Chapter 5

Introduction to the methods of Waste Water Treatment

2020

5.1 Introduction

Wastewater collected from urban areas and from different industries must ultimately be returned to receiving water bodies or to the land.

- ✓ The contaminants (pollutants) in wastewater are removed by physical, chemical and/or biological means, and the individual methods usually are classified as physical, chemical and biological unit processes or operations.
- ✓ Treatment methods in which the application of physical forces predominates are known as physical unit operations.

continued

- ✓ Typical physical unit operations are: screening, mixing, flocculation, sedimentation, flotation, and filtration and membrane filter operations.
- ✓ Treatment methods in which the removal or conversion of contaminants is brought about by the addition of chemicals or by other chemical reactions are known as chemical unit processes.
- ✓ Neutralization, oxidation, reduction, precipitation, gas transfer, adsorption, ion-exchange etc. are the most common examples of these processes used in wastewater treatment.

continued

- ✓ Treatment methods in which the removal of contaminants is brought about by biological activity are known as biological unit processes.
- ✓ Biological treatment is used primarily to remove the biodegradable organic substances (colloidal or dissolved) in wastewater.

5.1 Purpose of sewage treatment

- The primary purpose of the treatment of sewage is to prevent the pollution of the receiving waters.
- Specific concern is protection of human health by the destruction of pathogenic organisms present in sewage prior to treated effluent being discharged to receiving water bodies and land.

5.2 Wastewater Treatment Standards

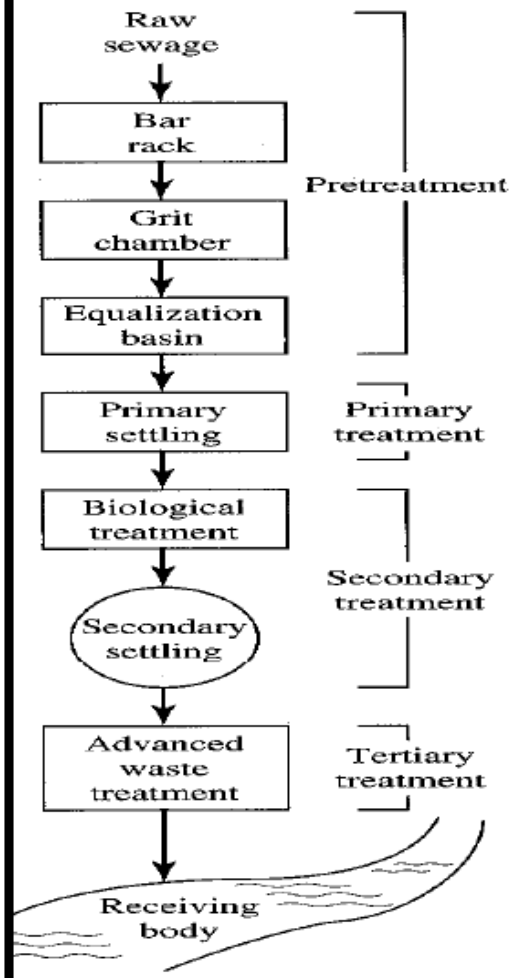
- Effluents from different establishments should be treated before being discharged to receiving bodies so that it should be:
  - ✓Free from materials and heat in quantities, concentrations or combinations which are toxic or harmful to human, animal, aquatic life.
  - ✓Free from anything that will settle in receiving waters or that will adversely affect aquatic life.
  - ✓Free from floating debris, oil, scum and other materials in amounts sufficient to be noticeable in receiving waters.

- ✓ Free from materials and heat that alone, or in combination with other materials will produce color, turbidity, taste or odor in sufficient concentration to create a nuisance or adversely affect aquatic life in receiving waters.
- ✓ Free from nutrients in concentrations that create nuisance, growths of aquatic weeds or algae in the receiving waters.

❖ Specific Limits

✓ Effluents discharged to receiving water bodies should achieved the following minimum wastewater quality limits

parameters	Effluent limit
BOD5	20mg/l
TSS	30mg/l
nitrate	30mg/l
phosphate	10mg/l
PH	6-9
Residual chlorine	1.5mg/l



