = 1- $e^{(-AW/Q)}$
- where, A = area of the plates in square mtr
- W= particle sedimentation velocity in an electric field in mtr/sec
- Q= Gas flow rate in m^3/sec

Problem

- A quantity of 50 m^3/sec of air flows from a cement manufacturing facility. It contains cement particles whose settling velocity is 0.12 mtr/sec. If 99% removal efficiency is required, calculate the surface area of the ESP or design an ESP.

Problem

- Calculate the percentage increase in area of the ESP plates, if the efficiency of the ESP unit is to be increased from 99% to 99.7%. Given the flow rate is 50m^3/sec & particulate velocity is 0.15mtr/sec.

Problem

- The drift velocity of fly ash particle is given by the empirical equation $w = 1.5X10^5\ d_p$, where d_p is particle size. Determine the plate area required to remove particles of dia 0.7µm with removal efficiency 95%. Flow to ESP is $5m^3/sec$.

Waste Minimization

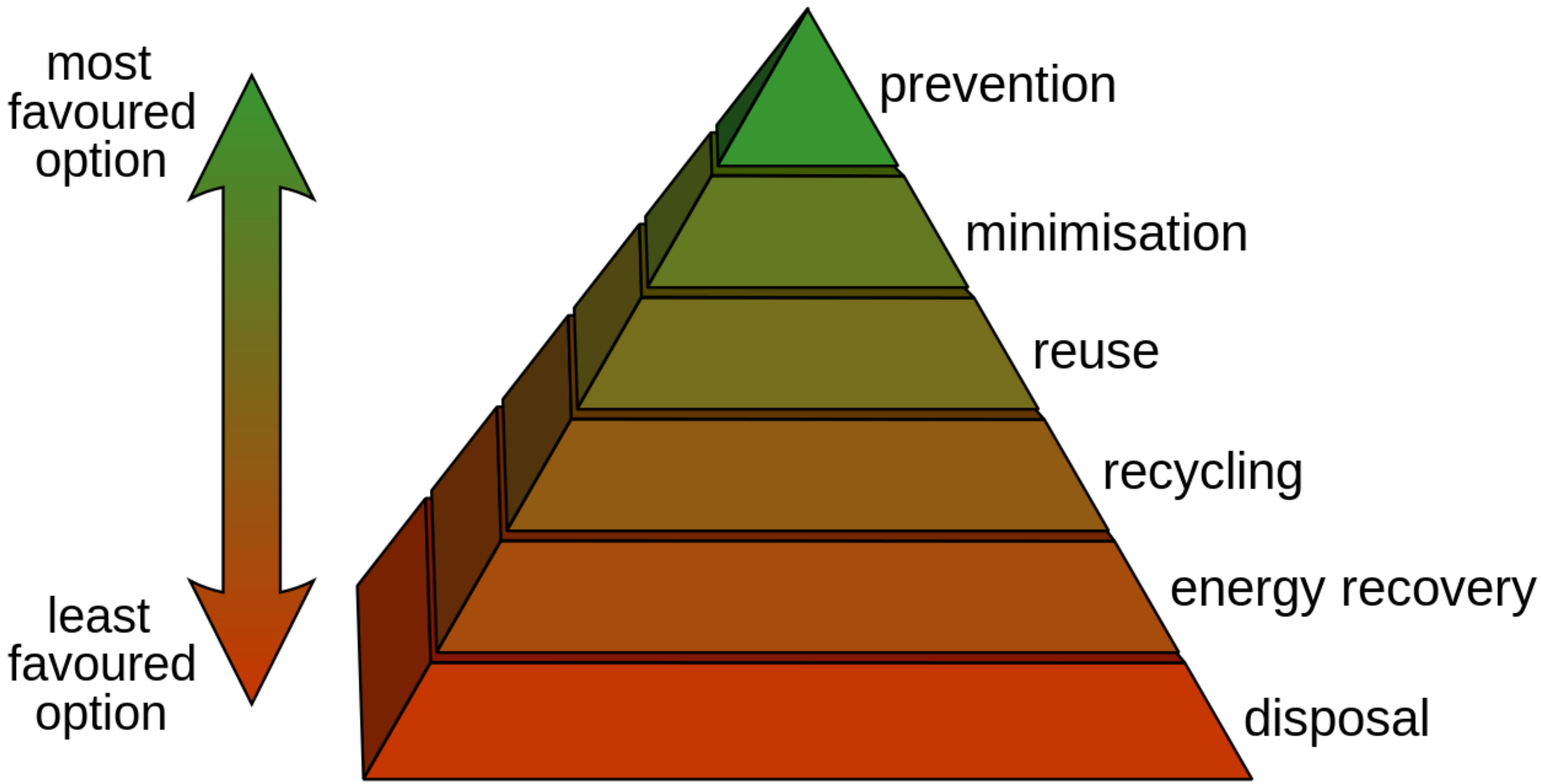
- Waste minimization is necessary :-
- i) To control pollution
- ii) To decrease the depletion rate of resources
- ii) To increase efficiency & hence profitability

