Characteristics of wastewater

Introduction

- Two types of wastewater
  - Domestic wastewater (Sewage)
  - Industrial waste water
- Wide variation in quality of Industrial waste water
- Less variation in the characteristics of sewage

Composition of Sewage

- Contain organic & inorganic matter, some gases & living organisms (mainly micro-organisms)
- Organic & inorganic matter may be in suspended, colloidal & dissolved form.
- Organic matter include
  - Carbohydrate like cellulose, starch, Sugar, cotton etc.
  - Fats & Oil received from kitchen, garbage
  - Nitrogeneous compound like protein & their decomposed product, including waste from urea, animal, fatty acid etc.
- Inorganic matter consist of salt & mineral like sand, gravel, dissolved salts, chlorides, sulphates etc.

Decomposition of Sewage

- ***Chemical process***
- ***Biological Process:*** Decomposition of organic matter by bacteria under biological action is termed as biological decomposition.
  - Depending upon the type of bacteria Biological decomposition Process can be of two type:
    - Aerobic Decomposition(also called aerobic oxidation)
      - COHNS + Bacteria + O_2 → CO_2 + H_2O +Bacteria + Energy
    - Anaerobic decomposition(also called putrefaction)
      - In the absence of Oxygen & end product is Methane, H_2S & ammonia.

Characteristics of Sewage

- **Physical Characteristics**
- **Color :**
  - Fresh sewage brown & yellowish color like soap solution
  - With the passage of time it become septic -black color
  - The color of industrial waste water depends upon the chemical process used in the industry
- **Odor**
  - Fresh sewage do not have offensive odor.
  - Stale sewage – offensive odor. (All the oxygen disappeared from the sewage)

- **Temperature**
  - Generally higher than the water supply.
  - Temperature effects sewage in following ways:
    - As the temperature increases the viscosity and bacterial activity increases
    - Solubility of gases in the waste water decrease as increase in temperature
    - DO content decreases which affects aquatic life

  Average temperature of sewage is 20°C close to ideal temp for biological activity.

- **Turbidity**
  - Due to suspended solids. It is a measure of light intensity.
  - Measured by Jackson turbidity meter, Nephelometric turbidity meter and turbidity rod.
  - It directly depend on the quantity of solid matter present in it in suspension state
  - The stronger or more concentrated sewage, higher is its turbidity

Chemical Characteristics

- **Solids :**
  - Sewage contain 99.9 % water & 0.1 % solid
  - Solids present are in 3 forms suspended, dissolved, &colloidal .
  - 45% organic solids & 55 % inorganic solids
- **pH :**
  - pH > 7 Alkalinity
  - pH< 7 Acidic
  - pH = 7 Neutral
  - Fresh sewage is alkaline in nature which is good for bacterial action with the passage of time pH value falls due to production of acids by bacterial action and sewage tends to become septic.
  - pH determination is important as some treatment method requires particular ph range as in biological treatment, Chemicalcoagulation,chlorination(Disinfection) .

- **Nitrogen Compound**
  - It exist in the form of nitrogenous compounds as
    - Organic Nitrogen – Total Organic nitrogen(before decomposition)
    - Free ammonia – First stage of decomposition
    - Nitrite – Partly decomposition of organic matter
    - Nitrate – fully decomposition of organic matter
- **Chloride content**
  - Main sources in sewage kitchen waste, human faeces & urinary discharge.
  - Water softener also contributes.
  - Infiltration of saline ground water
  - Industry like ice-cream plant, meat salting etc.

- **Fat, Oil & grease**
  - Main sources – from garage, kitchen of hotel & restaurant, discharge of animal & vegetable matter
  - Major problem in biological process – due to scum on the surface & affect oxygen diffusion
- **Toxic Compound**
- **Copper, lead, silver, Chromium, Arsenic, Phenol, boron, Cyanide etc are toxic compound**
  - Major source – Industrial wastewater
  - Affect biological treatment

- **Sulphide, sulphate & Hydrogen Sulphide Gases**
- Sulphur is required in synthesis of protein and is released in their degradation
  - In Aerobic decomposition
  - Sulphur → Sulphide → Sulphate
  - In Anaerobic Decomposition
  - Sulphur → Sulphide with $H_2S + CH_4$

- **Dissolved Oxygen**
  - Amount of oxygen present in sewage in dissolved state.
  - Presence of DO in sewage indicates that it is fresh or weak.
  - Its presence in effluent of treatment works indicates good treatment.
  - Besides for maintaining aerobic conditions in water receiving pollution matter so as to avoid anaerobic condition resulting into liberation of noxious gases and public nuisance, it is important that DO concentration should be maintained to a level of 4-8mg/l
  - Factor affect D.O.
    - Temperature
    - TDS of water

Biochemical Oxygen Demand:

Biochemical oxygen demand has been defined as the amount of oxygen required by the microorganisms (mainly bacteria) to stabilize the biodegradable organic matter under aerobic conditions.

NOTE : ***As the oxygen consumed by the microorganisms is directly proportional to the amount of biodegradable organic content, the BOD parameter indirectly measures the organic content of the liquid.***

NOTE : ***BOD parameter does not provide information about the amount of non-biodegradable organic contents of the liquid waste.***

Based on the first order kinetics of oxygen consumption by the microorganisms for carbonaceous organic matter present in the wastewater, following equations are used to compute the values of ultimate BOD (L_0) and BOD at any time t (L_t).

$$L_t = L_0 e^{-k't} \qquad \text{or} \quad L_t = L_0 \text{ x } 10^{-kt}$$

and

$$y_t = L_0(1 - e^{-k't}) \qquad \text{or} \quad y_t = L_0(1 - 10^{-kt})$$

where L_t = BOD at any time t, mg/L

L_0 = ultimate BOD at time t = 0, mg/L

K' = BOD rate constant to the base e, d^{-1}

K = BOD rate constant to the base 10, d^{-1}

$= k'/e = k'/2.3$ (normally assumed as 0.1 at 20°C)

y_t = BOD exerted or used at any time t, mg/L

The temperature correction for BOD rate constant is done by using the following equation.

$$K_T = K_{20}\ \theta^{(T-20)}$$

Where K_T = BOD rate constant at any temperature T°

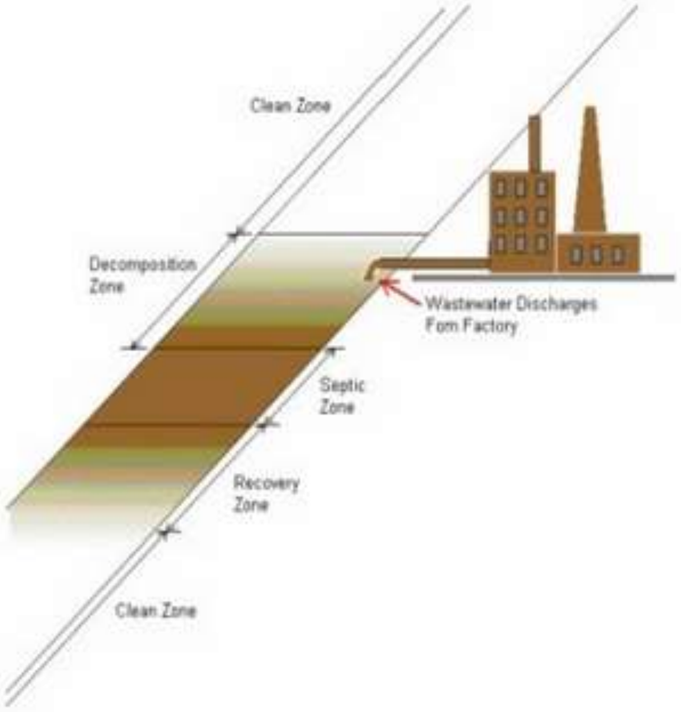
K_{20} = BOD rate constant at temperature 20° C

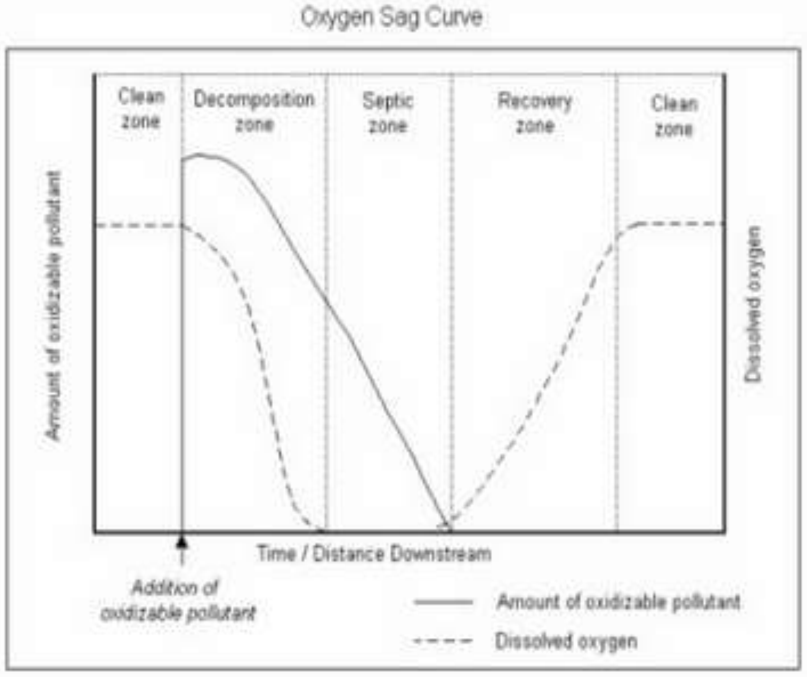
θ = temperature coefficient factor (varies from 1.056 to 1.135)

= 1.047 (normally assumed for temperature range of 20 to 30°C)

The presence of a sufficient concentration of dissolved oxygen is critical to maintaining the aquatic life and aesthetic quality of streams and lakes. Determining how organic matter affects the concentration of dissolved oxygen (DO) in a stream or lake is integral to water-quality management.

The decay of organic matter in water is measured as biochemical oxygen demand. Oxygen demand is a measure of the amount of oxidizable substances in a water sample that can lower DO concentrations.





The test for biochemical oxygen demand (BOD) is a bioassay procedure that measures the oxygen consumed by bacteria from the decomposition of organic matter (Sawyer and McCarty, 1978). The change in DO concentration is measured over a given period of time in water samples at a specified temperature

There are two stages of decomposition of organic matter in the BOD test: a carbonaceous stage and a nitrogenous stage.

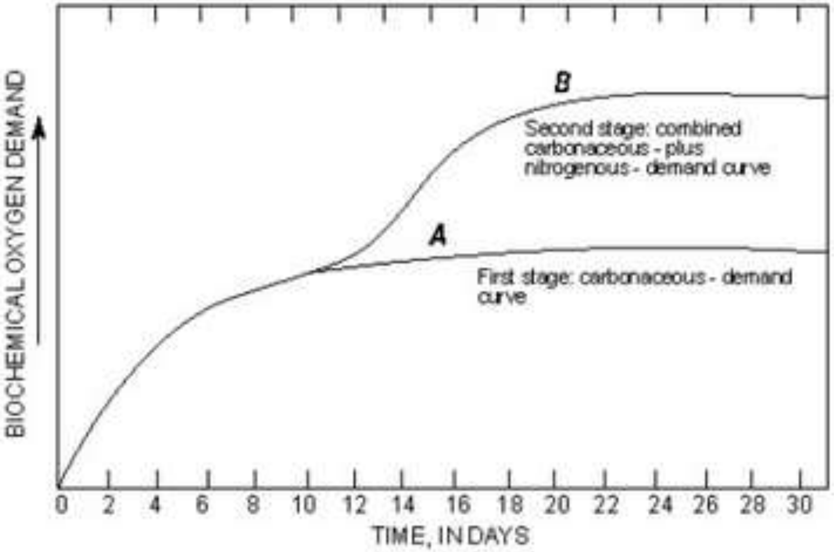


Figure : Biochemical oxygen demand curves: (*A*) typical carbonaceous-demand curve showing the oxidation of organic matter, and (*B*) typical carbonaceous- plus nitrogeneous-demand curve showing the oxidation of ammonia and nitrite. (Modified from Sawyer and McCarty, 1978.)

The carbonaceous stage, or first stage, represents that portion of oxygen demand involved in the conversion of organic carbon - to carbon dioxide.

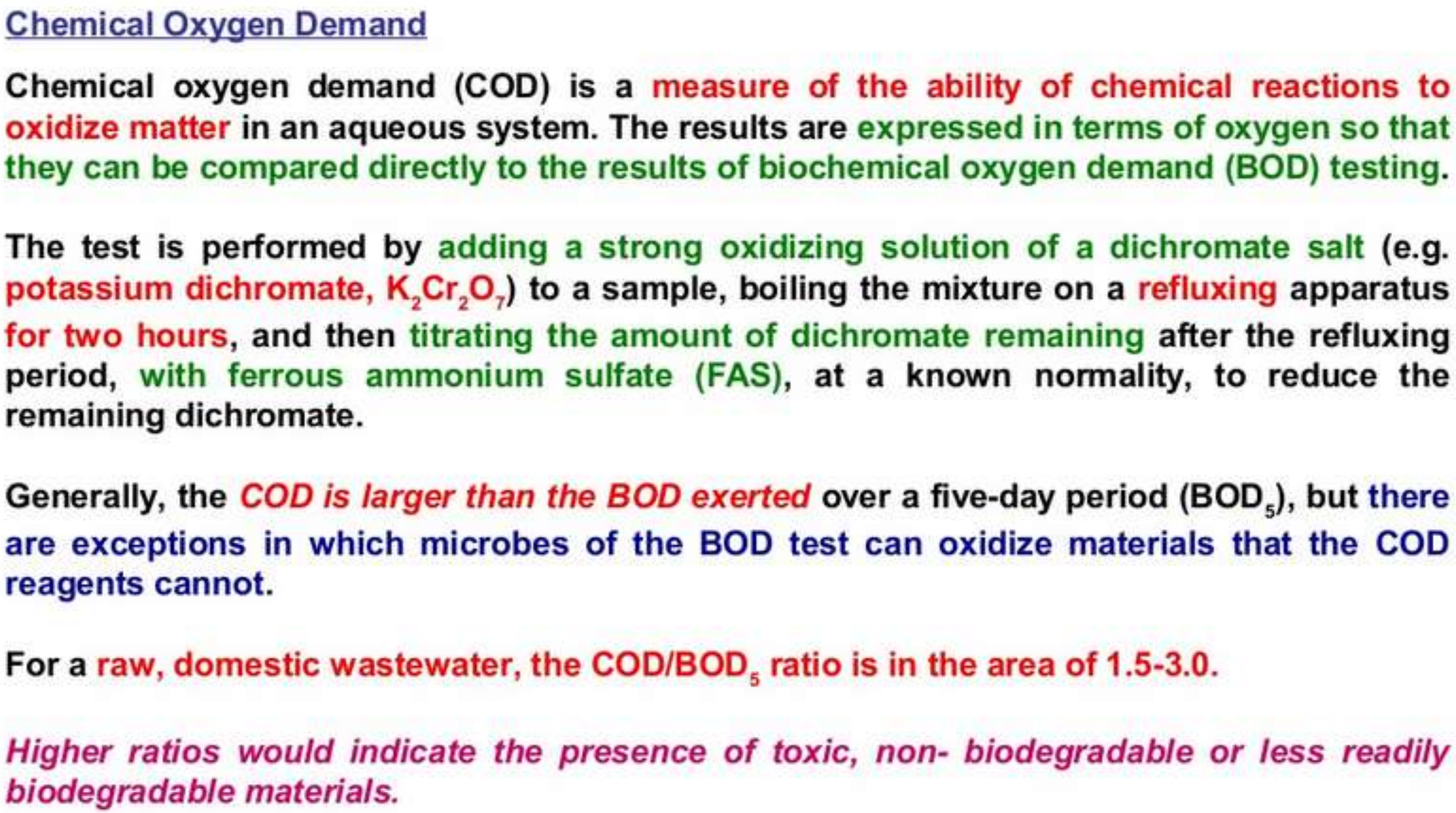
The nitrogenous stage, or second stage, represents a combined carbonaceous plus nitrogenous demand, when organic nitrogen, ammonia, and nitrite are converted to nitrate. Nitrogenous oxygen demand generally begins after about 6 days.

For some sewage, especially discharge from wastewater treatment plants utilizing biological treatment processes, nitrification can occur in less than 5 days if ammonia, nitrite, and nitrifying bacteria are present.

The standard oxidation (or incubation) test period for BOD is 5 days at 20 degrees Celsius (BOD_5). The BOD_5 value has been used and reported for many applications, most commonly to indicate the effects of sewage and other organic wastes on dissolved oxygen in surface waters.