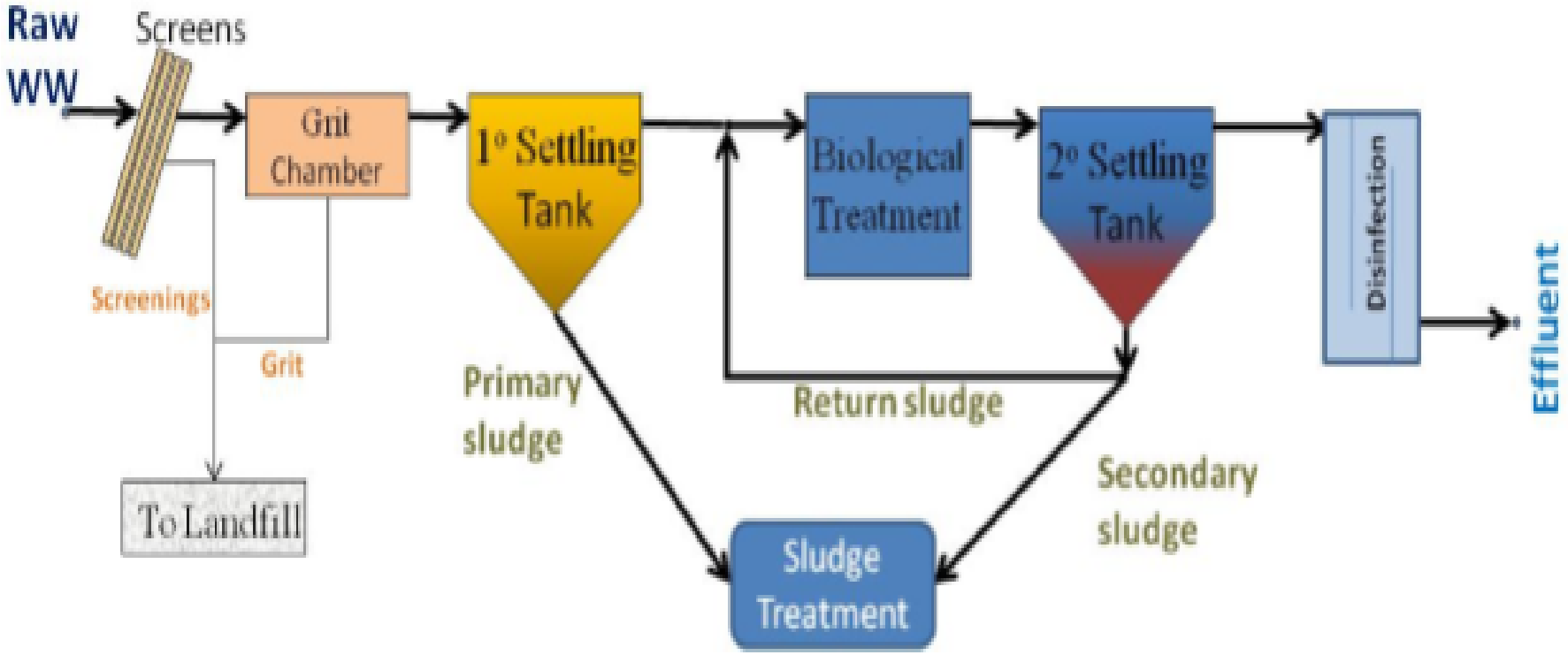
Municipal Wastewater Treatment Systems

Pretreatment – removes materials that can cause operational problems, equalization optional

Primary treatment – remove ~60% of solids and ~35% of BOD

Secondary treatment – remove ~85% of BOD and solids

Advanced treatment – varies: 95+ % of BOD and solids, N, P



Flow chart for wastewater treatment processes

5.3 General classification of WW treatment methods

1. Preliminary waste water Treatment

- ✓ Preliminary treatment consists of separating the floating materials (like dead animals, tree branches, papers, pieces of rags, wood, etc.), and also the heavy Settle able inorganic solids.
- ✓ It also helps in removing the oils and greases, etc. from the sewage.
- ✓ This treatment reduces the BOD of the wastewater, by about 15 - 30%.
- ✓ The processes used are
  - ➢ Screening
  - ➢ Grit chambers

A. Screening

- ✓ Is the very first operation carried out at a sewage treatment plant, and consists of passing the sewage through different types of screens, so as to trap and remove the floating matter, such as pieces of cloth, paper, wood, hair, kitchen refuse, focal solids, etc

Types of Screens

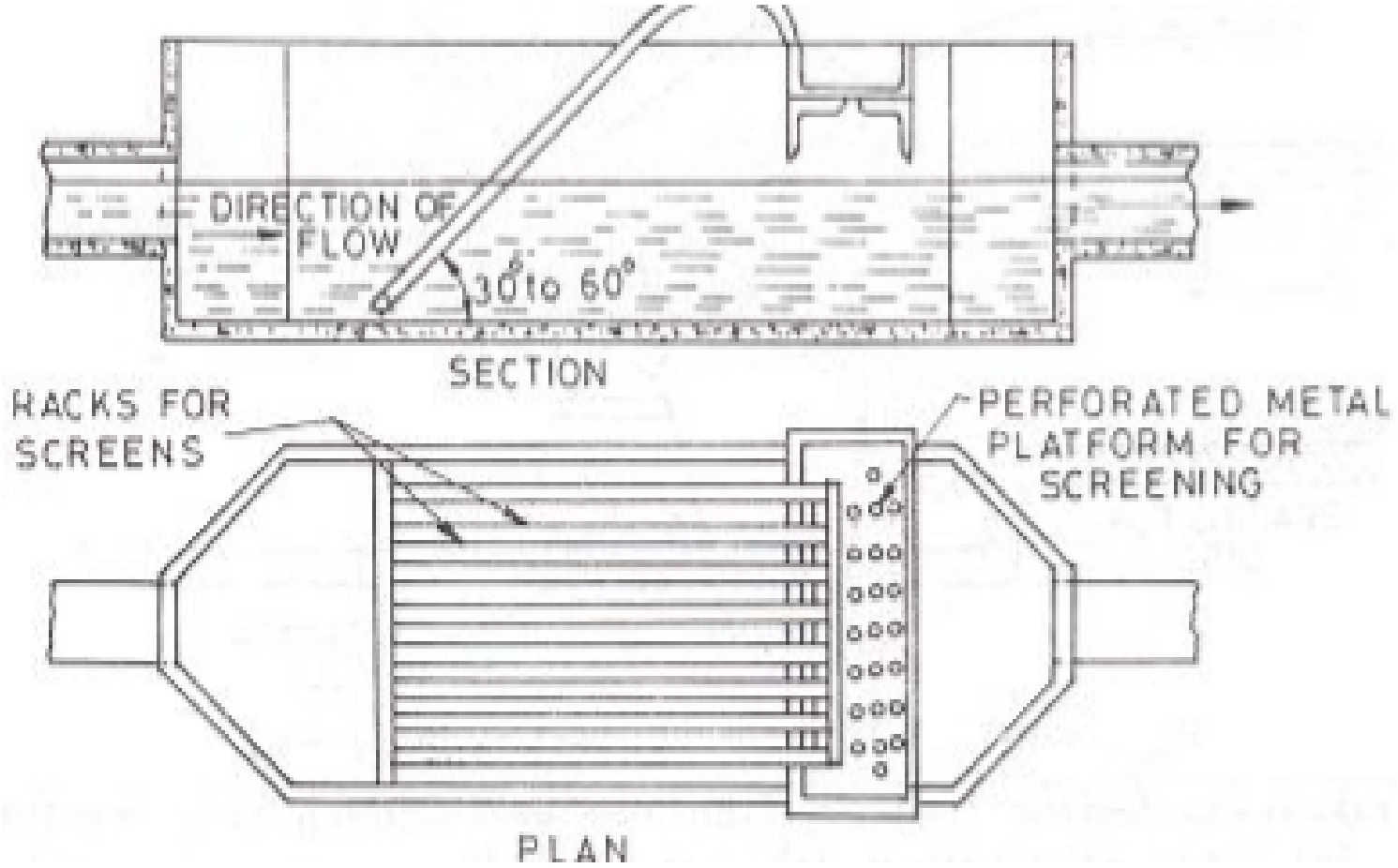
Depending on the size of opening screens can be classified as:

I. Coarse screens: are also known as **Racks**, and the spacing between the bars (i.e. opening size) is about 50 mm or more.