Waste Minimization

- Elements of a waste minimization strategy:-
- It includes –
- i) Reduction at source
- ii) Recycle/ Reuse
- iii) Treatment
- iv) Disposal

Waste Minimization Hierarchy

Waste Minimization Hierarchy



Waste Reduction Techniques

- It has four major categories:-
- i) Inventory Management
- ii) Production Process Modification
- iii) Volume Reduction
- iv) Recovery

Waste Reduction Techniques

- i) <u>Inventory Management</u>:-
- Inventory means
  a <u>detailed</u> list of articles, goods, property.
- Inventory management includes –
- a) Inventory Control
- b) Materials Control

Waste Reduction Techniques

- ii) Production Process Modification:-
- It includes –
- a) Operational & maintenance procedures
- b) Materials Change
- c) Process equipment modification

Waste Reduction Techniques

- iii) Volume Reduction:-
- It includes –
- a) Source Segregation
- b) Concentration

Waste Reduction Techniques

- iv) <u>Recovery</u>:-
- It includes –
- a) on-site
- b) off-site

Life Cycle Assessment(LCA)

- LCA is an useful environmental management tool.
- Any product may have the following stages in it’s lifecycle –
- i) Raw material acquisition
- ii) Bulk material processing

Life Cycle Assessment(LCA)

- iii) Engineered & specialty materials production
- iv) Manufacturing & assembly
- v) Uses & services
- vi) Retirement or expired
- vii) Disposal

Life Cycle Assessment(LCA)

- LCA has the following phases –
- i) Planning
- ii) Screening
- iii) Data Collection
- iv) Data treatment
- v) Evaluation

Diagram


PACKAGING
DISTRIBUTION
LIFE CYCLE
ASSESSMENT
MANUFACTURING
USAGE
MATERIALS
DISPOSAL

Environmental Impact Assessment

- Environmental Impact Assessment (EIA) is a process that requires consideration of the environment & public participation in the decision making process of project development.
- Environmental Impact Assessment (EIA) is an important management tool for ensuring optimal use of natural resources for sustainable development.

Environmental Impact Assessment

- The stages of EIA include –
- i) Screening
- ii) Scoping
- iii) EIS preparation
- iv) Review

Environmental Impact Assessment

- i) <u>Screening</u>:-
- By screening, it is to be decided which projects should be subject to environmental assessment.
- ii) <u>Scoping</u>:-
- It is the process which defines the key or important issues that should be included in the environmental assessment.

Environmental Impact Assessment

- iii) EIS preparation:-
- It is the scientific & objective analysis of the scale, significance & importance of impacts identified.
- iv) Review:-
- The review panel guides the study & then advises the decision makers.

Environmental Impact Assessment

- Origin of EIA:-
- All ecosystems including human beings have threshold of tolerance for pollution & disturbances, beyond which the system may suffer anything from temporary upsets to complete destruction. After second world war industrial & agricultural practices began to cause environmental damage which crossed the thresholds & lead to origin of EIA.