The 5-day value, however, represents only a portion of the total biochemical oxygen demand. Twenty days is considered, by convention, adequate time for a complete biochemical oxidation of organic matter in a water sample, but a 20-day test often is impractical when data are needed to address an immediate concern.

COD



Chemical Oxygen Demand

Chemical oxygen demand (COD) is a measure of the ability of chemical reactions to oxidize matter in an aqueous system. The results are expressed in terms of oxygen so that they can be compared directly to the results of biochemical oxygen demand (BOD) testing.

The test is performed by adding a strong oxidizing solution of a dichromate salt (e.g. potassium dichromate, $K_2Cr_2O_7$) to a sample, boiling the mixture on a refluxing apparatus for two hours, and then titrating the amount of dichromate remaining after the refluxing period, with ferrous ammonium sulfate (FAS), at a known normality, to reduce the remaining dichromate.

Generally, the *COD is larger than the BOD exerted* over a five-day period (BOD_5), but there are exceptions in which microbes of the BOD test can oxidize materials that the COD reagents cannot.

For a raw, domestic wastewater, the COD/BOD_5 ratio is in the area of 1.5-3.0.

Higher ratios would indicate the presence of toxic, non- biodegradable or less readily biodegradable materials.

The COD test is commonly used because it is a relatively short-term, precise test with little interference. However, the spent solutions generated by the test are hazardous. The liquids are acidic, and contain chromium, silver, mercury, and perhaps other toxic materials in the sample tested. For this reason laboratories are doing fewer or smaller COD tests in which smaller amounts of the same reagents are used.

COD/BOD ratio

The ratio of COD to BOD can give an indication of the biodegradability of a wastewater.

i) In domestic sewage which is known to be readily biodegradable and treated successfully world-wide using a variety of biological treatment methods, the COD/BOD ratio varies typically from 1.5: 2.

Thus *if the COD/BOD ratio of industrial wastewater is also < 2, this provides a good indication that the wastewater can be treated biologically.*

ii) If the COD/BOD ratio is high and generally >5:1 , this indicates that the wastewater is non biodegradable , toxicity or nutrient imbalance is present and thus will present problems if biological treatment selected.

iii) If COD/BOD falls between 2 – 5 :1 then this is a gray area. A lot of industrial wastewaters fall into this category. Therefore, further studies are needed.

- **BOD/COD ratio**
  - If BOD/COD > 0.6 biological treatment is feasible.
  - If BOD/COD between 0.3 to 0.6 acclimatization is essential
  - If BOD/COD is < 0.3 Biological treatment is not possible
- **Relative Stability**
  - $S = 100(1-0.794)^{t20}$
  - $S = 100(1-0.630)^{t37}$

SELFPURIFICATION

- If from the point of disposal of sewage in stream, the stream water is examined towards downstream side. It will be observed that quality of water changes successively.
- Near the place of disposal the water will be polluted and it becomes purified after some travel towards downstream side due to natural forces of purification.
- When sewage is discharged into streams water becomes polluted, suspended solids are gradually deposited in the stream bed, decomposition and stabilization of organic matter occurs in layers. In course of time decomposed materials are washed away with current or converted into simple constituents.
- Various organisms present in sewage start decomposition of volatile organic matter and stabilize it.
- Algae and other microscopic organism eat mineralized food and supply oxygen to the stream for maintaining aerobic condition.
- Natural purification process continues and makes stream water pure after some time

Sewage discharged into stream

↓

Suspended solid deposited
to stream bed layer

↓ By organism in sewage

Volatile organic matter decomposed & stabilized

↓ By current

Decomposed materials are washed away & converted to simple constituents (CO_2)

↓

Algae absorbed CO_2 & supply oxygen during stabilization

↓

Bacteria eaten by protozoa

↓

Protozoa become food for fish

Stream becomes free from bacteria &protozoa

↓

Natural purification process continues & makes stream water pure after some point

- The rate of self purification depends on various factor such as
  - Rate of aeration
  - Type of organic matter
  - Temperature
  - Velocity of flow
  - Presence of available oxygen
  - Sedimentation

- The various action involve in self purification process are physical, chemical and biological in nature and are listed below
  1. Dilution
  2. Sedimentation
  3. Oxidation
  4. Reduction
  5. Sunlight
  6. Temperature
  7. Dispersion

- Dilution
  - When sewage is discharged into large volume of water flowing in a natural stream or river, it is disperse and dilution take place.
  - Due to dilution concentration of organic matter, BOD, suspended solid etc is reduced and thus potential nuisance of sewage is also reduces.
  - When dilution factor is quit high large amount of DO will always be available which will reduce chance of putrefaction and pollution effects. Thus because of dilution aerobic conditions will always exist.

- Sedimentation
  - The settleable solid contained in sewage settle at the bottom of stream and thus easily separated. Further it is deposited in the form of slug in which anaerobic decomposition take place.
  - If dilution is sufficient the anaerobic conditions will not developed and scouring tendency of stream will wash the deposit
- Oxidation
  - The organic matter after mixing with stream or large quantity of water start getting oxidized due to development of oxidizing organism present in water.
  - This process prevails till complete oxidation of organic matter.
  - The oxygen demand is satisfied and stream becomes purified, due to this phenomenon streams get their oxygen demand by its aeration by wind or by microscopic organism.

- Reduction
  - The reduction occurs in the streams due to hydrolysis of the organic matter biologically or chemically , anaerobic organism start splitting complex organic matter present in the sewage. This action produces odor and gas and stabilization start
- Sunlight
  - It is effective in self purification through its stablizing and bleaching effect on bacteria and through the biological action of certain microorganism deriving energy from the sun converting themselves into food for other forms of light, absorbing CO_2 and giving of O_2 -a process commonly known as photosynthesis

Factor Affecting Self-Purification

- TEMPRATURE:
  - At low temperature- Activities of bacteria is low hence rate of decomposition will also be slow. But DO content will be more due to increase solubility of oxygen.
  - At high temperature- DO will b less but more decomposition due to more bacterial activity. Hence self-purification takes lesser time.
- DISPERSION:
  - When there is no current sewage matter is deposited near the outfall causing formation of sludge bank and foul odor.
  - In heavy current sewage is thoroughly mixed up with stream preventing all nuisance.
  - In slow current sedimentation takes place causing growth of algae resulting in production of oxygen.

Zone of Pollution in River or Stream

- **Zone of degradation**-
  - it is situated just near the point where outfall sewer is discharging sewage into stream or river.
  - This zone is characterized by water becoming dark and turbid with formation of sludge deposition at bottom.
  - DO content is reduced to about 40% of saturation value.
  - There is increase in co_2 content, reoxygenation occurs but is slower than de-oxygenation.
  - Conditions are unfavorable for aquatic life but fungi at higher points and bacteria at lower points bacteria breed small worms & stabilize sewage sludge.

IN THIS ZONE DECOMPOSITION OF SOLID MATTER TAKES PLACE AND ANAEROBIC DECOMPOSITION PREVAILS.

- **Zone of Active Decomposition**
    - It is just after degradation zone & is marked by heavy pollution.
    - Water in this zone becomes grayish and darker than in previous zone.
    - In this zone DO falls to 0.Active anaerobic decomposition of organic matter takes place with evolution of methane, carbon dioxide, nitrogen and hydrogen sulphide bubbling to the surface with masses of sludge forming black scum layer at surface.
    - After decomposition reaeration starts DO content again rises to level of about 40% near the end of this zone.

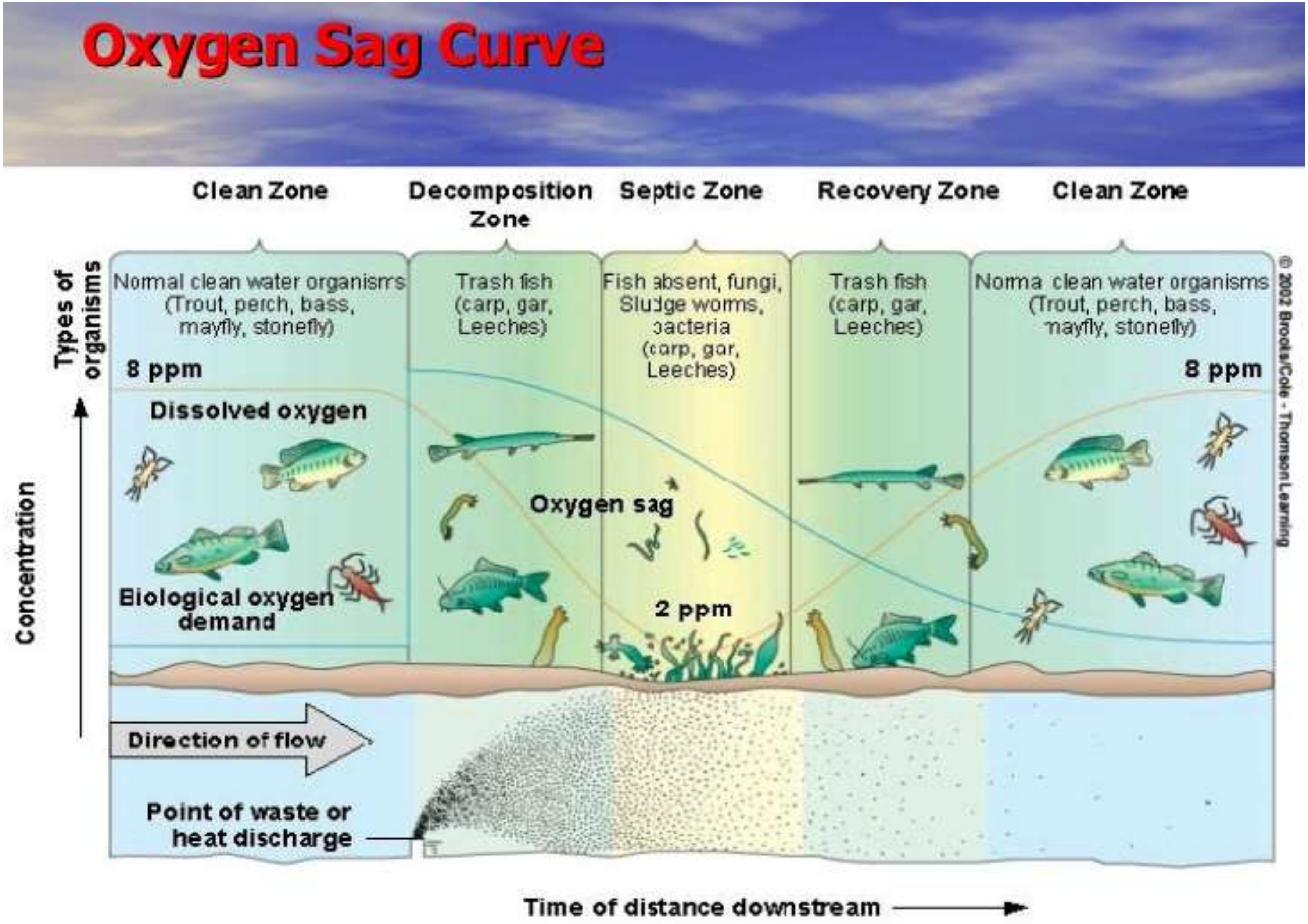
IN THIS ZONE FISH LIFE IS ABSENT BUT BACTERIA FLORA FLOURISH.

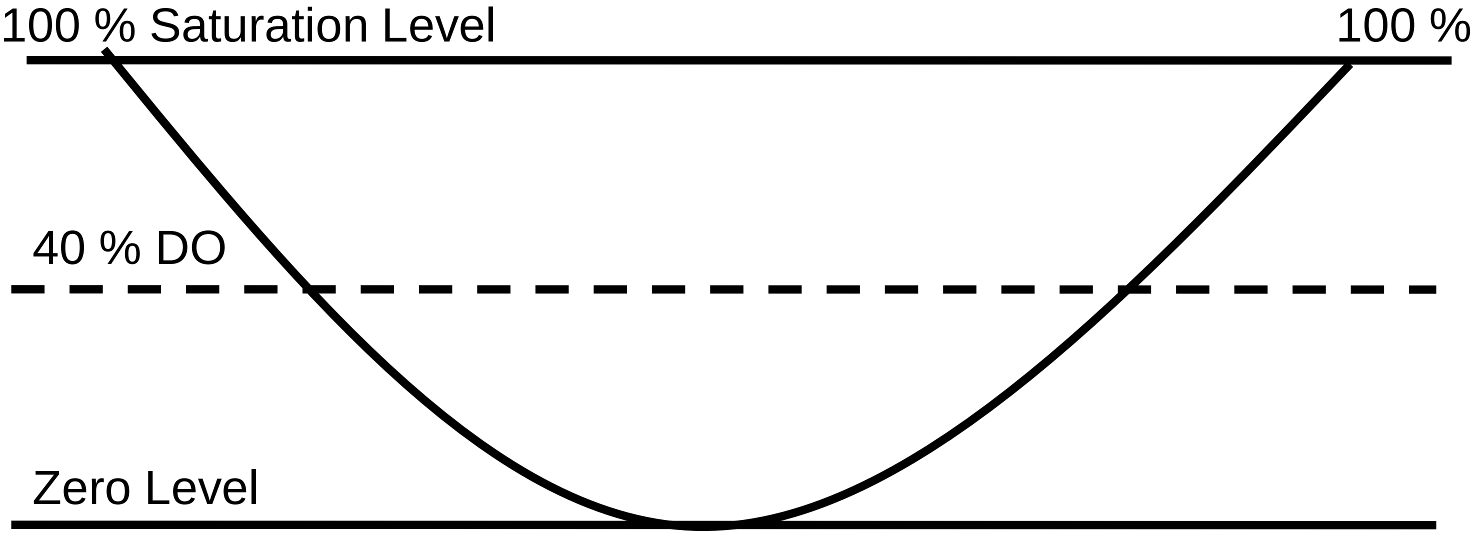
- **Zone of recovery**
  - In this zone process of recovery starts and condition in stream or river changes from its degraded condition to its former condition.
  - Most of stabilized organic matter settles down as sludge, BOD falls and DO content rises above 40% of saturation value.
  - Algae and microscopic organism reappears, water becomes clearer fungi decrease and algae reappears.
  - Further in this zone mineralization is active and products such as nitrates, sulphates and carbonates are formed.

- Zone of clear water
  - River or stream attains its original condition.
  - Water becomes clearer and attractive in appearance .
  - The content of DO rises to saturation level and is much higher than BOD.
  - Thus oxygen balance (DO - BOD at first stage) is attained and recovery is said to be complete.

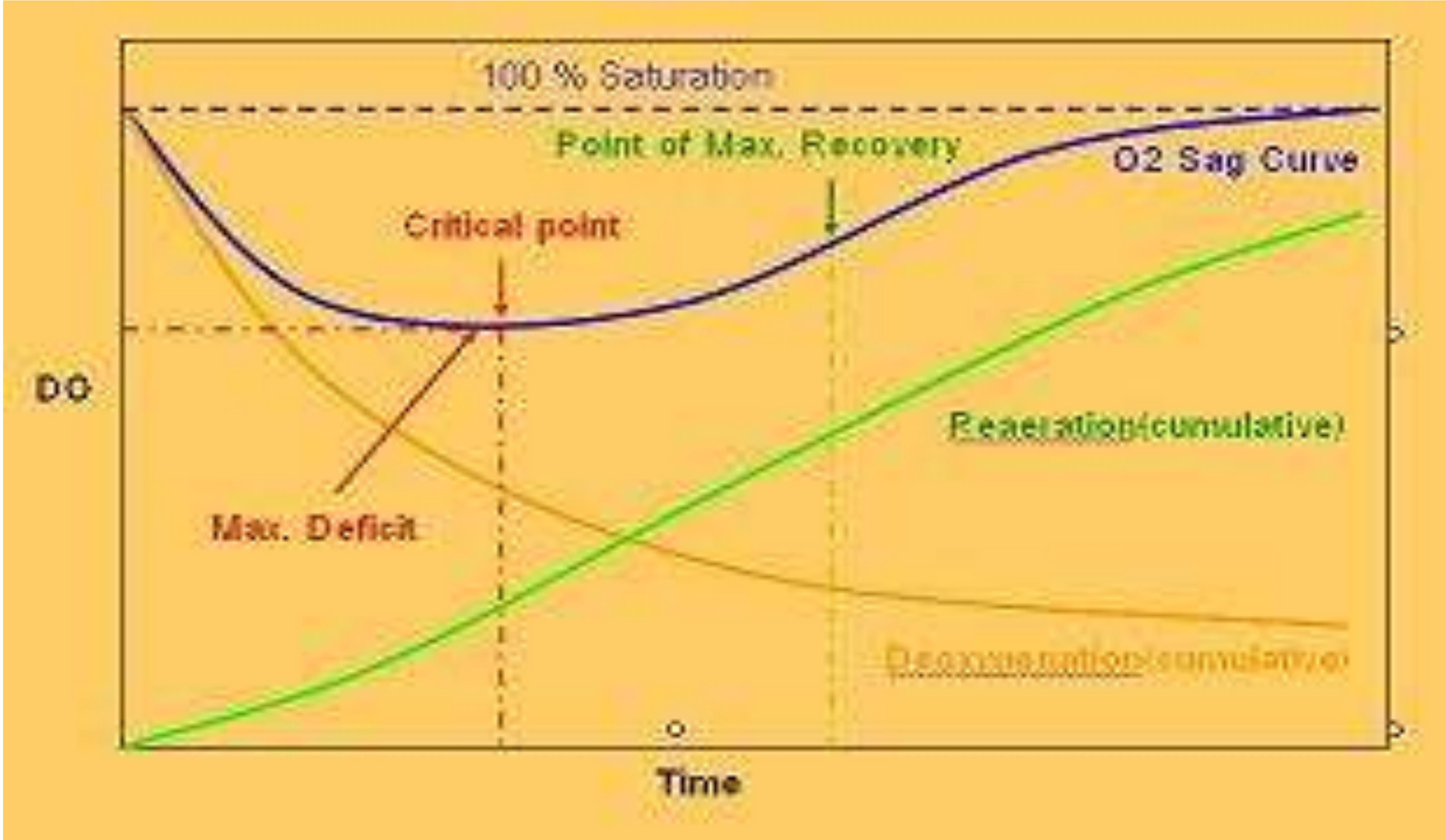
However some bacteria still remains which confirms the fact that when once a stream or river has been polluted by sewage discharged into it it will not be safe to drink its water unless properly treated.