- ✓ These screens help in removing large floating objects from sewage. They will collect about 6 litters of solids per million litter of sewage

II. Medium screens

- ✓ the spacing between bars is about 6 to 40 mm.
- ✓ These screens will ordinarily collect 30 to 90 litters of material per million litter of sewage.
- ✓ They are made of steel bars, fixed parallel to one another at desired spacing on a rectangular steel frame, and are called **bar screens.**
- ✓ Now-a-days, these screens are generally kept inclined at about 30 to 60° to the direction of flow,



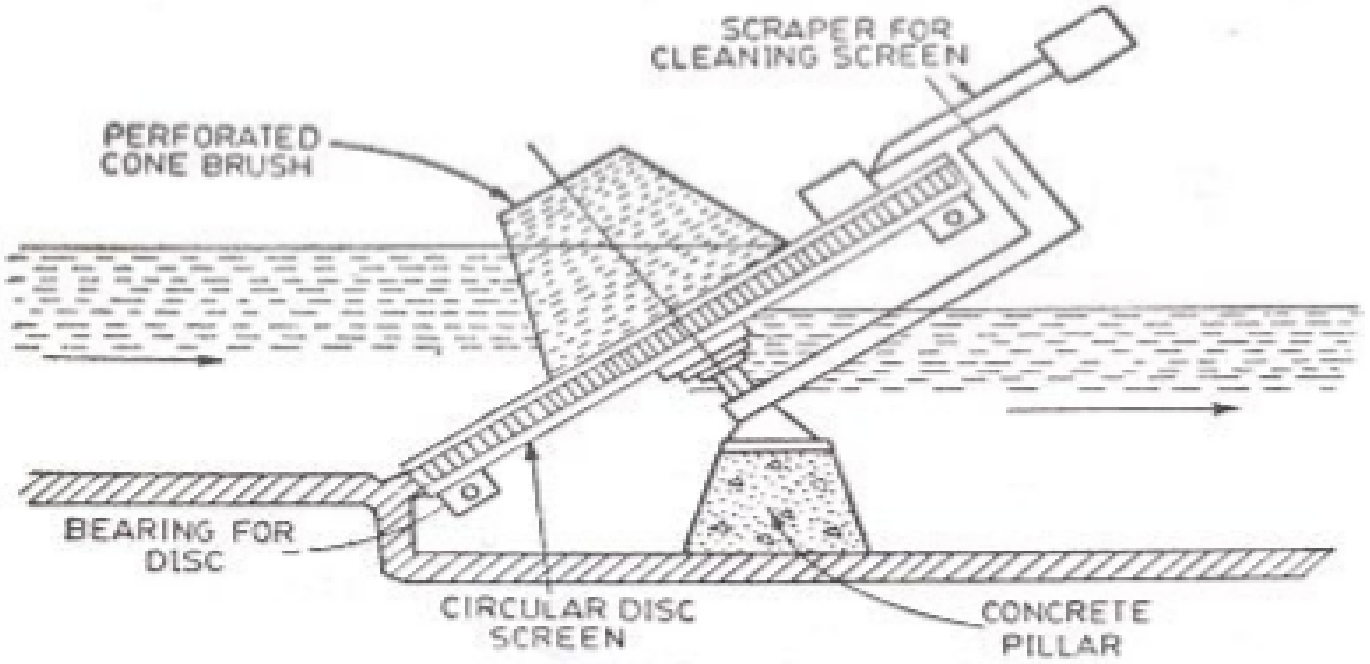
Fixed bar type coarse or medium screen

III. Fine Screens

✓have perforations of 1.5 mm to 3 mm in size.

✓The installation of these screens proves very effective, and they remove as much as 20% of the suspended solids from sewage.

✓These screens, however, get clogged very often, and need frequent cleaning.



Head Loss Through Bar Screen

Can be calculated by:

$$h_l = \frac{1}{c} * \left(\frac{v_2^2 - v_1^2}{2g} \right)$$

Where;

c=empirical discharge coefficient to account for turbulence and eddy motion. (c=0.7 for clean bar and 0.6 for clogged bar screen)

V2=velocity of flow through openings

V1= approaching velocity of upstream channel

g= gravitational acceleration (9.81m/s2)

Head Loss Through fine Screen

- ✓ Similarly for fine screen the head loss is given by:

$$hl = \frac{1}{c(2g)} * \left(\frac{Q}{A}\right)^2$$

- ✓ Where;

c=empirical discharge coefficient to account for turbulence and eddy motion. (c=0.6)

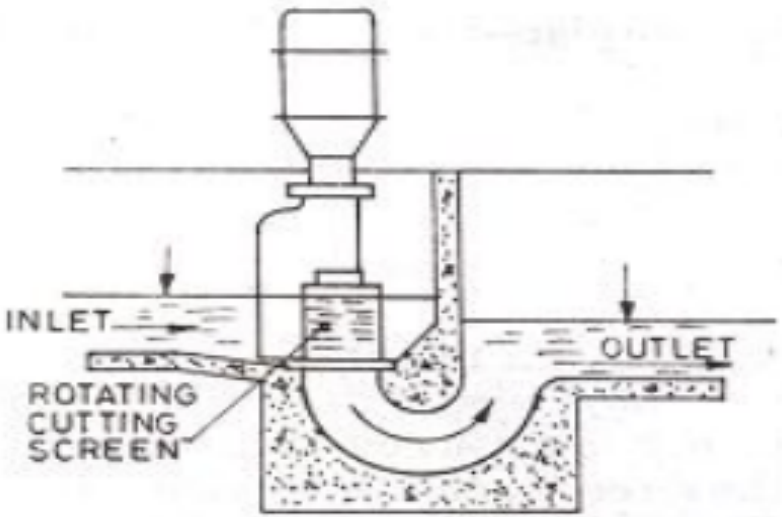
g= gravitational acceleration (9.81m/s2)