Environmental Impact Assessment

- EIA Procedure:-
- There are generally three options for establishing EIA procedures.
- i) Legislative Option i.e. Legal approach
- ii) Middle Ground Option i.e. within accepted planning & Procedures
- iii) Policy Option i.e. within the administrative policy of government

Environmental Impact Assessment

- Project Screening for EIA:-
- The success of EIA depends on effective coverage & application of projects. The various methods commonly used to select projects for EIA are –
- i) The use of positive (EIA required) & negative (EIA not required) list

Environmental Impact Assessment

- ii) The use of project criteria
- iii) The sensitive area criteria
- iv) Matrices
- v) Initial Environmental Evaluation(IEE)

Environmental Impact Assessment

- Initial Environmental Evaluation(IEE):-
- IEE is a mini EIA.
- It requires a description of the environment & the development & the identification of environmental impacts those are anticipated.

Environmental Impact Statement(EIS)

- EIS is a review document prepared for assessment in the EIA process.
- Scope Studies of EIS:-
- Scoping is the procedure for establishing the TOR(Terms Of Reference) for the EIS.

Environmental Impact Statement(EIS)

- In general, the objectives would be to identify the concerns & issues those need attention, necessary for public involvement & to prepare a detailed report for the investigation of specific issues associated with the development.

Environmental Impact Statement(EIS)

- Preparation of an EIS:-
- One of the important elements of any project is the preparation of documentation to communicate the findings & conclusions of the study.

Environmental Impact Statement(EIS)

- The value of the project is sharply diminished, if it’s findings don’t reach it’s requisite results or intended audiences.
- The important points to be considered are –
- i) Planning
- ii) Purpose
- iii) Audience
- iv) Structure

Environmental Impact Statement(EIS)

- Review of an EIS:-
- The functions of the review authority includes-
- i) The scope of the assessment i.e. which projects should be subjected to a full or partial EIS.
- ii) General or specific guidelines & advice on the methods of EIS.

Environmental Impact Statement(EIS)

- iii) Formulate the TOR(Terms Of Reference) & initiate a detailed EIS.
- iv) Ensure that, the EIS had been adequately completed within the TOR.

Solid Waste Management

- Solid waste is the unwanted or useless solid materials generated from combined residential, industrial and commercial activities in a given area.
- Management of solid waste reduces or eliminates adverse impacts on the environment and human health and supports economic development and improved quality of life.

Solid Waste Management

- It may be categorised according to its <u>origin</u> (domestic, industrial, commercial, construction or institutional); according to its <u>contents</u> (organic materials like plastics, rubber, food items & inorganic materials like glass, metal etc); or according to <u>hazard potential</u> (toxic, non-toxic, flammable, radioactive, infectious etc).

Solid Waste Management

- A number of processes are involved in effectively managing waste for a municipality.
- These include monitoring, collection, transport, processing, recycling and disposal.

Solid Waste Management

- The order or hierarchy of solid waste management includes –
- i) Waste prevention & minimization
- ii) Reuse & Recycling
- iii) Transformation
- iv) Landfill

Solid Waste Management

- <u>Reuse</u>:-
- A newly purchased product is put to another use after the first use is completed.
- <u>Recycling</u>:-
- It is the processing of used materials or waste into new products to prevent waste of potentially useful materials.

Solid Waste Management

- <u>Properties of MSW(Municipal Solid Waste)</u>:-
- The various properties of MSW includes –
- i) Physical Properties of MSW
- ii) Biological Properties of MSW
- iii) Chemical & Energy Properties of MSW

Solid Waste Management

- i) Physical Properties of MSW:-
- The various Physical Properties of MSW are –
- a) Particle Size Distribution
- b) Density & Moisture Content
- c) Field Capacity
- d) Shear Strength
- e) Hydraulic Conductivity

Solid Waste Management

- a) Particle Size Distribution:-
- Particle size is measured in terms of size of screens in mm through which wastes are passing.
- This distribution will provide the information of various materials present.