Zone of Pollution



Particulars	Clear water	Zone of degradation	Zone of active Decomposition	Zone of recovery	Zone of clear water
Oxygen Sag Curve					
Physical Properties	Clear water No bottom sludge	Floating solids, colour, Turbidity, bottom sludge	Grayish & darker colour CH_4, H_2S, CO_2, N_2 gases Black scum at top	Turbid with bottom sludge	Clear water with no bottom sludge

Oxygen Sag Curve



Oxygen Sag Curve

- Oxygen sag or oxygen deficit is the difference between saturation DO content and actual DO content of water.

Oxygen Deficit D = (Saturation DO- Actual DO)

- Saturation DO for fresh water depends on temperature and it decreases with increase in temperature

$0^{O}C$ --- 14.62 mg/l

$20^{O}C$ --- 9.17 mg/l

$30^{O}C$ --- 7.63 mg/L

Oxygen Sag Curve

- Rate of deoxygenation depends on amount of organic matter remains to be oxidized and temperature of polluted water
- Rate of reoxygenation depends on
  - Depth of water (rate is more for shallow depth)
  - Velocity of water (rate is less for stagnant water)
  - Deficit of DO
  - Temperature of water
- Ordinates below deoxygenation curve indicate DO content remaining in water flowing in river after meeting BOD requirement

Oxygen Sag Curve

- Ordinate below reoxygenation curve indicate oxygen content absorbed by water
- Critical point is maximum deficit
- Oxygen sag curve represents the net oxygen balance
- Ordinates above the curve indicates DO deficit at different times.

Disposal on land

Broad Irrigation: In this process, sewage is caused to flow over cultivated lands, from which a part of sewage evaporates and through which the reminder percolates ultimately to escape into surface drainage channels.

Purification here is due to
Physical action – aeration at the surface and filtration underneath the soil.
Chemical action – Oxidation
Bio-chemical action due to soil bacteria converting sewage matter in to plant food

Sewage Farming

- Sewage which flows over land contains nutrients like nitrogen,phosporous and potassium.
- Sewage can be employed for fertilizing crops like cotton, sugarcane, mustard, sunflower etc.
- Helps in increasing the fertility of the soil and also its drainage characteristics.
- Increase is around 33 percent more than canal irrigation.
- Sewage should undergo primary treatment to eliminate harmful constituents.

Standards

- Royal commission report on sewage disposal are:
- Irrigation without cropping on good solid and sub-soil such as sandy, loamy overlying gravel and sand can handle 280000 liters of sewage per day per hectare.
- Irrigation with cropping on good solid and sub-soil such as sandy, loamy overlying gravel and sand can handle 78500 - 134000 litres of sewage per day per hectare.
- Irrigation with cropping on heavy soil overlying clay subsoil can handle 56000 litres of sewage per day per hectare.
- Irrigation with cropping on stiff clay soil overlying dense clay can handle 34000 litres of sewage per day per hectare.

Sub surface irrigation(Infiltration)

- Done through a system of open jointed pipes/drains laid near the ground enabling sewage to percolate in to surrounding soil.
- Purification and filtration removes the suspended matter and biochemical action by aerobic and anaerobic near the surface and below respectively.

Conditions favouring sub-surface irrigation are:-

- Where dilution water is not easily available
- Climate is dry, favouring drying up conditions
- Land is cheap and plentiful
- Sub-surface strata are porous favouring large infiltration
- Rainfall is meagre and demand for irrigation water is heavy
- Subsoil water is low.

SEWAGE SICKNESS

- When sewage is applied continuously on a piece of land, pores or voids of soil get filled up or clogged thereby free circulation of air is prevented and anaerobic condition develop.
- At this stage land is unable to take any further sewage load and due to anaerobic decomposition of organic matter foul smelling noxious gases are produced.This phenomenon of soil is known as sewage sickness of land.

MEASURE TO PREVENT SEWAGE SICKNESS

- Pretreatment of sewage: sewage should be applied on land only after giving primary treatment such as screening, grit removal and sedimentation.

This will help in removing settleable solids and reducing BOD load by 30% and hence soil pores will not get clogged.

- Provision of extra land: there should be ample provision of extra land so that land with sewage sickness can be given desired rest.
- Drainage of soil: subsoil drain pipes with open joints should be laid to collect the percolating effluent.this will minimize sewage sickness.

- **Proper choice of land:** land chosen for this purpose should be sandy or loamy having high permeability. Clayey soil should be avoided.
- **Rotation of crops:** sewage sickness can be reduced by growing different crops in rotation instead of growing single type of crop. This will help in utilizing different crops in rotation instead of growing single type of crop. This will help in utilizing different fertilizing elements of sewage and helps in aeration of soil.
- **Shallow depth application**: sewage should be applied in shallow depths. If it is applied in greater depths chances of sewage sickness are increased. The depth of sewage on land should be carefully decided by keeping in view the climatic conditions, drainage facilities, nature of crops and characteristics of soil.

- **Intermittent application:** sewage should be applied on land at intervals. The period between successive application depends on general working of sewage farm and permeability of soil. It may vary from few hours to few weeks to months.
- **Treatment of land:** the land affected by sewage sickness should be properly treated before it is put up in use again. Clogged soil should be broken up by suitable equipment.

TOTAL ORGANIC CARBON(TOC)

- It is another approach to evaluate amount of organic matter present in waste water by determining amount of organic carbon in waste water.
- Applicable to small concentration of organic matter.
- Acidification of waste water sample to convert inorganic carbon to CO_2
- Instrument -carbonaceous analyzer

TOTAL OXYGEN DEMAND(TOD)

- It is another instrumental method to measure organic contents of sewage.
- It involves quantitative measurement of amount of oxygen used to burn organic substances.
- Instrument- Platinum catalysed combustion chamber

TOTAL OXYGEN DEMAND(TOD)

- Oxidisable components are converted into their stable oxide in combustion chamber
- This disturb oxygen equilibrium in nitrogen carrier gas stream
- Depletion in oxygen concentration in carrier gas is detected by oxygen recorder
- TOD value obtained for sample is compared with standard TOD calibration solution.

Theoretical Oxygen Demand (ThOD)

- This is theoretical method of computing oxygen demand of various constituents of organic matter present in sewage

OBJECTIVES OF SEWAGE COLLECTION AND DISPOSAL

The objective of sewage collection and disposal is to ensure that

Sewage discharged from communities is properly collected, transported, treated to the required degree so as not to cause danger to human health or unacceptable damage to the natural environment and finally disposed off without causing any health or environmental problems.

OBJECTIVES OF SEWAGE COLLECTION AND DISPOSAL

Thus, efficient sewerage scheme can achieve the following:

- To provide a good sanitary environmental condition of city protecting public health.
- To dispose the human excreta to a safe place by a safe and protective means.
- To dispose of all liquid waste generated from community to a proper place to prevent a favorable condition for mosquito breeding, fly developing or bacteria growing.
- To treat the sewage, as per needs, so as not to endanger the body of water or groundwater or land to get polluted where it is finally disposed off. Thus, it protects the receiving environment from degradation or contamination.

Methods of Collections

- Dry or Conservancy system of collection
  - In this system different type of refuse are collected separately and then each type is carried and suitably disposed of f.
  - The refuse is collected from roads and streets in pans or basket then conveyed by carts , trucks etc to some suitable place
  - The garbage is separated into two categories
    - Flammable - burnt into incinerators
    - Inflammable matters - buried into low lying areas for reclamation of soil
  - The night soil is collected in pans from lavatories and the sewage is carried by labour in carts trucks etc which is buried into the ground and converted into manure

The storm water and sullage are collected and conveyed separately by closed or open channels which are discharged in natural river or streams

Methods of Collections

- Water Carriage system
  - In this system water is used as medium to convey the sewage to the point of its treatment or final disposal.
  - The quantity of water to be mixed with solid matter is quit sufficient and dilution ratio of solid matter with water is so great that mixture behaves more or less like water.
  - In this system garbage is collected and conveyed as in case of conservancy system.
  - The storm water may be carried separately or may be allowed to flow with the sewage.
  - It permits compact design of structure laid below ground, hence it not visible but hygienic.
  - There is no chances of putrefaction and has come up as an urban system
  - The city appears neat and clean and there is no risk of pollution of under ground sources of water as sewage is carried in close sewer

DEFINITIONS

- House sewer (or drain) is used to discharge the sewage from a building to a street sewer.
- Lateral sewer is a sewer which collects sewage directly from the household buildings.
- Branch sewer or submain sewer is a sewer which receives sewage from a relatively small area.
- Main sewer or trunk sewer is a sewer that receives sewage from many tributary branches and sewers, serving as an outlet for a large territory.
- Depressed sewer is a section of sewer constructed lower than adjacent sections to pass beneath an obstacle or obstruction. It runs full under the force of gravity and at greater than atmospheric pressure. The sewage enters and leaves the depressed sewer at atmospheric pressure.

DEFINITIONS

- Intercepting sewer is a sewer laid transversely to main sewer system to intercept the dry weather flow of sewage and additional surface and storm water as may be desirable. An intercepting sewer is usually a large sewer, flowing parallel to a natural drainage channel, into which a number of main or outfall sewers discharge.
- Outfall sewer receives entire sewage from the collection system and finally it is discharged to a common point.
- Relief sewer or overflow sewer is used to carry the flow in excess of the capacity of an existing sewer.

TYPES OF SEWERAGE SYSTEM

The sewerage system can be of following three types:

- ***Combined system***
- ***Separate System***
- ***Partially separate system***

- **Combined system:** In combined system along with domestic sewage, the run-off resulting from storms is carried through the same conduit of sewerage system. In countries like India where actual rainy days are very few, this system will face the problem of maintaining self cleansing velocity in the sewers during dry season, as the sewage discharge may be far lower as compared to the design discharge after including storm water.

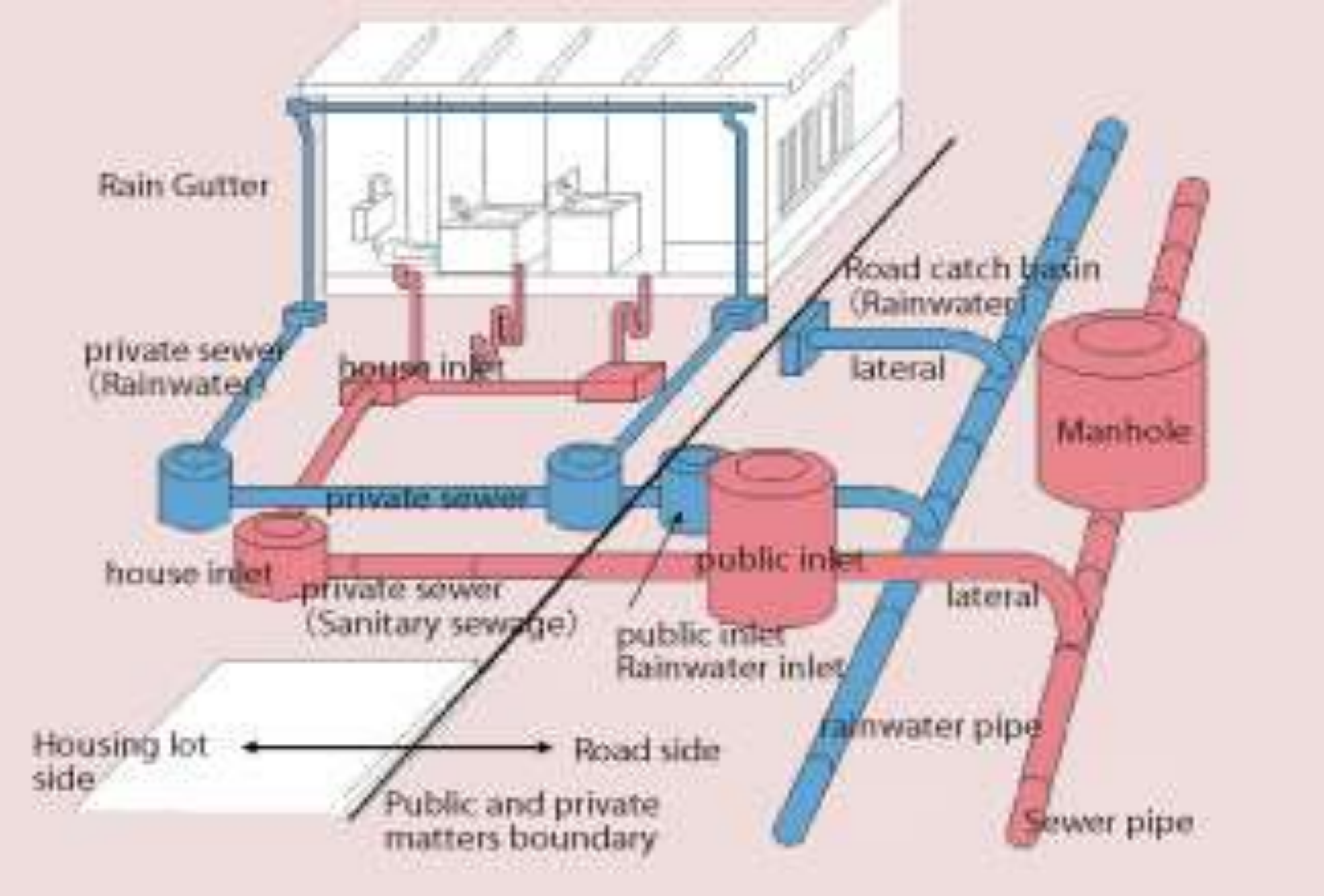
TYPES OF SEWERAGE SYSTEM

- ***Separate System:*** In separate system, separate conduits are used; one carrying sewage and other carrying storm water run-off. The storm water collected can be directly discharged into the water body since the run-off is not as foul as sewage and no treatment is generally provided. Whereas, the sewage collected from the city is treated adequately before it is discharged into the water body or used for irrigation to meet desired standards. Separate system is advantageous and economical for big towns.