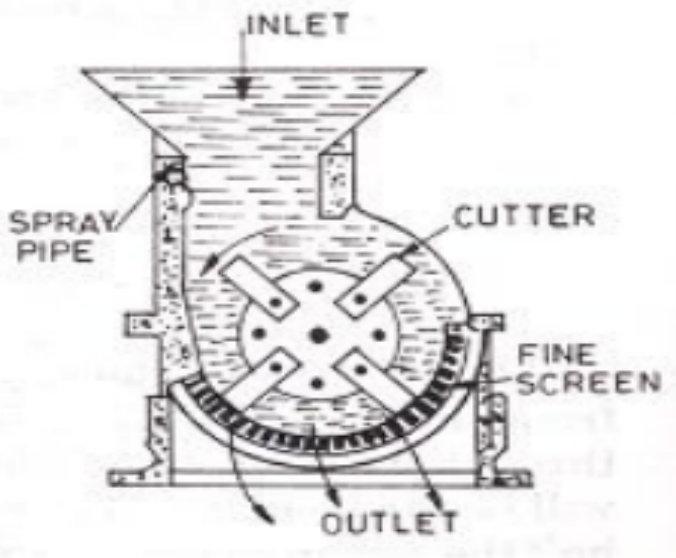
Q= discharge (m3/s)

A=effective opening area of the screen

B. Comminutor

- ✓ Are the patented devices, which **break the larger** sewage solids to about 6mm in size, when the sewage is screened through them.
- ✓ Used to grid or cut waste solids.
- ✓ Such a device consists of a revolving slotted drum, through which the sewage is screened.





C. Grit channels

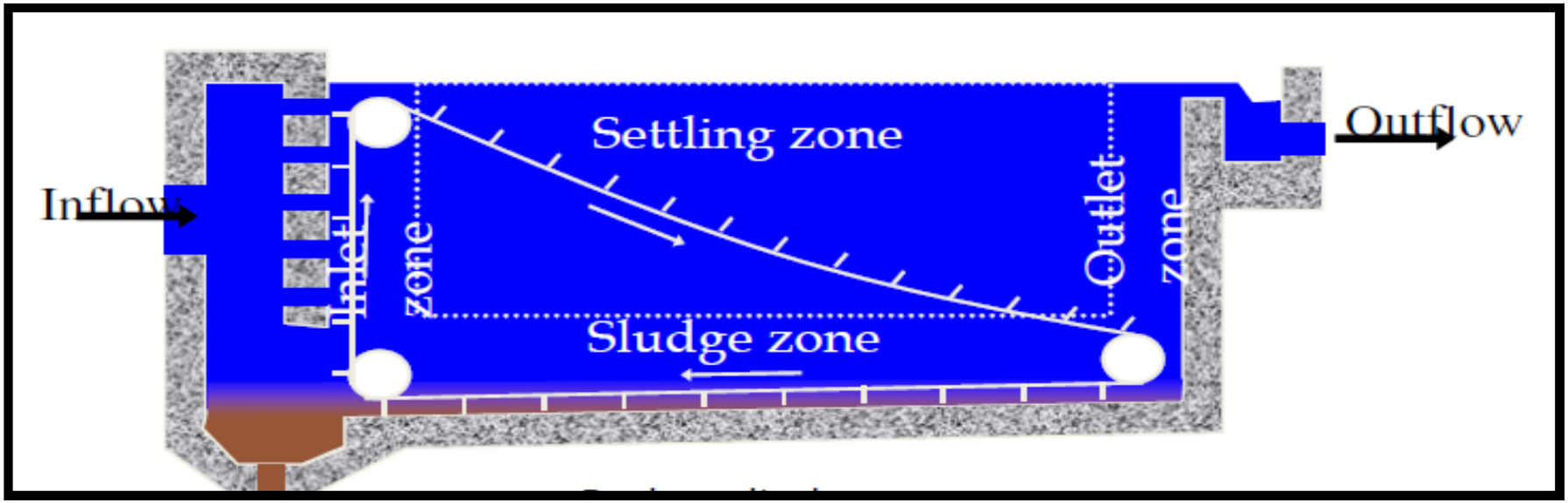
- ✓ Are the sedimentation basins placed in front of the wastewater treatment plant.
- ✓ The grit chamber remove the inorganic particles (specific gravity about 2.65 and nominal diameter of 0.15 to 0.20mm or larger) such as sand, gravel, grit, egg shells, bones, and other non-putresible materials that may clog channels or damage pumps due to abrasion, and to prevent their accumulation in sludge digesters.

2. Primary waste water treatment

- ✓ Primary treatment consists in removing large suspended organic solids.
- ✓ This is usually accomplished by sedimentation.
- ✓ The basin in which the sedimentation process carried out is primary sedimentation tank.
- ✓ Removal of suspended solids ranges from 50–65%, and 30–40% reduction of the five-day biochemical oxygen demand (BOD) can be expected.

continued

- ✓ Sedimentation is removal of particulate materials suspended in water by quiescent settling due to gravity.
- ✓ It is designed to remove only the heavy inorganic solids of size more than 0.2 mm and of sp. gravity 2.65) are generally removed by the sedimentation tanks.
- ✓ The sedimentation tanks are thus designed to remove a part of the organic matter from the sewage effluent coming out from the grit chambers.



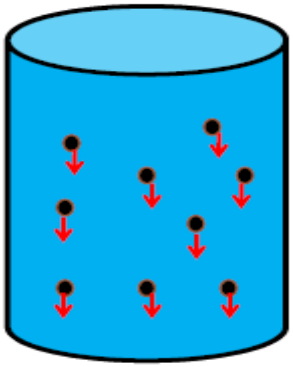
Sedimentation tank

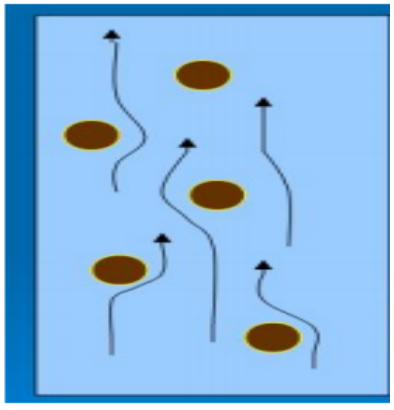
Types of settling

- Depending on the particles concentration and the interaction between particles, four types of settling can occur,

Type I Sedimentation (Discrete particle settling)

- ✓ The particles settle ***without interaction*** and occur under low solids concentration.
- ✓ Particles do not change in **size, shape and weight.**
- ✓ Particles settle as individual particles and do not flocculate or stick to other particles during settling.
- ✓ Examples of these particles are sand and girt material.
- ✓ the **vertical velocity of the particle** with respect to the surrounding fluid will **remain constant.**