Solid Waste Management

- b) Density & Moisture Content:-
- Density is mass per unit volume, which is a useful physical parameter used for separating various wastes from each other before treatment.

Solid Waste Management

- The moisture content is expressed as mass of water vapour per unit mass of substance.
- Moisture Content(%) = {(a-b)/a}X100
- Where,
- ‘a’ is initial mass of sample &
- ‘b’ is mass of sample after drying

Solid Waste Management

- c) <u>Field Capacity (FC)</u>:-
- It is the maximum percentage of volumetric soil moisture that a MSW sample will hold freely against earth's gravity.
- FC can be calculated by –
- $FC = 0.6 – 0.55(W/4500+W)$
- Where, W is overburden weight in Kg.

Solid Waste Management

- d) Shear Strength:-
- Solid wastes when compacted usually have high shearing strength & hence don’t flow on standing, but sludge has poor shearing strength & therefore very often sludge is co-disposed with MSW.

Solid Waste Management

- e) Hydraulic Conductivity:-
- Sludge in landfills tend to resist the movement of water through them due to low hydraulic conductivity, as sludge has high moisture content.

Solid Waste Management

- ii) Biological Properties of MSW:-
- Organic or biological matter in MSW is significant for the energy recovery by biodegradation.
- Biodegradation can be accomplished either by aerobic or anaerobic process.

Solid Waste Management

- The biodegradability of the organic fraction of MSW is given by –
- $BF = 0.83 - 0.028LC$
- Where,
- BF is Biodegradable Fraction
- LC is Lignin(organic) Content in % of dry weight
- High LC will give low biodegradability.

Solid Waste Management

- iii) Chemical & Energy Properties of MSW:-
- The various steps involved in this are –
- a) Proximate Analysis
- b) Ultimate Analysis
- c) Energy Content

Solid Waste Management

- a) Proximate Analysis:-
- It deals with the determination of moisture content(W%), volatile matter(VM%), non-combustible fraction (i.e. ash%) & Fixed Carbon(FC).
- FC can be found out by –
- FC=100 - W(%) - VM(%) - ash(%)

Solid Waste Management

- FC is the solid combustible residue that remains after the material is heated & the volatile matter is ejected.

Solid Waste Management

- b) Ultimate Analysis:-
- It is the elemental analysis of essential major elements like C,H,O,N,P,S in percentage mass.

Solid Waste Management

- c) Energy Content:-
- Heating value or calorific value of MSW may be defined as the amount of heat liberated in calorie, when a gram of MSW is burnt.
- It gives the amount of organic matter present in the MSW.
- Generally, terms like E, H_u, H_{wf}, H_{awf} are used to express energy content.

Solid Waste Management

- E is Energy Content
- H_u is LHV(Lower Heat Value) i.e. energy received from waste as collected from site
- H_{wf} is NHV(Normal Heat Value) i.e. energy received from water-free waste
- H_{awf} is HHV(Higher Heat Value) i.e. energy received from ash-water-free waste

Solid Waste Management

- $H_u = H_{awf} \times B - 2.445 \times W$
- Where,
- B is flammable fraction or combustible component
- W is moisture content fraction or water content

Solid Waste Management

- The energy content of MSW can be determined from following equations –
- i) Dulong Equation
- ii) Khan Equation

Solid Waste Management

- i) Dulong Equation:-
- H_{awf} = 337(C)+1419{(H)- 0.125(O)} + 93(S) + 23(N)
- Where, C, H, O, S, N are the % by weight of each element present in the material.