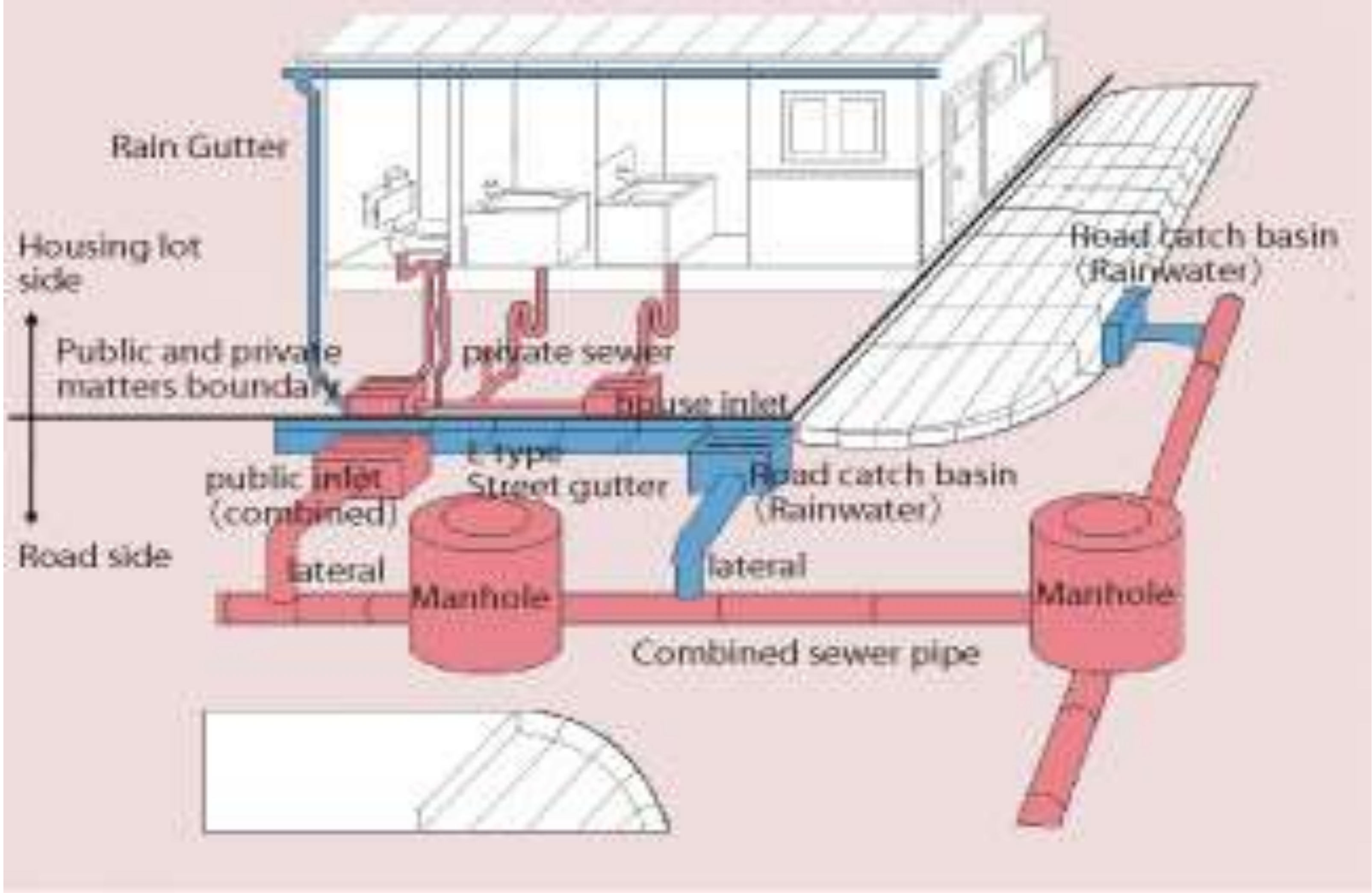
TYPES OF SEWERAGE SYSTEM

- ***Partially separate system:*** In this system part of the storm water especially collected from roofs and paved courtyards of the buildings is admitted in the same drain along with sewage from residences and institutions, etc. The storm water from the other places is collected separately using separate storm water conduits.

SEPARATE SYSTEM



COMBINED SYSTEM



Advantages of combined system

- In an area where rainfall is spread throughout a year, there is no need of flushing of sewers, as self cleansing velocity will be developed due to more quantity because of addition of storm water.
- Only one set of pipe will be required for house plumbing.
- In congested areas it is easy to lay only one pipe rather than two pipes as required in other systems.

Disadvantages of combined system

- Not suitable for the area with small period of rainfall in a year, because dry weather flow will be small due to which self cleansing velocity may not develop in sewers, resulting in silting.
- Large flow is required to be treated at sewage treatment plant before disposal, hence resulting in higher capital and operating cost of the treatment plant.
- When pumping is required this system is uneconomical.
- During rains overflowing of sewers will spoil public hygiene.

Advantages of separate system

- As sewage flows in separate pipe, hence the quantity to be treated at sewage treatment plant is small, resulting in economy of treatment.
- This system may be less costly as only sanitary sewage is transported in closed conduit and storm water can be collected and conveyed through open drains.
- When pumping is required during disposal, this system is economical due to less flow.

Disadvantages of separate system

- Self cleansing velocity may not developed at certain locations in sewers and hence flushing of sewers may be required.
- This system requires laying two sets of pipe, which may be difficult in congested area.
- This system will require maintenance of two sets of pipelines and hence maintenance cost is more.

Advantages of partially separate system

- Economical and reasonable size sewers are required.
- Work of house plumbing is reduced as rain water from roofs, sullage from bathrooms and kitchen, etc. are combined with discharge from water closets.
- Flushing of sewers may not be required as small portion of storm water is allowed to enter in sanitary sewage.

Disadvantages of partially separate system

- Increased cost of pumping as compared to separate system at treatment plants and intermediate pumping station wherever required.
- In dry weather self-cleansing velocity may not develop in the sewers.

CONSIDERATIONS FOR THE TYPE OF SYSTEM

Following points are considered before finalizing the type of collection system.

- The separate system requires laying of two sets of conduits whereas in combined system only one bigger size conduit is required.
- Laying of two separate conduits may be difficult in the congested streets.
- In combined system sewers are liable for silting during non-monsoon season, hence they are required to be laid at *steeper gradients*. Steeper gradients for the sewers may *require more number of pumping stations*, particularly for flat terrain, which may make the system costly.

CONSIDERATIONS FOR THE TYPE OF SYSTEM

- Large quantity of wastewater is required to be treated before discharge in case of combined system. Hence, large capacity treatment plant is required.
- In separate system, only sewage is treated before it is discharged into natural water body or used for irrigation. No treatment is generally given to the rainwater collected before it is discharge in to natural water body.
- In case of separate system pumping is only required for sewage. Pumping can be avoided for storm water lines, as they are not very deep and normally laid along the natural slopes.

CONSIDERATIONS FOR THE TYPE OF SYSTEM

- In combined system large capacity pumping station is required to safely handle the flow that is likely to be generated during highest design storm considered.
- Based on site conditions the economy of the system needs to be evaluated and selection is made accordingly.

PATTERNS OF COLLECTION SYSTEM

- The network of sewers consists of house sewers discharging the sewage to laterals. The lateral discharges the sewage into branch sewers or sub-mains and sub-mains discharge it into main sewer or trunk sewer. The trunk sewer carries sewage to the common point where adequate treatment is given to the sewage and then it is discharged.

PATTERNS OF COLLECTION SYSTEM

The patterns of collection system depend upon:

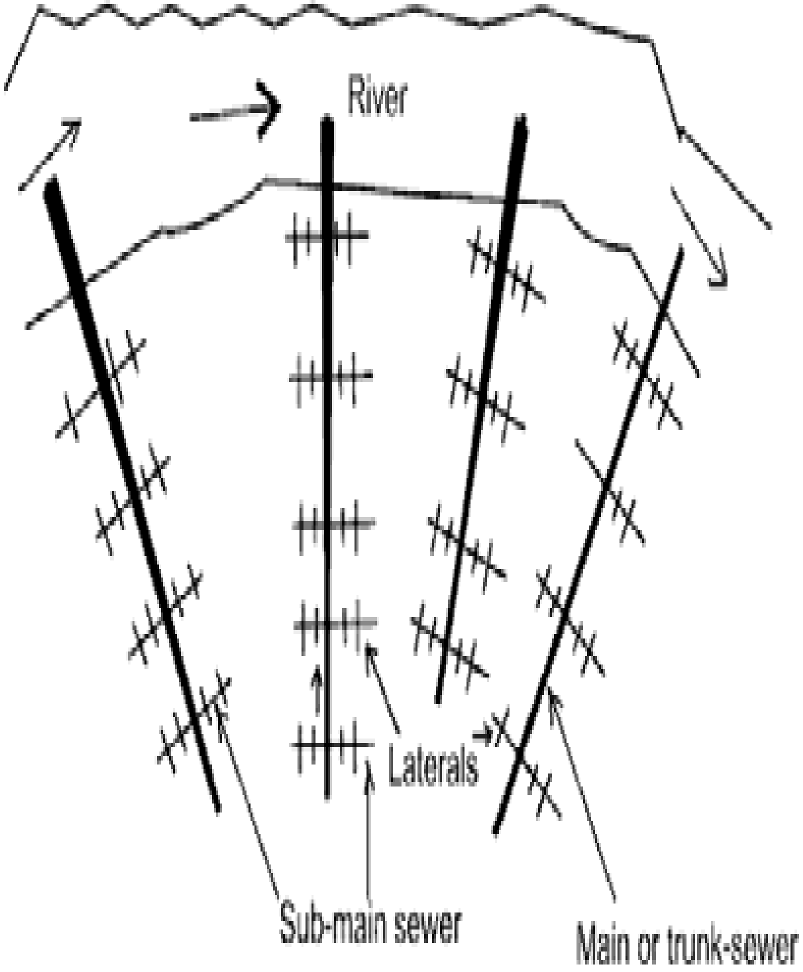
1. topographical and hydrological features of the area.
2. location and methods of treatment and disposal works.
3. type of sewerage system employed
4. Extent of area to be served.

Types of pattern

- **a. Perpendicular pattern**
- **b. Interceptor pattern**
- **c. Radial Pattern**
- **d. Fan Pattern**
- **e. Zone Pattern**

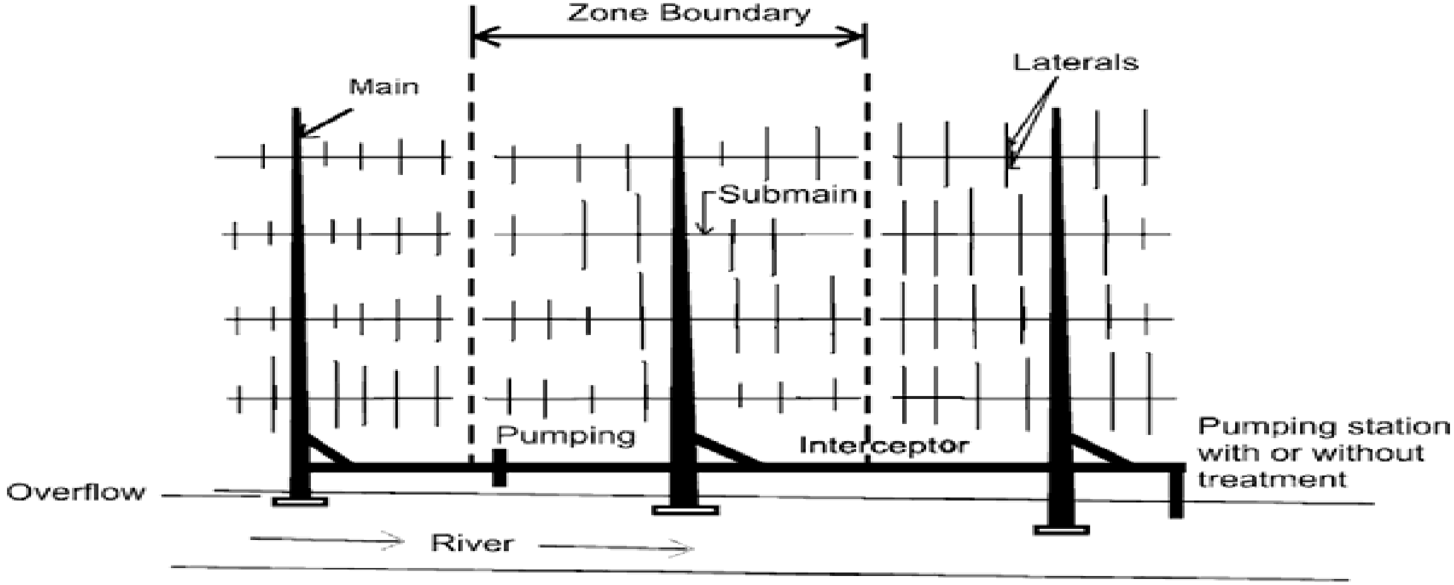
a. Perpendicular pattern

- The shortest possible path is maintained for the rains carrying storm water and sewage
- It is suitable for separate system and partially separate system for storm water drains.
- This pattern is not suitable for combined system, because treatment plant is required to be installed at many places; otherwise it will pollute the water body where the sewage is discharged.



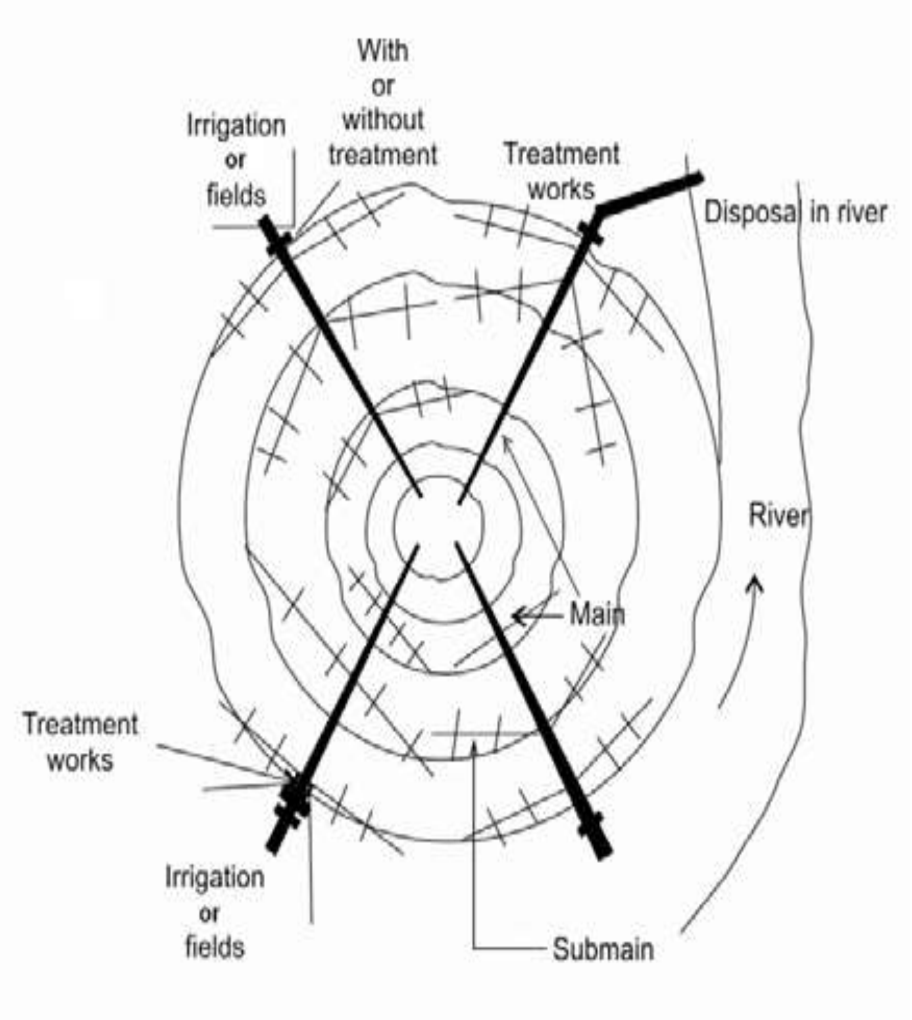
b. Interceptor pattern

- Sewers are intercepted with large size sewers
- Interceptor carries sewage to a common point, where it can be disposed off with or without treatment.
- Overflows should be provided to handle very large flow.



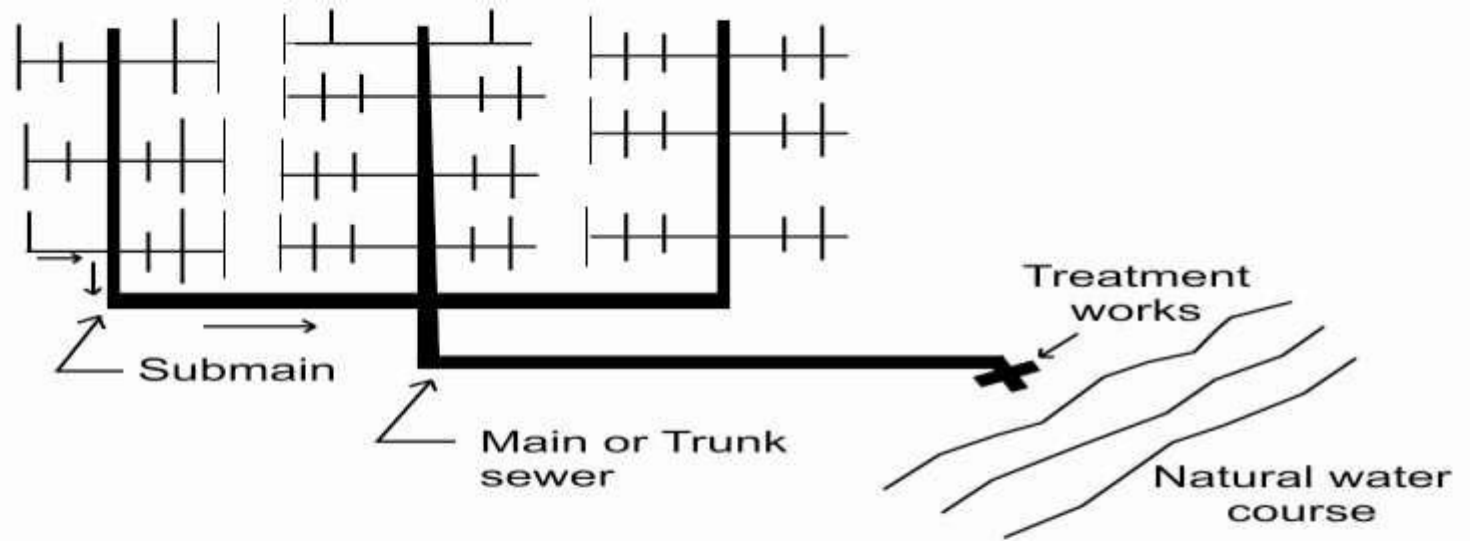
c. Radial Pattern

- It is suitable for land disposal.
- In this pattern sewers are laid radialy outwards from the centre, hence this pattern is called as radial pattern.
- The drawback in this pattern is more number of disposal works are required.