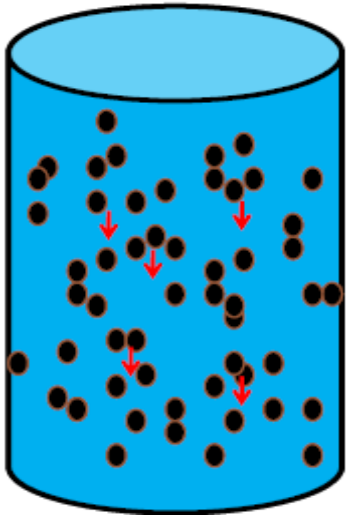


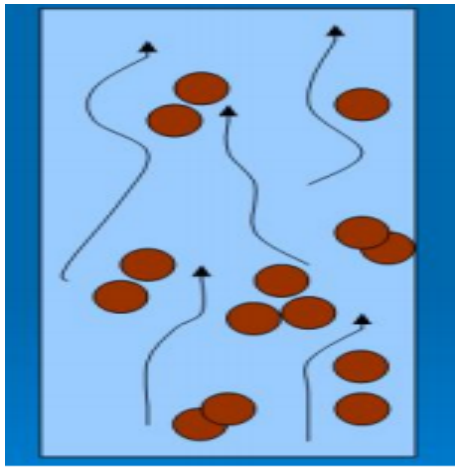


Discrete

Type II Sedimentation (Flocculent settling)

- ✓ Under quiescent conditions suspended particles in many waters exhibit a natural tendency to **agglomerate** or the **addition of chemical agents** promotes this tendency. This phenomenon is known as **flocculent.**
- ✓ Particles collide and adhere to each other resulting in particle growth
- ✓ Since they flocculate, their size, shape, weight and settling velocity will increase.

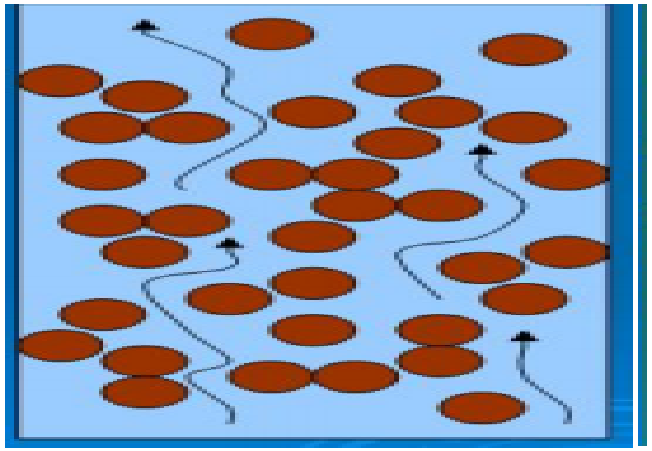




Flocculent

Type III Sedimentation (Hindered/Zone settling)

- ✓ Hindered/zone settling ;Inter-particle forces are sufficient to hinder the settling of neigh boring particles.
- ✓ The particles tend to remain in *fixed positions* with respect to each others.
- ✓ Particles are *so close together* movement is restricted
- ✓ Solids *move as a block* rather than individual particles



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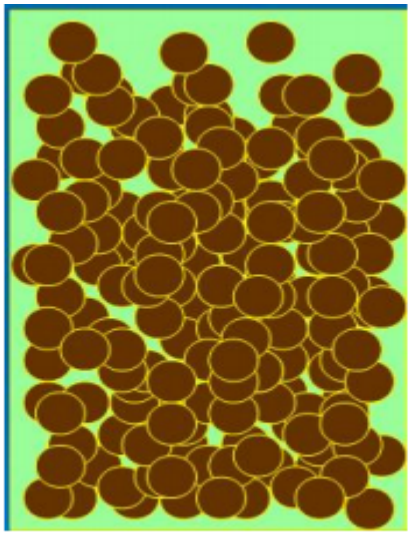
Type IV Sedimentation (Compression settling)

- ✓ This occurs when the particle *concentration is high*, so that particles at one level are mechanically influenced by particles on lower levels.
- ✓ The settling velocity then drastically (highly) reduces.
- ✓ Particles physically in contact
- ✓ Water is displaced from pores as particles settle
- ✓ Volume of solids may decrease
- ✓ High concentration of solids (sludge)



Compression

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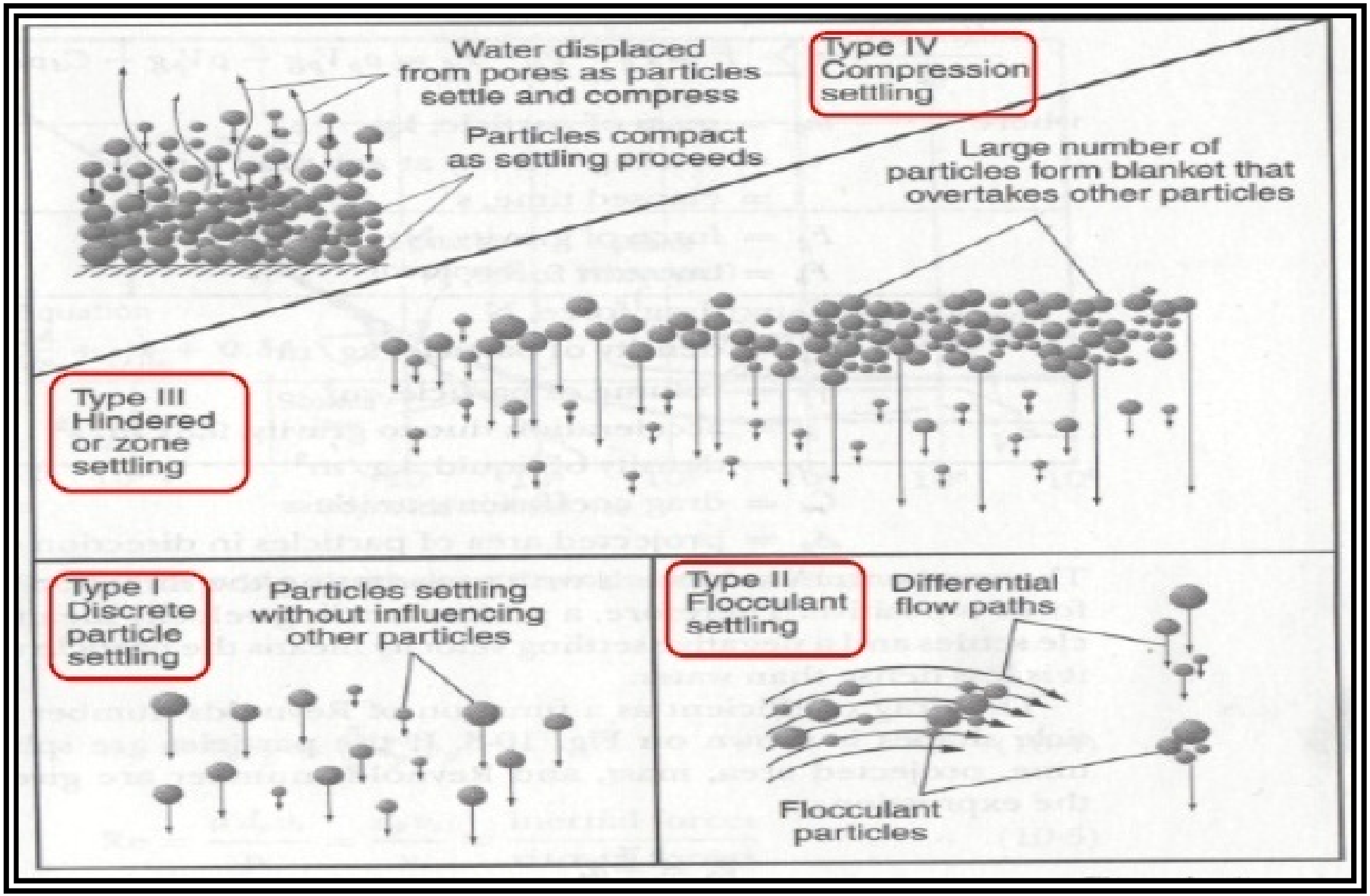