Solid Waste Management

- ii) Khan Equation:-
- $E = 0.051\{F + 3.6(CP)\} + 0.352(PLR)$
- Where, E = Energy content,
- F = % of food material by weight
- CP = % of Cardboard & Paper by weight
- PLR = % of Plastic & Rubber by weight

Solid Waste Management

- Q. Calculate the heat value of domestic MSW, if the chemical composition is $C_{450}H_{2050}O_{950}N_{12}S$.
- Q. Calculate the lower heat value of the above MSW if water content(w) = 21% & ash content(A) = 20%

Solid Waste Management

- Separation of MSW:-
- The different major components of MSW must be separated from one & the other in order to have suitable management of MSW.
- The component separation can be done at the household or at the industry i.e. at the source or at the transfer station or at the final destination, where mechanical sorting or separation is possible.

Solid Waste Management

- <u>Storage & Transport of MSW</u>:-
- It depends on types of collection facility available & materials present, which can be –
- i) Door Step Collection
- ii) Regular Roadside Collection
- iii) Dustbins at market places
- iv) Community Recycle bin

Solid Waste Management

- Integrated Waste Management:-
- The ideal integrated waste management plan might have following priorities –
- i) Minimize all components of waste fraction.
- ii) Recycle, what is possible of paper, cardboard, non-ferrous metals.
- iii) Reuse plastics, ferrous metals, glass.

Solid Waste Management

- iv) Compost food fraction of MSW.
- v) Incinerate the remaining food waste.
- vi) Landfill the remaining after proper treatment.

Solid Waste Management

- Leachate in Landfills:-
- Leachate is the contaminated water in landfills which arrive at the landfill site through external precipitation.
- The amount of leachate produced in a landfill depends on it’s water balance, which can be expressed as follows –
- LC = PR + SRT – SRO – EP – ST

Solid Waste Management

- Where,
- LC is Leachate,
- PR is Precipitation
- SRT is Surface Run To i.e. water outside the site entering the landfill
- SRO is Surface Run-off
- EP is Evapotranspiraton
- ST is Change in water storage

Solid Waste Management

- Q. Calculate the Landfill area requirement for 20 years for a city of population of about 5 lakhs. Assume MSW generation as 500gm per capita per day & density of MSW is 500kg/m^3.

Hazardous Waste Management

- Hazardous waste is defined as, any waste which because of it's physical, chemical quality, quantity and infectious characteristics can cause significant hazards to human health or the environment, when improperly treated, stored, transported or disposed.

Hazardous Waste Management

- A substance is hazardous, if it exhibits one or more of the following characteristics.
- i) <u>Ignitable</u>:- The substance causes or enhances fire.
- ii) <u>Reactive</u>:- The substance reacts with other materials & may explode.

Hazardous Waste Management

- iii) Corrosive:- The substance destroys tissues or metals.
- iv) Toxic:- The substance is a danger to health, water, food & air.

Hazardous Waste Management

Hazardous Category	Nature of Waste
H1	Explosive
H2	Oxidiser
H3A	Highly Flammable
H3B	Flammable
H4	Irritant
H5	Harmful

Hazardous Waste Management

- <u>Generation of Hazardous Waste</u>:-

Industry Type	Hazardous Substances
Battery	Cd, Pb, Ag, Zn
Electroplating	Co,Cr,Cu,Zn
Printing	As,Cr, Cu,Pb,Se
Textiles	Cr, Cu, Organics

Hazardous Waste Management

- <u>Medical Hazardous Wastes</u> :-
- These are the wastes generated from hospitals, medical colleges, nursing homes, clinical laboratories & operation theatres etc.

Hazardous Waste Management

- Medical hazardous wastes include –
- i) Expired or Obsolete medicines
- ii) Infectious dressing materials
- iii) Pathological wastes from medical laboratories & operation theatres
- iv) Wastes from dental clinics etc.

Hazardous Waste Management

- <u>Household Hazardous Waste</u>:-
- The household hazardous wastes come from kitchen, bathroom, garage, garden etc.
- It may include –
- i)Used or Exhausted batteries
- ii)Chemicals like dyes, perfumes
- iii)Pesticides, herbicides, used oils, lubricants etc.