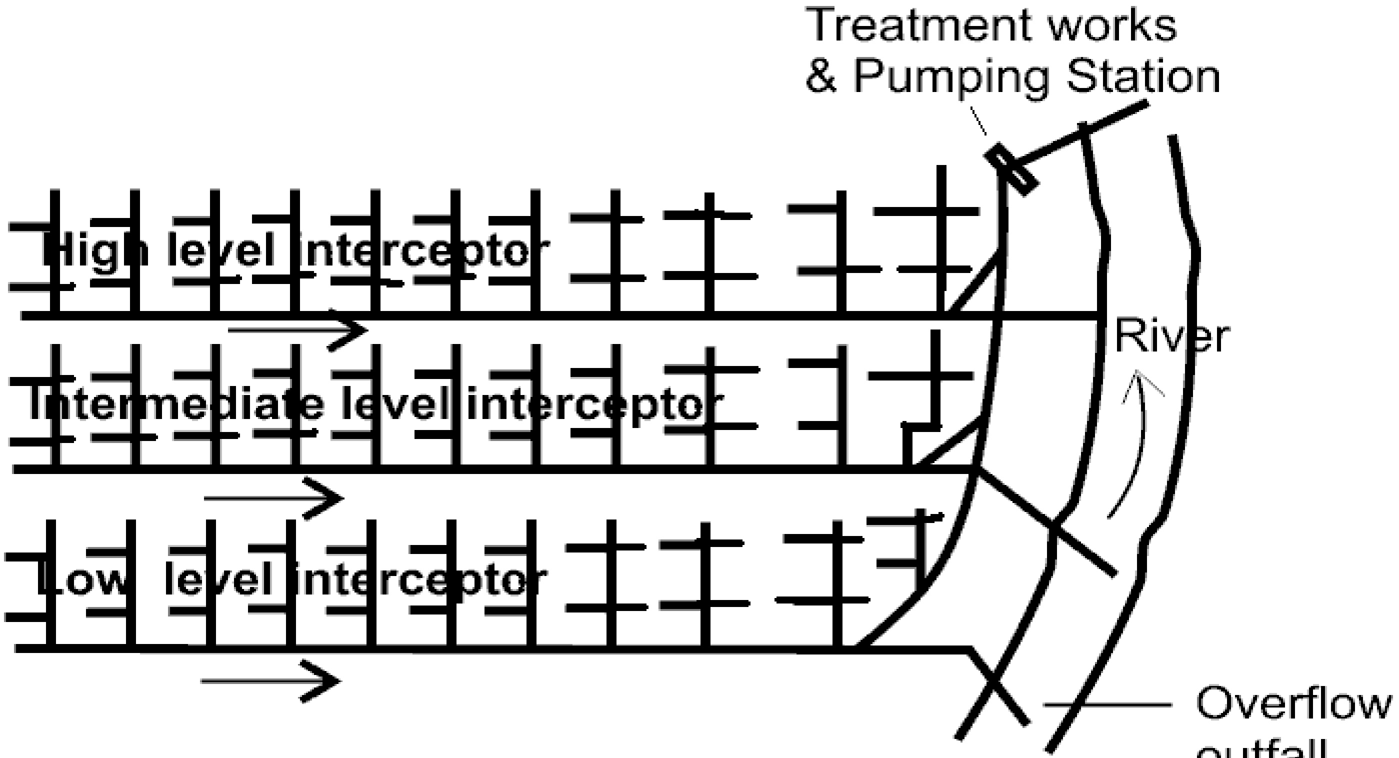
d. Fan Pattern

- This pattern is suitable for a city situated at one side of the natural water body, such as river.
- The entire sewage flows to a common point where one treatment plant is located
- In this number of converging main sewers and sub-mains are used forming a fan shape. Single treatment plant is required in this pattern.
- The drawback in this pattern is that larger diameter sewer is required near to the treatment plant as entire sewage is collected at a common point.
- In addition, with new development of the city the load on existing treatment plant increases.



e. Zone Pattern

- More numbers of interceptors are provided in this pattern
- This pattern is suitable for sloping area than flat areas.



Quantity of Sanitary Sewage

- It includes both domestic sewage and industrial waste along with any infiltration due to ground water flow depends upon population and per capita contribution of sewage.
- Quantity of sewage should be visualized for future condition over the design period and should accordingly be provided for.
- Sanitary sewage also called dry weather flow (D.W.F.) is the total average discharge of sanitary sewage and is the normal flow in a sewer during dry weather expressed in liters/capita/day

Quantity of Sanitary Sewage

- It depends upon following factor
  - Population
    - Quantity of sanitary sewage directly depends on the population as population increases quantity of sewage also increases.
    - Population of town in future is predicted by various methods already discussed (AI, GI etc)
    - Swear pipe line are generally design to carry peak flows for maximum population for local area to be served

Quantity of Sanitary Sewage

- Type of area served
  - A town and city is classified into different areas
    1. Residential and domestic
    2. Industrial
    3. Commercial

1. The quantity of sewage produced in residential areas directly depends on quantity of water supply to that area. This type of sewage is expressed in Liters/capita/day. and quantity is obtained by multiplying the population with this factor.
2. Industrial area contain number of factories . Commercial area have whole sale and retail stores, offices and other public building. Here rate of floe of sewage is expressed in liter/day/m^2 of area.
3. Necessary study of development is carried out for accurately predicting the flow

Quantity of Sanitary Sewage

- Rate of water supply
  - The quantity of used water discharged into a sewer system should be less than amount of water originally supplied to the community because of losses as leakage from pipes or deduction as lawn sprinkling , manufacturing processes
  - On average 80% of per capita water consumption may be considered in the design for reaching the sewers. While the per capita consumption for water supply is kept at a minimum of 135 liters/capita/day, the sewers should be designed for minimum flow of 150lpcd

Quantity of Sanitary Sewage

Ground water infiltration

- It depends upon the following
  - Nature of soil
  - Material of sewers
  - Pipe joints
  - Depth at which sewer is laid
- Ground water infiltration is generally expressed in liter/days with permissible infiltration rate in the range of 50 to 500 liters/day/mm of pipe diameter per Km length of sewer ( )

Quantity of Sanitary Sewage

- **Fluctuation of sewage**
  - The sewage flow is not constant but varies in a similar way , be seasonal or monthly daily or hourly
  - The maximum and minimum rate of sewage flow are controlling factor in design of sewers.
  - Sewer must be of ample capacity to carry maximum flow with reasonable factor of safety and also ensure sufficient velocity to produce requisite self cleansing which should be available in case of minimum flow
  - The maximum flow capacity of sewer and permissible velocities of flow would depend upon the type of sewerage system (separate or combined)

Quantity of Sanitary Sewage

- **Flow of sewage**
  - The flow of sewage in sewer occurs under two conditions
    - Open channel flow
    - Closed channel flow
  - The open channel flow occur when hydraulic grade line lies in the surface of flowing liquid which is thus exposed to atmosphere.
  - It is however not necessary that channel should be without cover.
  - If covered as in pipe, the sewer must run full otherwise pressure might rise above or fall below the atmospheric pressure, a condition oppose to open channel flow
  - The closed channel flow occur when sewage flow in a conduit at a pressure above or below atmospheric.

Hydraulic Formulae

Based upon these two condition of flow the Hydraulic formula governing sewage flow generally used are

1. Manning's Formula

This is most commonly used for design of sewers.

$$v = \frac{1}{n} r^{2/3} s^{1/2}$$

v = velocity of flow in the sewer m/sec

r = Hydraulic mean depth of flow m, r = a/p=$(\Pi D^2/4)/(\Pi D)$

r = D/4

a = Cross section area of flow, m^2

p = Wetted perimeter, m

n = Rugosity coefficient, depends upon the type of the channel surface i.e., material and lies between 0.011 and 0.015. For brick sewer it could be 0.017 and 0.03 for stone facing sewers.

s = Hydraulic gradient, equal to invert slope for uniform flows.

2.Chezy's Formula

$$v = C\, r^{1/2} s^{1/2}$$

Where, C is Chezy's constant and remaining variables are same as above equation

3.Crimp and Burge's Formula

$$v = 83.5\, r^{2/3} s^{1/2}$$

4. Hazen- Williams Formula

$$V = 0.849\, C\, R^{0.63}\, S^{0.54}$$

Value of C for **Hazen- Williams Formula**

Sl. No	**Type of Pipe material**	**Value of C for new pipe**	**Value of C for design purpose**
1	Concrete & RCC pipes	140	110
2	CI Pipe	130	100
3	GI Pipe	120	100
4	Steel pipe with welded joint	140	100
5	Steel pipe with rivetted joint	110	95
6	Steel pipe with welded joint lined with cement for bituminous enamel	140	110
7	AC Pipe	150	120
8	Plastic pipe	150	120

Velocities

- The sewage must flow in the sewer at all time with velocity sufficient to keep it in suspension.
- The velocity should neither become very small nor very great. If two small suspended matter get settle down in sewer . If velocity is too great the suspended matter is likely to erode the material of sewer.

Minimum Velocity: Self Cleansing Velocity

The velocity that would not permit the solids to settle down and even scour the deposited particles of a given size is called as self-cleansing velocity. **This minimum velocity should at least develop once in a day so as not to allow any deposition in the sewers.**

This minimum velocity or self-cleansing velocity can be worked out as below:

$$Vs = \sqrt{\frac{8K}{f'}(Ss - 1)g.d'}$$

K= constant, for clean inorganic solids = 0.04 and for organic solids = 0.06
f' = Darcy Weisbach friction factor (for sewers = 0.03)
Ss = Specific gravity of sediments
g = gravity acceleration
d' = diameter of grain, m

- Hence, while finalizing the sizes and gradients of the sewers, they must be checked for the minimum velocity that would be generated at minimum discharge, i.e., about 1/3 of the average discharge.
- While designing the sewers the flow velocity at full depth is generally kept at about 0.8 m/sec or so. Since, sewers are generally designed for ½ to ¾ full, the velocity at 'designed discharge' (i.e., ½ to ¾ full) will even be more than 0.8 m/sec.

Thus, the minimum velocity generated in sewers will help in the following ways:

- Adequate transportation of suspended solids,
- Keeping the sewer size under control; and
- Preventing the sewage from decomposition by moving it faster, thereby preventing evolution of foul gases.

- Minimum Velocity-
  - in separate sewer 0.6 m/s should be maintain
  - In combined sewer 0.75 m/s should be maintain
- Maximum Velocity
  - Is limited to about 3 m/s

Forms of Sewer

- The cross section sewer would depend upon
  - Efficiency of flow
  - Structural stability
  - Cost
  - Ease of maintenance and operation
  - Resistance to internal and external pressure
  - Resistance to corrosion
- Based on these factor sewer cross section may be classified as
  - Circular section
  - Non circular section

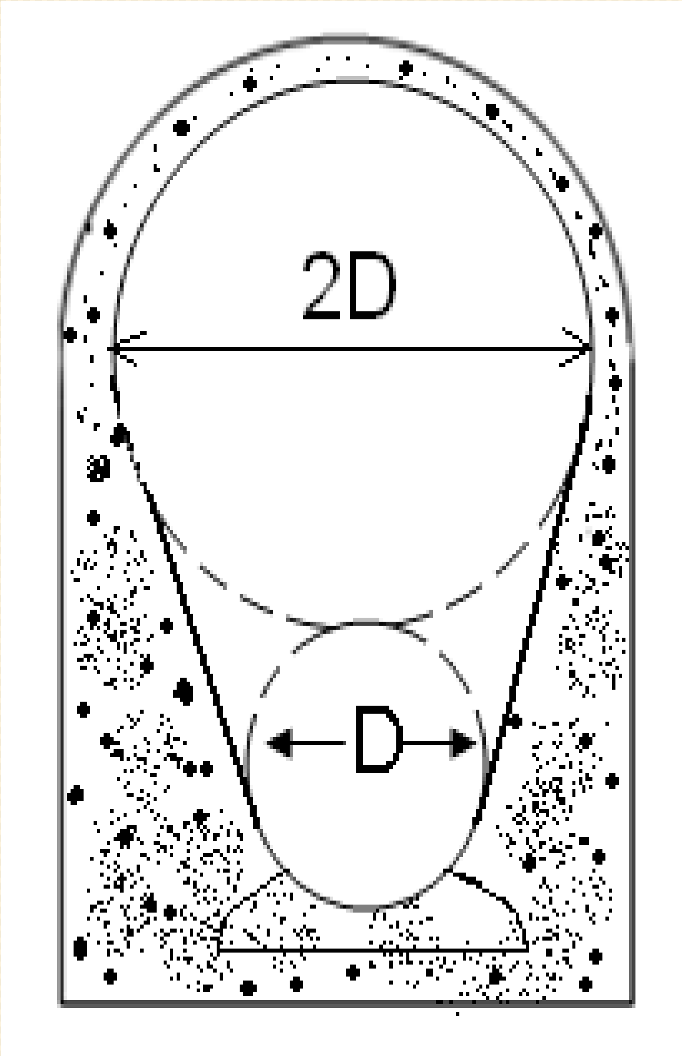
Shapes of Sewer Pipes

- Sewers are generally circular pipes laid below ground level, slopping continuously towards the outfall. These are designed to flow under gravity. Shapes other than circular are also used.