Water displaced from pores as particles settle and compress
Particles compact as settling proceeds
Type IV Compression settling
Large number of particles form blanket that overtakes other particles
Type III Hindered or zone settling
Type I Discrete particle settling
Particles settling without influencing other particles
Type II Flocculant settling
Differential flow paths
Flocculant particles

Comparison of preliminary and primary treatment methods

S.No	Type of Treatment	Purification effected	Process or unit employed	BOD removal as percentage of original	Removal of SS and DS as percentage of original	Removal of Bacterial load as percentage of original	Disposal of residuals
1.	Preliminary Treatment	(a) Removal of floating materials dead animals, like tree branches, pieces of rags, wood and other large sized floating materials.	Coarse and fine screens of different designs	5 - 10	2 - 20	10 - 20	Screenings can be disposed of easily, either by burials or burnings.
		(b) Removal of heavy settleable inorganic solids.	Grit chambers or Detritus tanks	10 - 20	20 - 40	10 - 20	The grit can be easily disposed of either by burials or burnings for raising low lying areas.
		(c) Removal of fats and greases	Skimming tanks or Vacuators	20 - 30	20 - 40	10 - 20	The skimming contains unstable volatile organic materials and have to disposed of by first stabilizing them in digestion tanks by anaerobic process.
2	Primary Treatment	Removal of suspended settleable organic solids	(i) Sedimentation tanks or	30 - 35	60 - 65	25 - 75	Sludge containing organic material has to be stabilized first, in digestion tanks and the digested material is then used as a manure or soil builder.

3. Secondary/Biological/wastewater treatment

- ✓ After primary treatment, the greater part of the BOD remaining in the sewage is in the form of dissolved organic matter.
- ✓ Secondary sewage treatment, which is predominantly biological, is designed to remove most of this organic matter and reduce the BOD
- ✓ The primary purpose of secondary waste water treatment is to reduce BOD.
- ✓ The principal biological process used for wastewater treatment can be divided into two
  - ✓ **Suspended growth**
  - ✓ **Attached growth (or bio film) process**

Suspended growth (Activated sludge system)

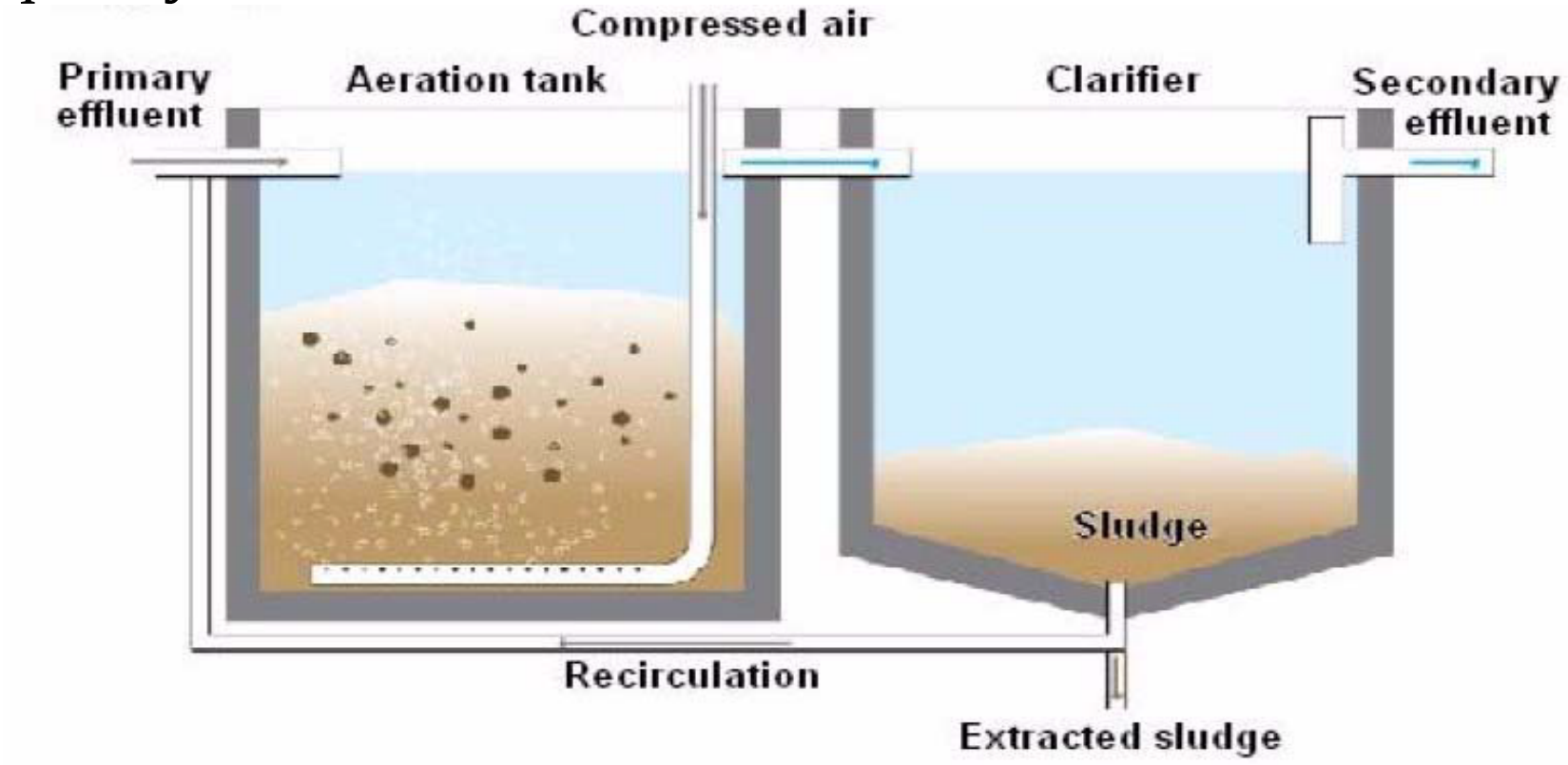
- ✓ Microorganism(**biomass)** responsible for treatment maintained in liquid suspension by aporaparate mixing method
- ✓ Increase suspended biomass concentration
- ✓ Many time Domestic waste water operated with positive dissolved oxygen conc.(Aerobic)