Hazardous Waste Management

- Transportation of Hazardous Waste :-
- The data or information required for Transportation of Hazardous Waste are –
- i) Waste Generator
- ii) Composition of Waste
- iii) Physical Appearance
- iv) Method of Packaging

Hazardous Waste Management

- v) ADR/RID classification
- ADR means transport of dangerous goods by road
- RID means transport of dangerous goods by rail
- vi) UN Number(United Nation Number)

Hazardous Waste Management

- ADR/RID classification:-

Class	Item Description
1a	Explosive Items
1b	Items loaded with explosives
1c	Detonators & similar types of goods
2	Gases, Compressed, Condensed or dissolved under pressure
3	Flammable Liquids

Hazardous Waste Management

- The UN numbers range from UN0001 to about UN3500 and are assigned by the United Nations Committee of Experts on the Transport of Dangerous Goods.

Hazardous Waste Management

UN Number	Hazardous Item
1001	Acetylene Dissolved
1002	Compressed Air
1003	Liquefied air, refrigerated
1005	NH_3, dry, liquefied

Hazardous Waste Management

- For Hazardous Waste transport, special numbers are also used.
- 1759 – Corrosive Solid Compounds
- 1760 – Corrosive Liquid
- 1906 – Waste Acids
- 1992 – Flammable Liquid, toxic
- 1993 – Flammable Liquid

Hazardous Waste Management

- <u>Treatment of Hazardous waste</u>:-
- i) Thermal Treatment (Incineration)
- ii) Chemical Treatment (Neutralization)
- iii) Physical Treatment (Filtration, Flocculation)
- iv) Disposal (Secure Landfill)

Hazardous Waste Management

- <u>Incineration</u>:-
- Incineration can be defined as controlled high temperature oxidation of primarily organic compounds to produce CO_2 & H_2O with non-objectionable by-products.

Hazardous Waste Management

- <u>3 T’s of Incineration</u>:-
- i) Time
- ii) Temperature
- iii) Turbulence

Hazardous Waste Management

- i) Time:-
- Adequate residence time for solids for complete destruction or breaking of bonds.
- It depends on feed rate, incinerator dimension & rotation speed.

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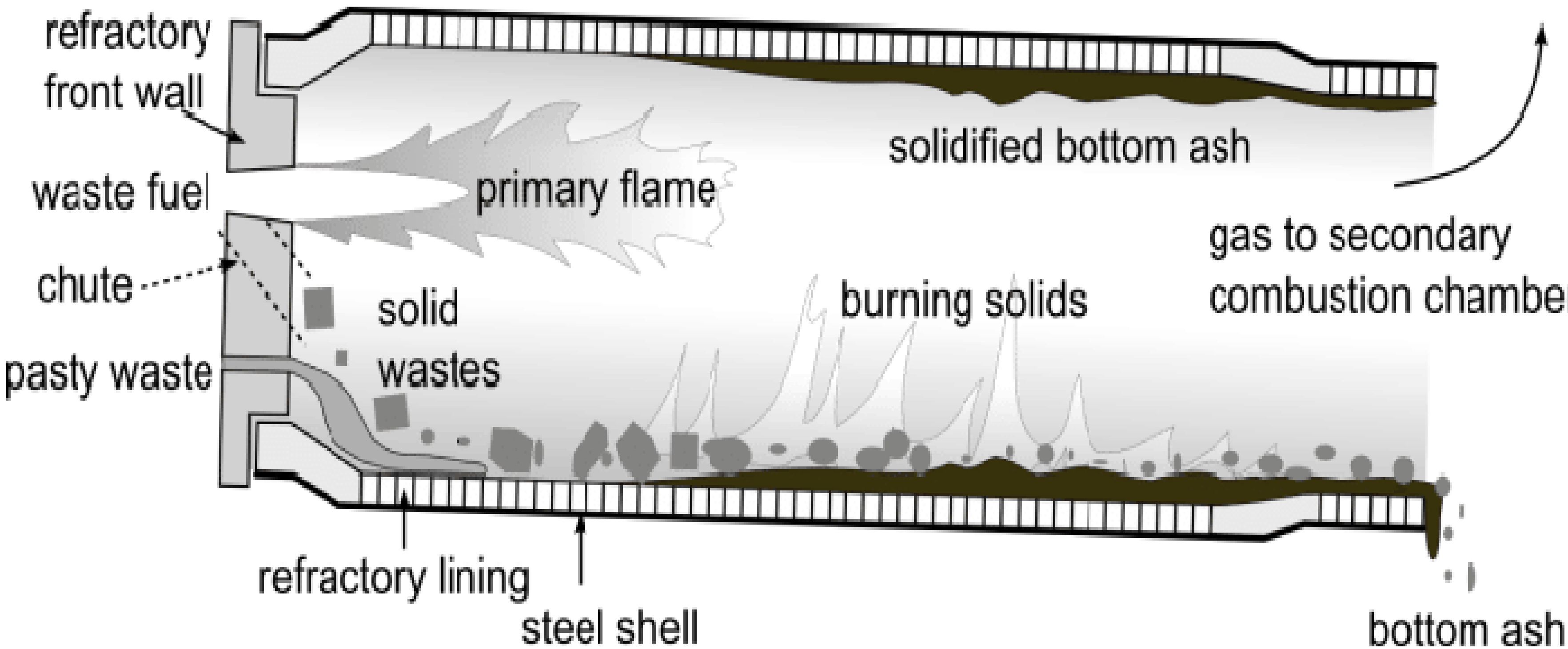
- ii) Temperature:-
- High enough temperature is required for destruction of hazardous waste.
- iii) Turbulence:-
- Sufficient turbulence with adequate air or oxygen for mixing of waste with oxygen.
- This depends on rotation speed & incinerator types.