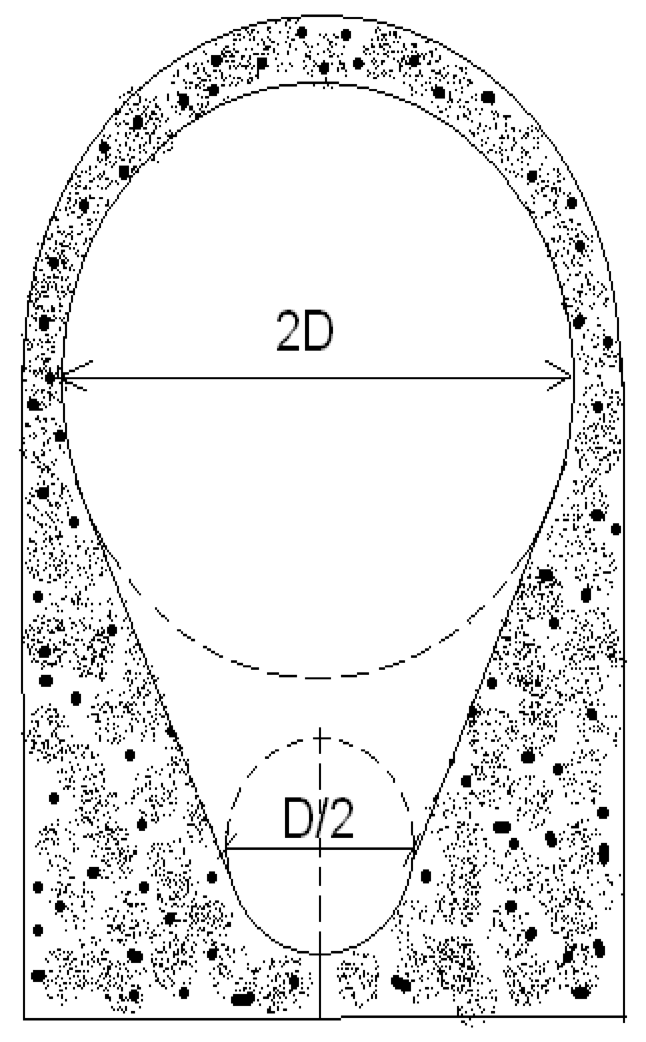
Non circular shapes used for sewers are

- a. Standard Egg-shaped sewer
- b. New egg-shaped sewer
- c. Horse shoe shaped sewer
- d. Parabolic shaped sewer
- e. Semi-elliptical section
- f. Rectangular shape section
- g. U-shaped section
- h. Semi-circular shaped sewer
- i. Basket handled shape sewer

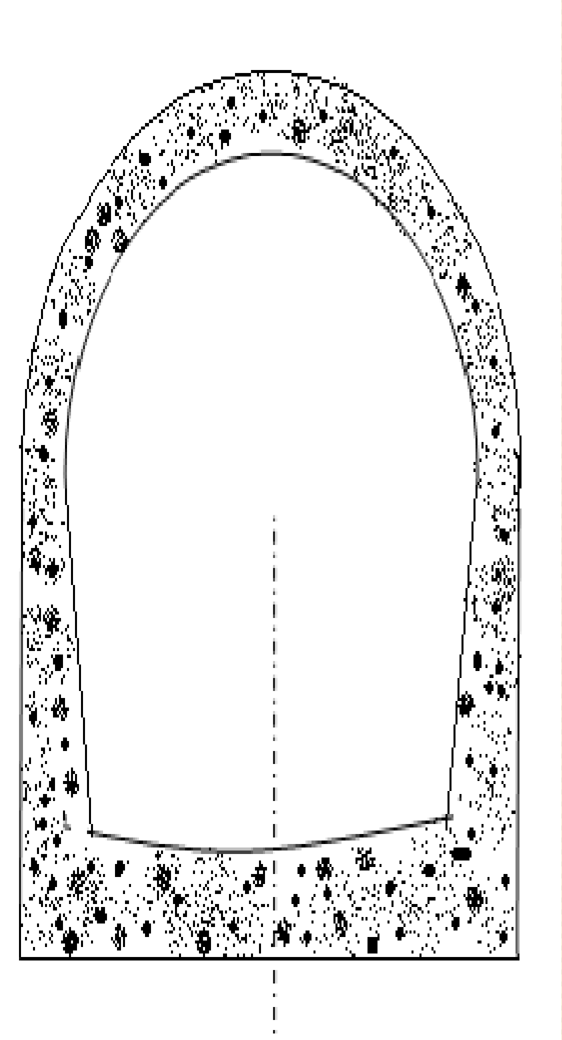
a. Standard Egg-shaped sewer



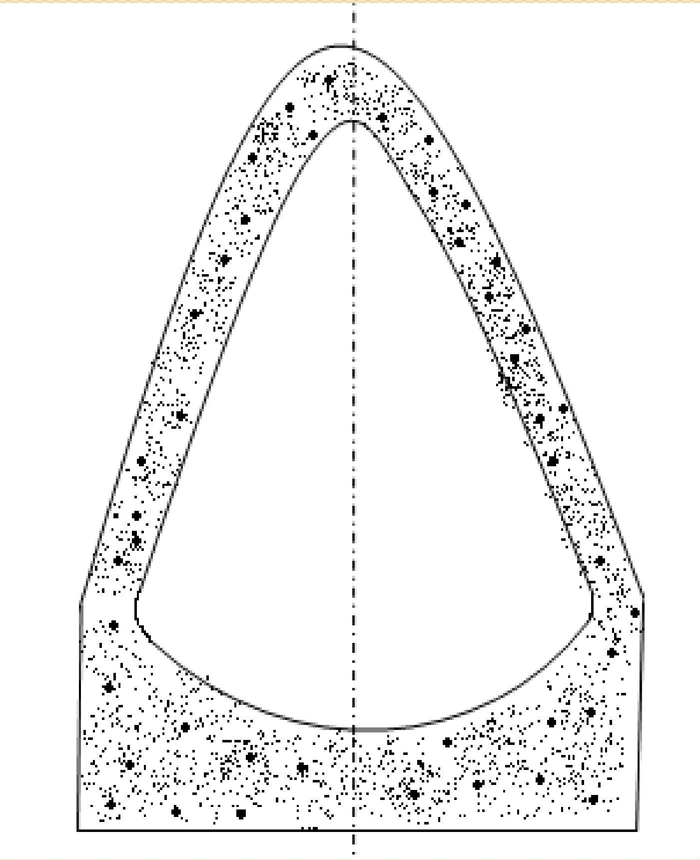
b. New egg-shaped sewer



c. Horse shoe shaped sewer

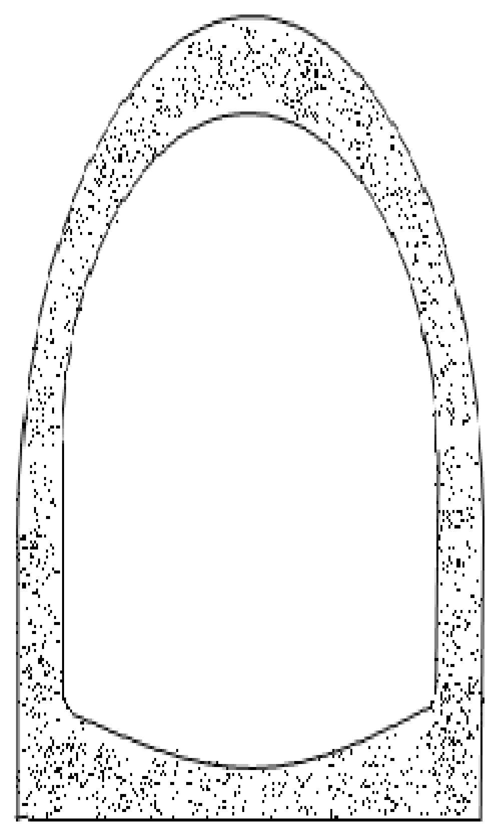


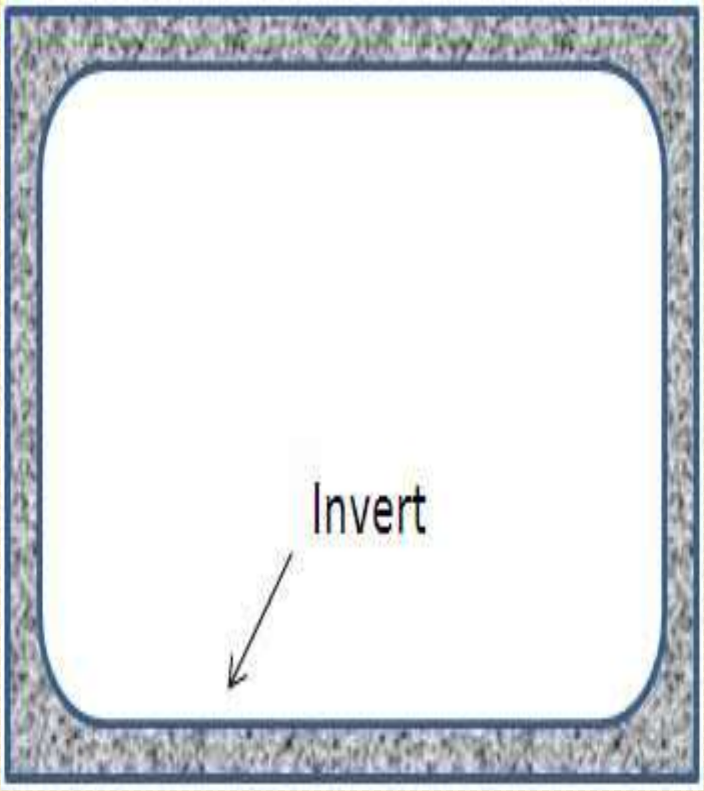
d. Parabolic shaped sewer



e. Semi-elliptical section

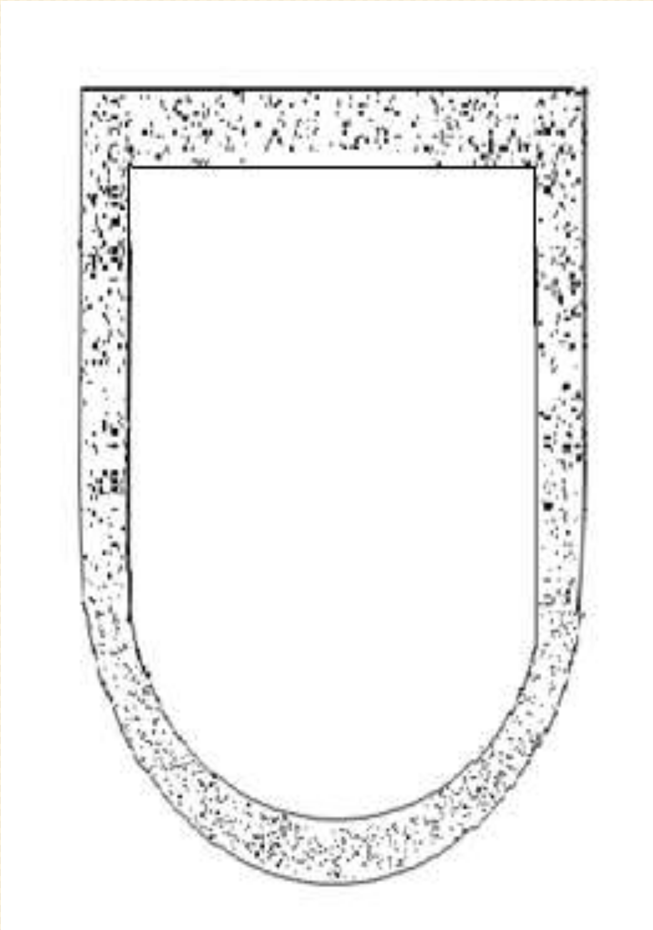
f. Rectangular shape section

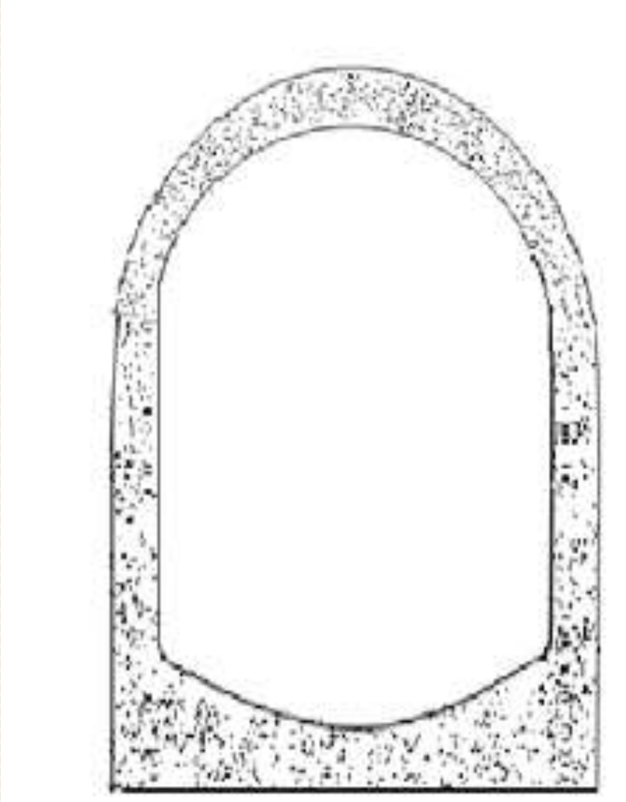




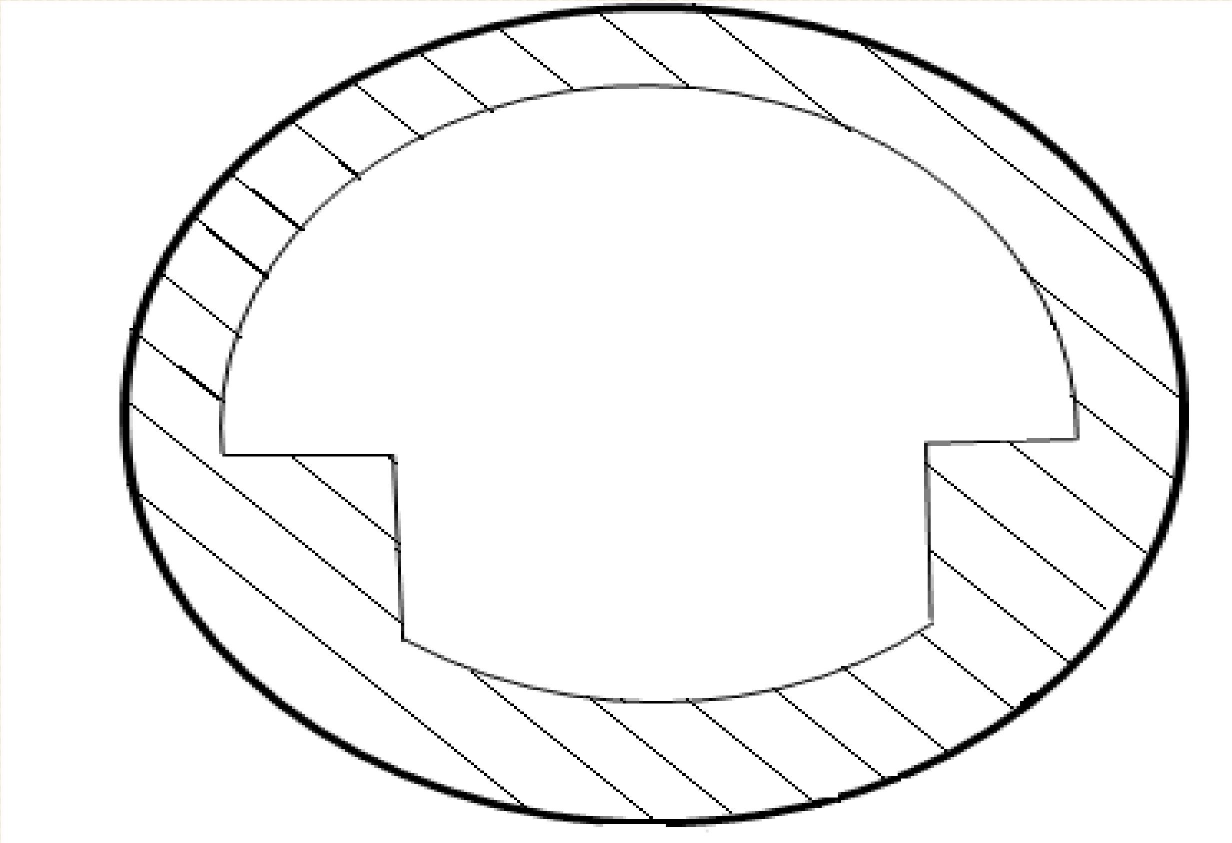
g. U-shaped section sewer

h. Semi-circular shaped sewer





i. Basket handled shape



Shapes of Sewer Pipes

- Standard egg-shaped sewers, also called as ovoid shaped sewer, and new or modified egg-shaped sewers are used in combined sewers.
- These sewers can generate self cleansing velocity during dry weather flow.
- Horse shoe shaped sewers and semi-circular sections are used for large sewers with heavy discharge such as trunk and outfall sewers.

Shapes of Sewer Pipes

- Rectangular or trapezoidal section is used for conveying storm water. U-shaped section is used for larger sewers and especially in open cuts.
- Other sections of the sewers have become absolute due to difficulty in construction on site and non availability of these shapes readily in market.