***Attached growth** (or biofilm) process.*

- ✓ Microorganism(**biomass)** responsible for treatment maintained in attached to an inert pocking material
- ✓ The organic mater and nutrient removed from ww flowing past attached growth –Biofilms
- ✓ Packing material for attach: rock, gravel, slang, plastic etc.
    - ✓ Trickling filter
    - ✓ Rotating Biological Contractor(RBC)

The activated-sludge

- ✓Activated Sludge is a multi-chamber reactor unit that makes use of (mostly) aerobic microorganisms to degrade organics in wastewater and to produce a high-quality effluent.



Trickling Filter

- Old process for the secondary treatment of domestic wastewater dating from the beginning of the 20th century
- A trickling filter is a fixed bed, biological filter that operates under (mostly) aerobic conditions.
- The wastewater moves through the filter, the organic matter is adsorbed onto the film and degraded by a mixed population of aerobic microorganisms.

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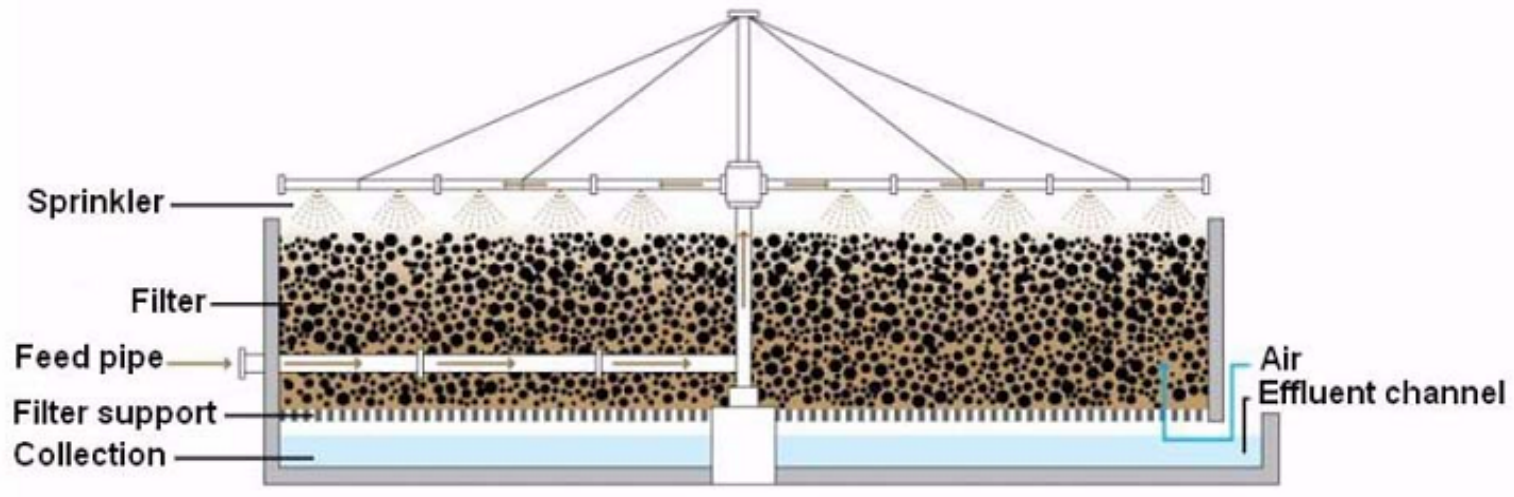

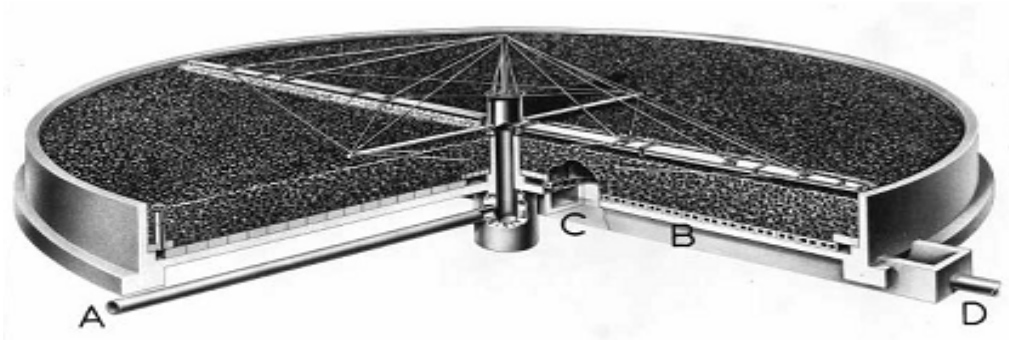

Note: A, inlet pipe; B, underdrain blocks; C, effluent channel; D, outlet pipe.