Hazardous Waste Management

- Types of Incinerator:- (P-724-731,G.kiely)
- i) Rotary Kiln
- ii) Liquid injection
- iii) Plasma Arc Destruction
- iv) Wet Air Oxidation
- V) Fluidized Bed Combustion

A rotary kiln incinerator



Hazardous Waste Management

- i) <u>Rotary Kiln</u>:-
- This is most common type of incinerator.
- Here Chemical destruction of waste occurs.
- ii) <u>Liquid injection</u>:-
- This is for treating liquid organic waste.

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- iii) <u>Plasma Arc Destruction</u>:-
- In this case, electric arc of very high temperature is used.
- iv) <u>Wet Air Oxidation</u>:-
- It is an aqueous phase oxidation where materials are exposed to gaseous source of oxygen.

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- V) Fluidized Bed Combustion:-
- This is suitable for uniform types of waste.
- In this case, heat transfer is very fast & uniform.

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- <u>DRE(Destruction & Removal Efficiency)</u>:-
- Destruction and removal efficiency (DRE) is the efficiency of the unit (kiln) in destruction and removal of a particular targeted organic compound.
- In incineration DRE of above 99% is required.

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- DRE can be calculated by using the following formula –
- DRE= $\{(W_{in} – W_{out})/W_{in}\}$ x 100
- Where,
- W_{in} is mass feed rate of specific organic component to the incinerator
- W_{out} is mass emission rate of same organic component from the incinerator

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- CE(Combustion Efficiency):-
- Combustion efficiency is a measurement of how well the fuel being burned or is being utilized in the combustion process.

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- CE can be calculated by using the following formula –
- CE = $\{(C_{CO2} - C_{CO})/C_{CO2}\} \times 100$
- Where,
- C_{CO2} is concentration of CO_2 in the emitted gas
- C_{CO} is concentration of CO in the emitted gas

Hazardous Waste Management

- Q. Find out CE(Combustion Efficiency) & DRE(Destruction & Removal Efficiency) of an incinerator from the following data –
- i) Input of phenolic waste is 18.2% & outlet phenol is 0.04%
- ii) Outlet gas concentration of CO is 0.1% & CO_2 is 25.7%