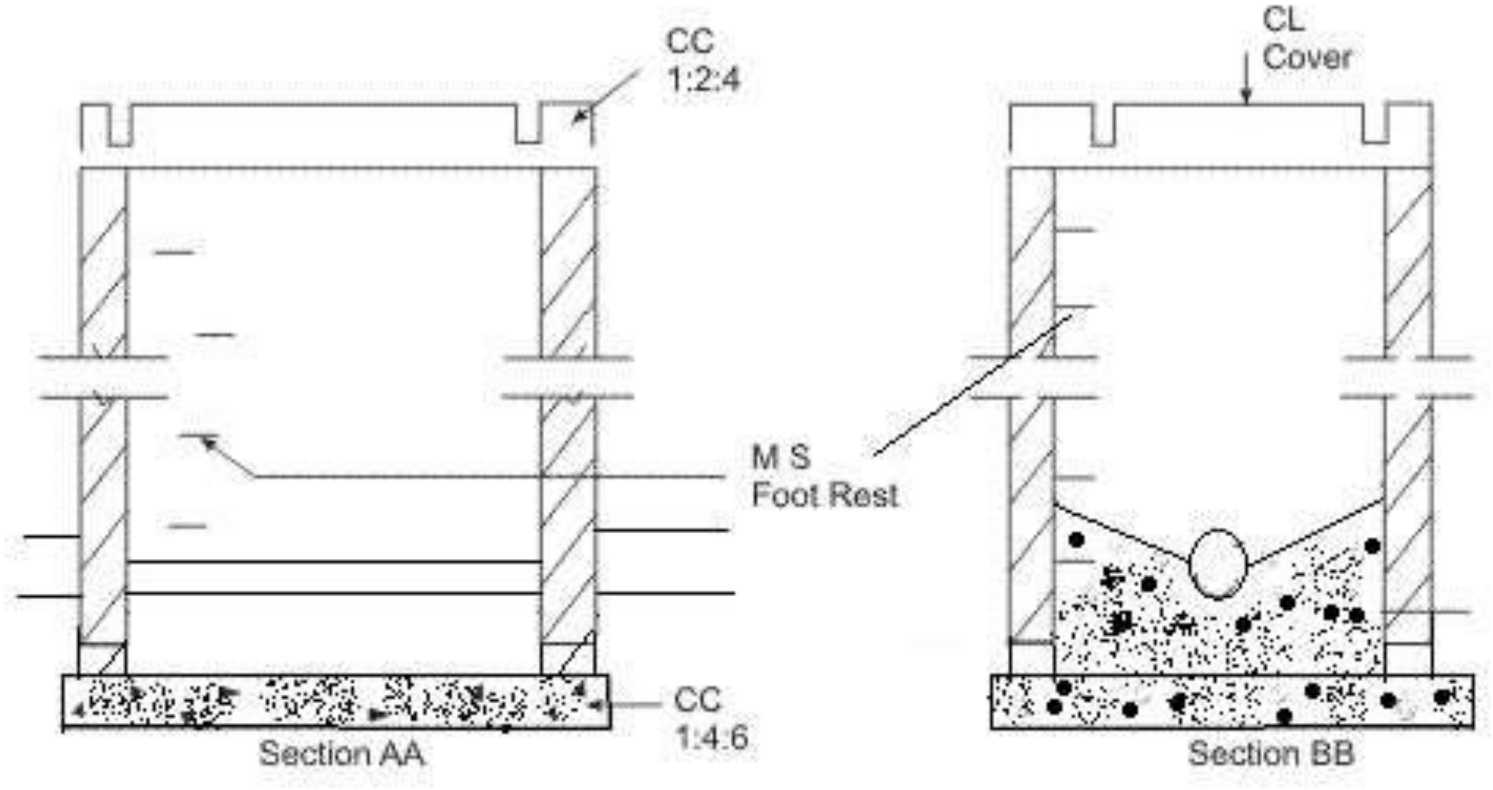
sewer appurtenances

The structures, which are constructed at suitable intervals along the sewerage system to help its efficient operation and maintenance, are called as sewer appurtenances. These include:

- (1) Manholes,
- (2) Drop manholes,
- (3) Lamp holes,
- (4) Clean-outs,
- (5) Street inlets called Gullies,
- (6) Catch basins,
- (7) Flushing Tanks,
- (8) Grease & Oil traps,
- (9) Inverted Siphons, and
- (10) Storm Regulators.