Figure 19.1 *Sectional Perspective View of a Circular Biofilter Showing the Rotating Wastewater Distributor and Filter Medium*

Rotating Biological Contractor(RBC)

- RBC is a simple, effective method of providing secondary wastewater treatment.
- The system consists of biomass media, usually plastic, that is partially immersed in the wastewater.
- As it slowly rotates, it lifts a film of wastewater into the air, the wastewater trickles down across the media and absorbs oxygen from the air.

Secondary Clarifier (Secondary sedimentation basin)

- With the majority of the suspended material removed from the sewage, the liquid portion flows over a weir at the surface of the secondary settling tank
- Chlorination of the effluent from the secondary settling tank takes place in accordance with state and local laws
- The bacteria are subsequently removed in secondary clarifiers
- A secondary sedimentation basin (clarifier) is usually required to settle bacteria.

4. Tertiary waste water treatment

- ✓ More advanced processes (advanced or tertiary treatment) may be required for special wastes.
- ✓ When the effluent from secondary treatment is unacceptable, a third level of treatment, tertiary treatment, can be employed.
- ✓ The purpose of tertiary treatment is to provide a final treatment stage to raise the effluent quality before it is discharged to the receiving environment (sea, river, lake, ground, etc.). Which includes:

Filtration, Nutrient removal, Nitrogen removal,

Phosphorus removal, Disinfection, Odour Control etc.

Generally there are two types of wastewater treatment system:

- ✓ **On-site Sewage Treatment (decentralized)**
  - ✓ WW treated at the point of production (generation)
  - ✓ example septic tank
- ✓ **Centralized Sewage Treatment**
  - ✓ Collects WW from all Residences and treated at the treatment site far from point of WW generation.

5.4 Septic Tanks design

✓A septic tank is a watertight tank, usually located just below ground.

✓Homes and businesses in areas of low population density that are not connected to municipal sewerage systems often use a **septic tank.**

✓A device whose operation is similar in principle to primary settling.

continued

- ✓*Sewage enters a holding tank, and suspended* solids settle out and the sludge in the tank must be pumped out periodically and disposed of.
- ✓The effluent flows through a system of perforated piping into a leaching (soil drainage) field.

Septic tank design

- ❖The guidelines and the **design criteria** for typical septic tanks are as follows:
  - ➢Septic tanks should be watertight so that they do not permit way- in groundwater and way- out sewage
  - ➢A septic tank installation shall be provided for both settlement of solids and **partial biological treatment of sewage.**

continued

- ✓ Septic tank could be constructed from bricks, stone masonry, HCB, concrete etc
- ✓ Calculation of the total capacity of septic tank shall be made on the basis of
  - ✓ The number of persons to be served,
  - ✓ Water consumption,
  - ✓ Sludge production per capita and
  - ✓ The hydraulic detention time.

continued

- ✓ Since the digestion process is anaerobic, not requiring oxygen, no direct ventilation is necessary.
- ✓ However, provision should be made to permit the escape of the gases produced in the tank, thorough a ventilation pipe.

- The following formula is recommended for general use:

V= Vww+ Vd **Vc1=1/3* V, Vc2=2/3* V**

Vww= Td x P x q

Vd = v x Nd x P

$$\mathbf{V= (Td \times P \times q) /10^3 + (v \times Nd \times P)/ 10^3}$$

continued

Where

- ✓V= Effective volume of the tank- m3
- ✓Vww = volume of ww.
- ✓Vd = volume of sludge produced.
- ✓Td = Hydraulic detention time in days – min. 1 day
- ✓P =User population.
- ✓q =Water consumption per capita per day- liters
- ✓v = Sludge production per capita per day- litres (approx. 0.15l.
- ✓Nd=Number of days between desludging-min. 365 days.

example

Design a septic tank for the following data:

- ✓No of population= 100
- ✓Sewage /capita/day= 120 Liter
- ✓De-sludging period=1 year
- ✓Length : width =3:1

5.5 SEWAGE EFFLUENT DISPOSAL

- ✓The study of the sources/place of disposal is important, because the amount of treatment required to be given to sewage depends very much upon the source of disposal,
- ✓There are two general methods of disposing of the sewage effluents:

a) Dilution i.e. disposal in water; and

b) Effluent Irrigation or Broad Irrigation or Sewage Farming, i.e. disposal on land

1. Disposal by dilution

- ✓ Disposal by dilution is the process whereby the treated sewage or the effluent from the sewage treatment plant is discharged into a river stream, or a large body of water, such as a lake or sea.
- ✓ The discharged sewage, in due course of time, is purified by what is known as self purification process of natural waters.
- ✓ The degree and amount of treatment given to raw sewage before disposing it into the river depends not only upon the *quality of raw sewage* but also upon the self purification capacity of the river and the intended use of its water.

Conditions for disposal by dilution

- ✓When sewage is comparatively fresh and free from floating and settle able solids.
- ✓Where diluting waters are not used for the purpose of navigation or water supply for at least some reasonable distance on the downstream from the point of sewage disposal.
- ✓When the outfall sewer of the city or the treatment plant is situated near some natural waters having large volumes
- ✓When the diluting water (i.e. the source of disposal) has high dissolved oxygen (DO) content.

2. Disposal on land for irrigation

- ✓ This method, in addition to disposing of the sewage, may help in increasing crop yields by 33% as the sewage generally contains a lot of fertilizing minerals and other elements.
- ✓ However, the sewage effluent before being used as irrigation water must be made safe.

❖ Conditions for disposal on land for irrigation

- When some natural rivers or water courses are not located in the vicinity,
- When irrigation water is scarcely available, the use of sewage for irrigating crops is a good alternative.

continued

- ✓ The method of effluent irrigation will prove useful in areas of low rainfall, as this will help in maintaining good absorption capacity of the soil.
- ✓ This method of disposal of sewage, poses problems during the periods when no irrigation water is required for the crops especially during rains.
- ✓ This method is, therefore preferred when sewage can be diverted to some river streams during rainy season.

End of chapter five