sewer appurtenances

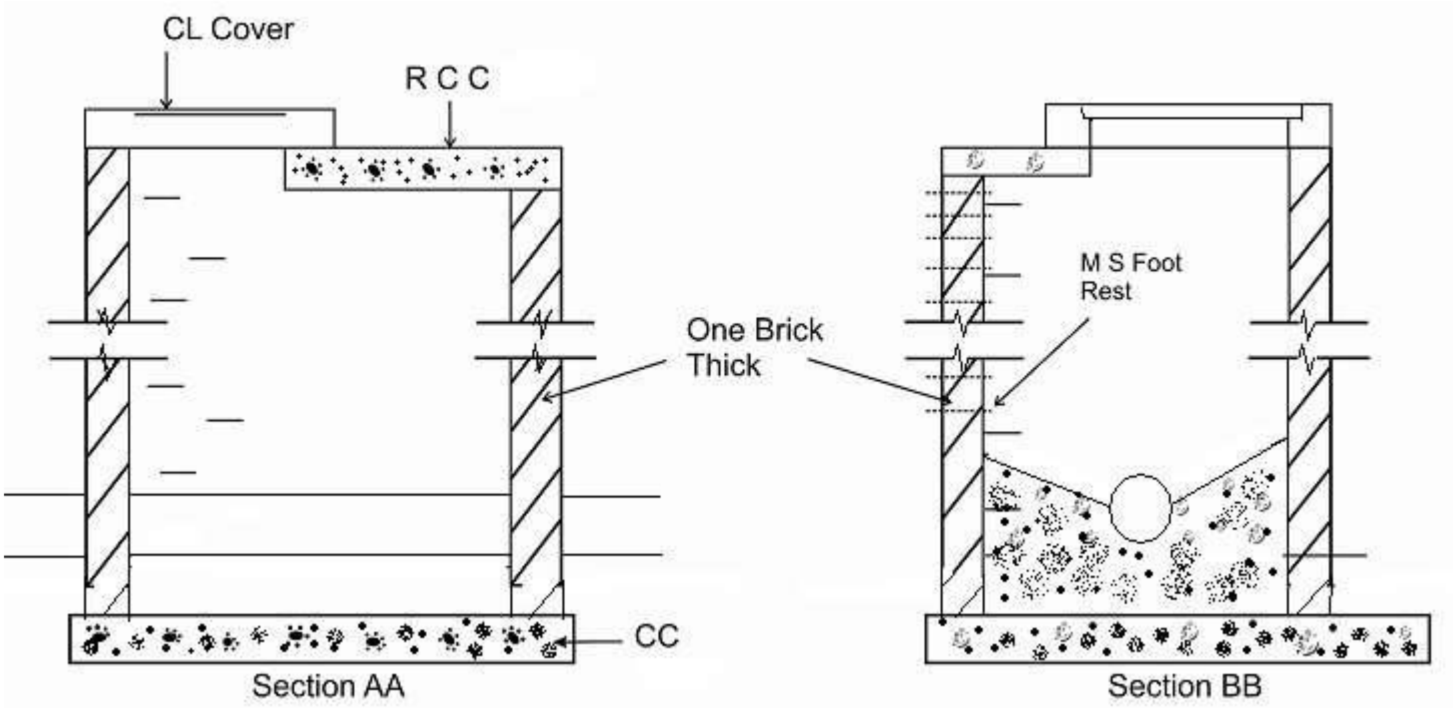
(1) Manholes



Shallow manhole

sewer appurtenances

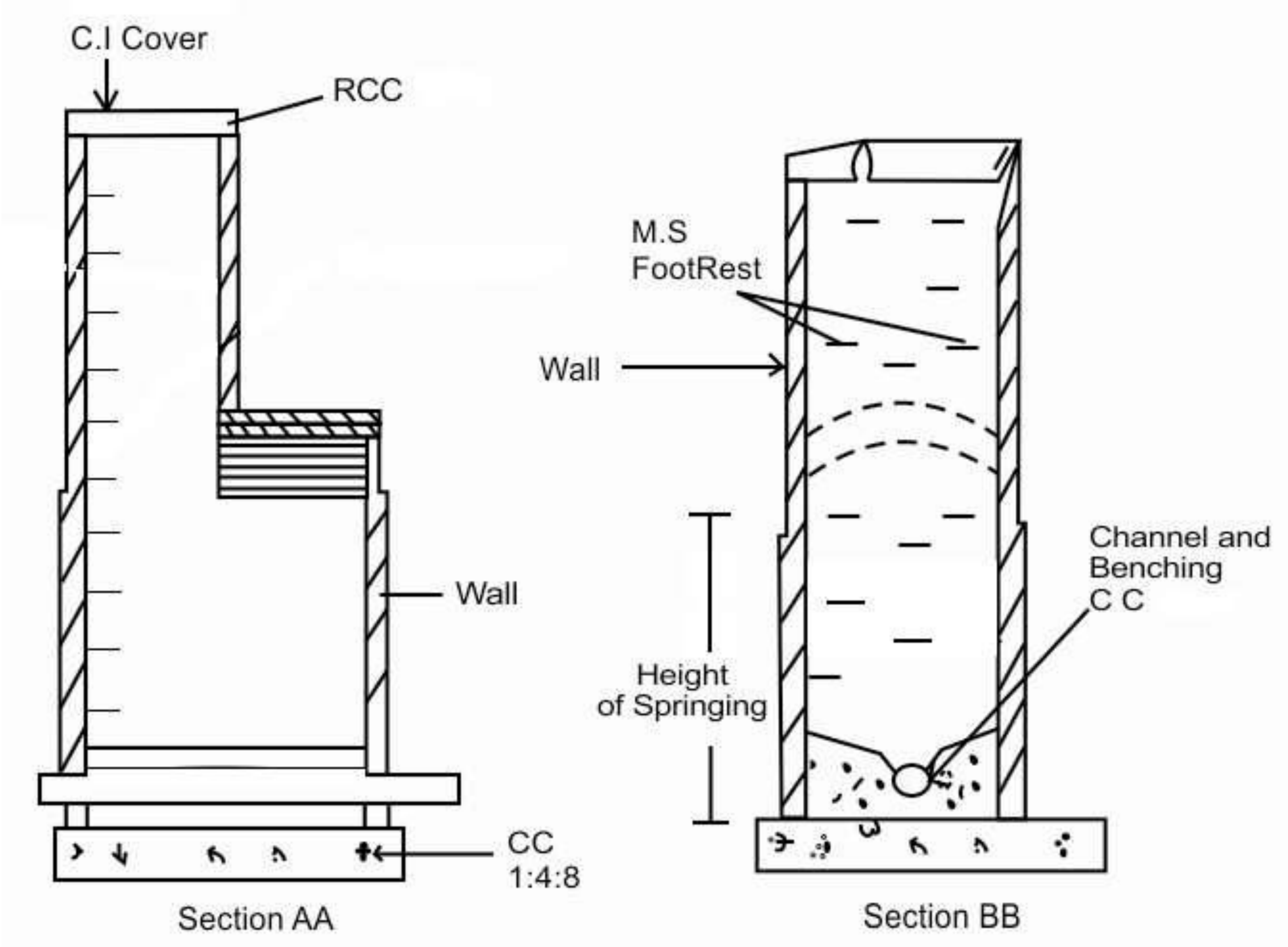
(1) Manholes



Rectangular manhole for depth 0.9 m to 2.5 m

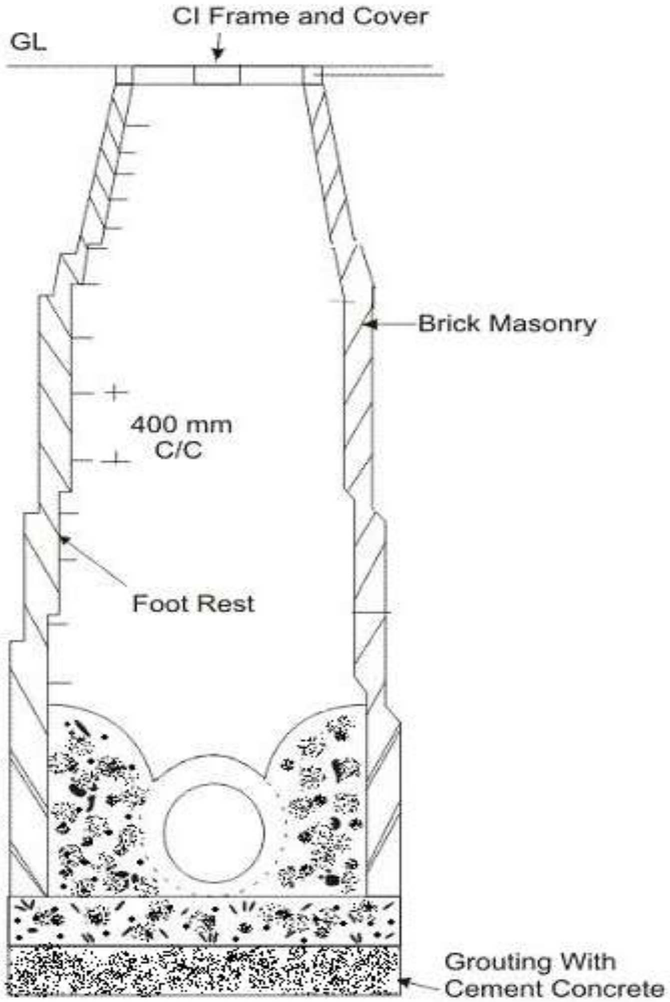
sewer appurtenances

Manholes



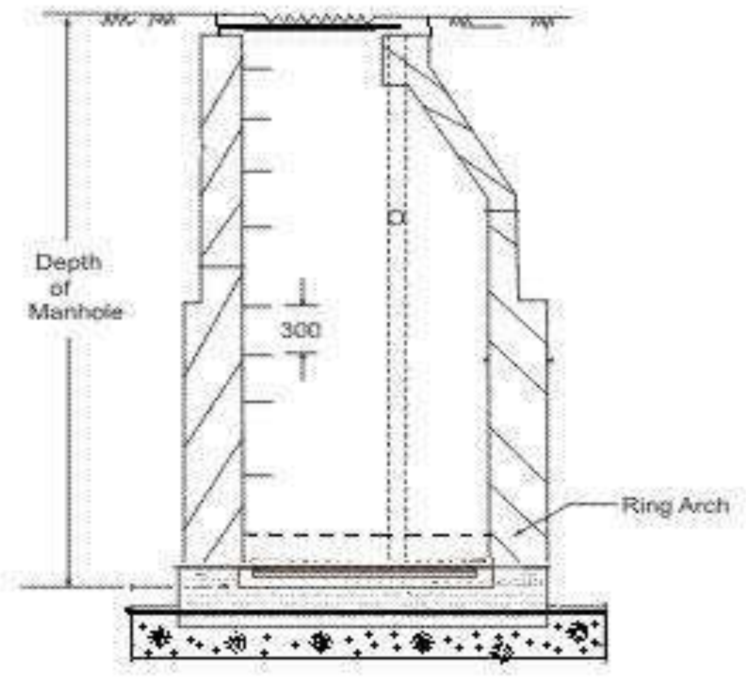
sewer appurtenances

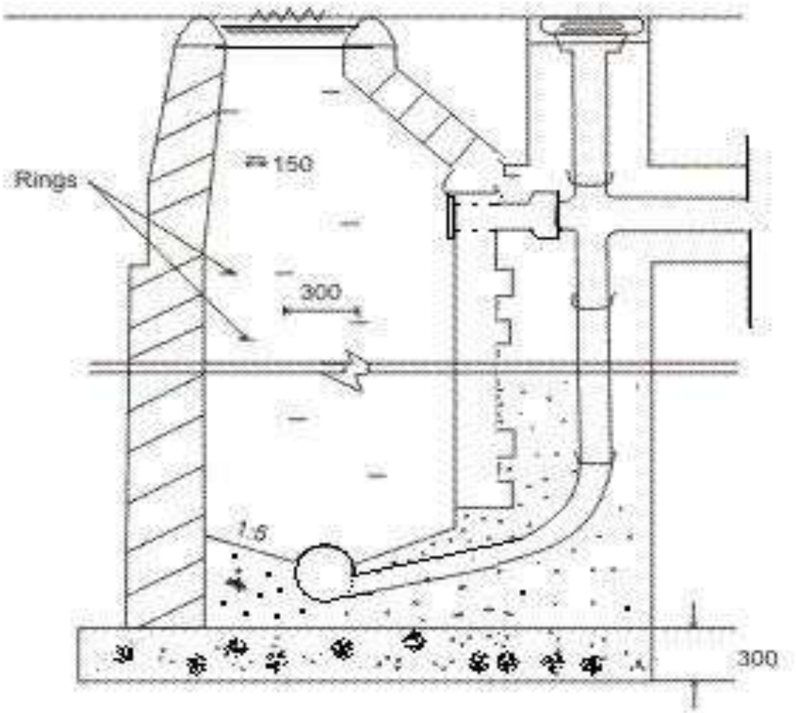
Manholes



sewer appurtenances

(2) Drop manholes





sewer appurtenances

(3) Lamp holes

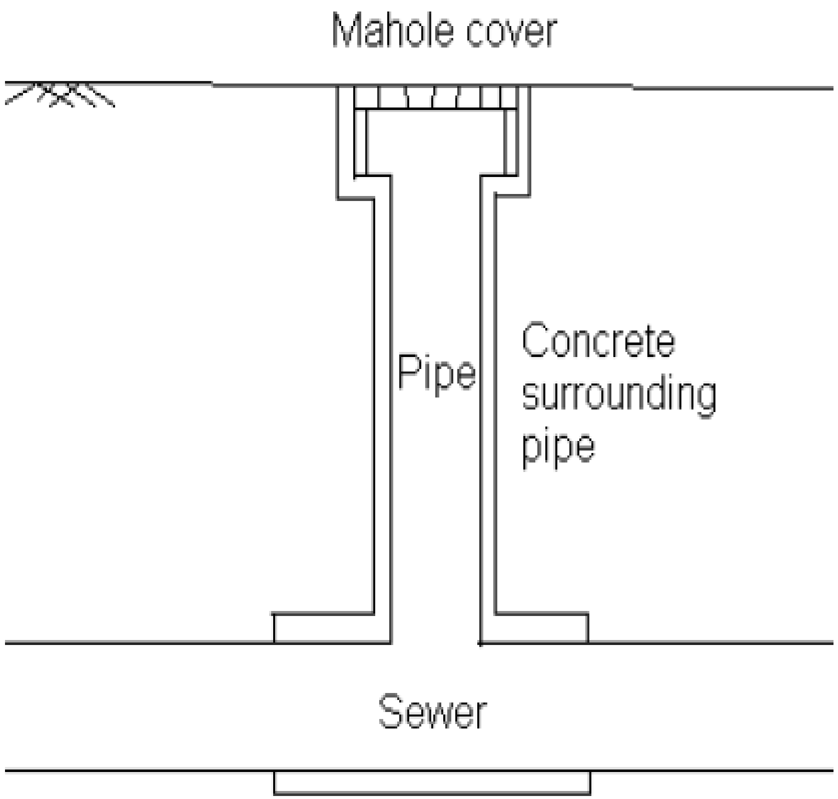
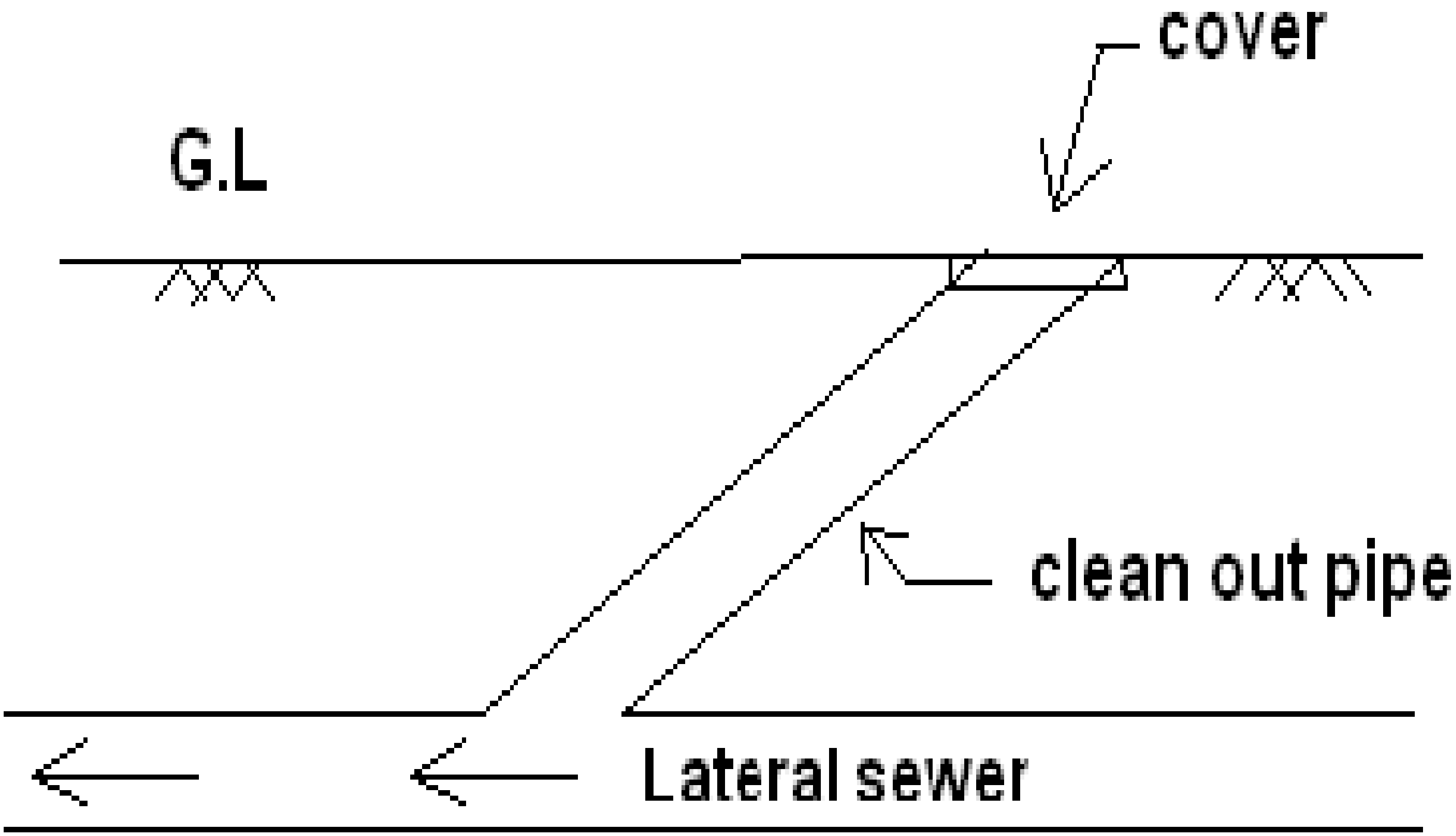


Figure 8.12 Lamp hole

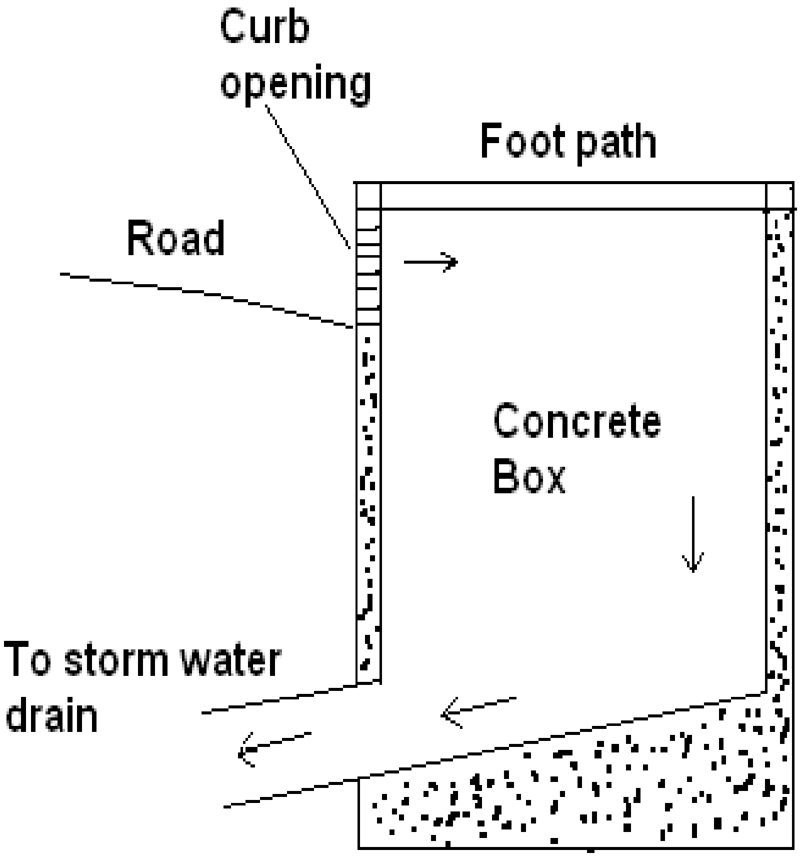
sewer appurtenances

(4) Clean-outs

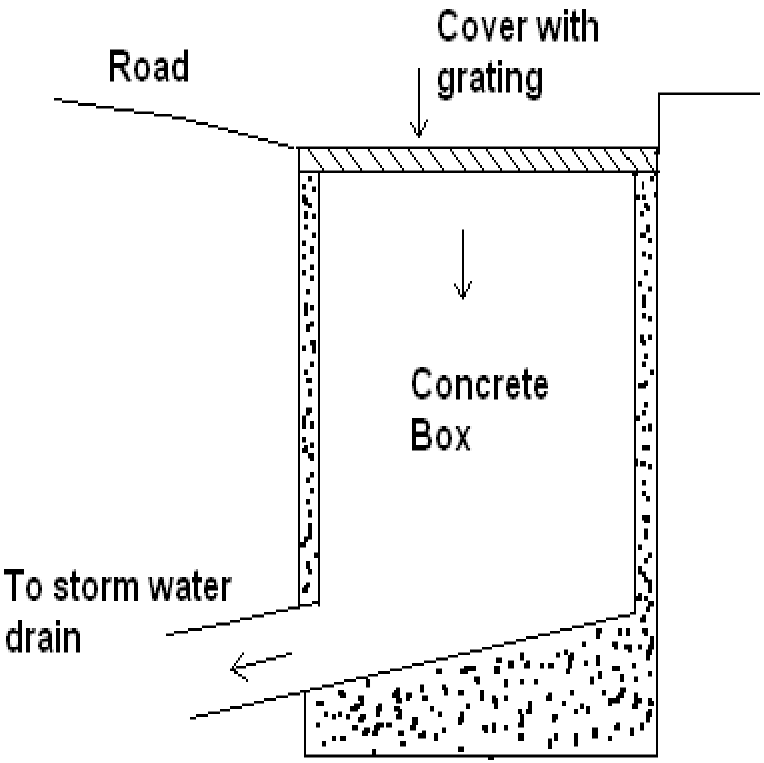


sewer appurtenances

(5) Street inlets called Gullies



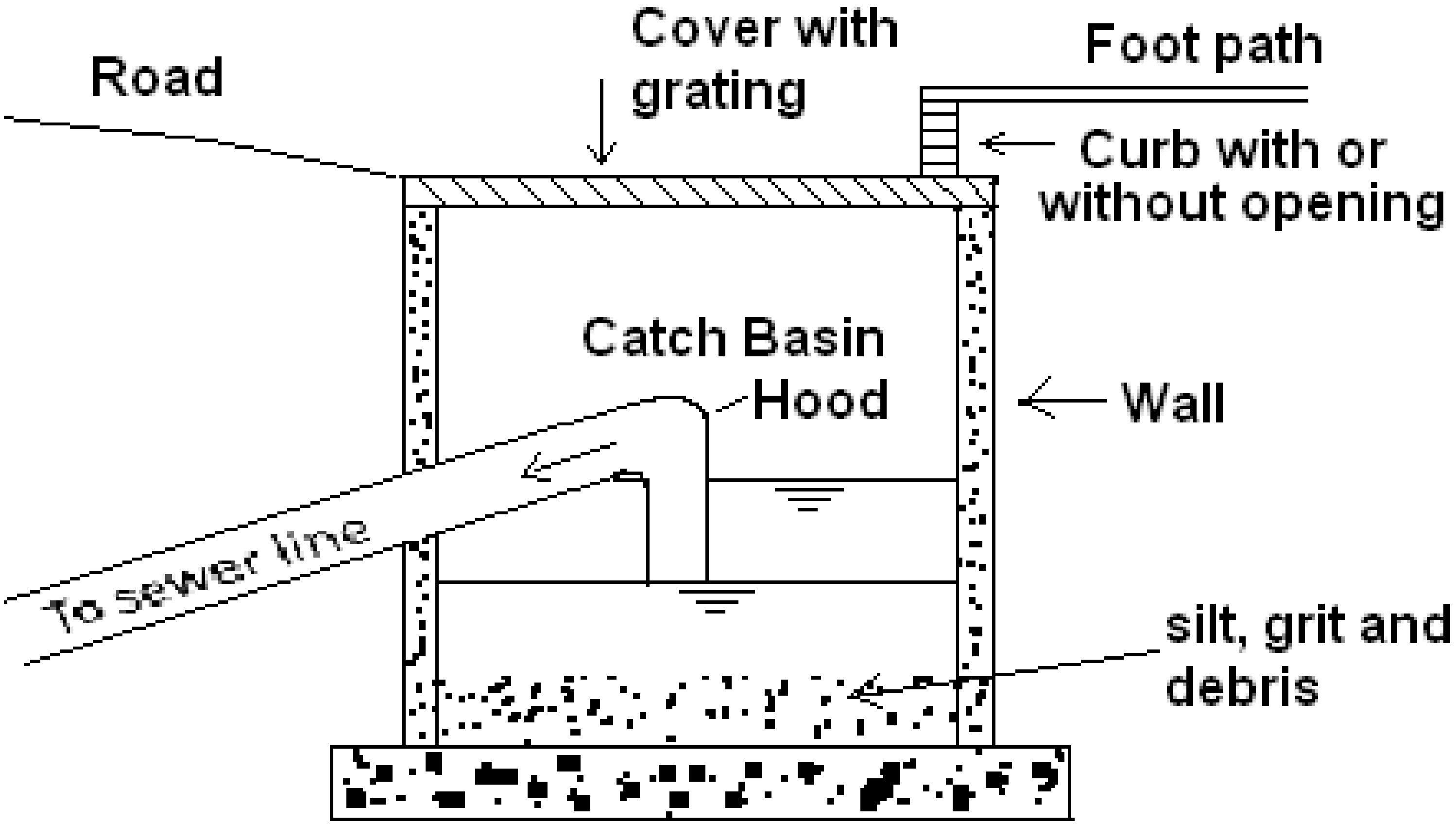
(a) Curb inlet



(b) Gutter inlet

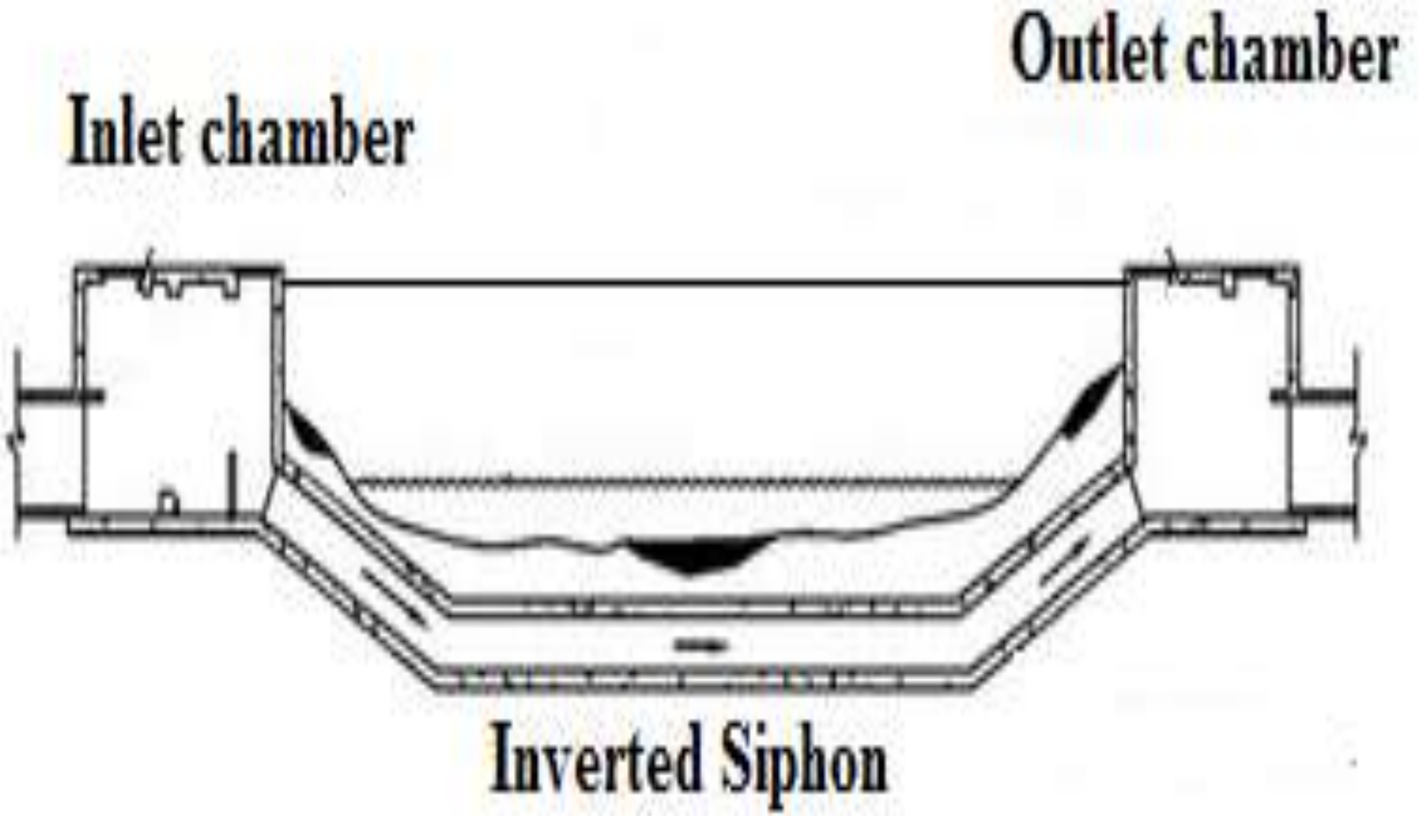
sewer appurtenances

(6) Catch basins,



sewer appurtenances

(9) Inverted Siphons



Pumps

Following types of pumps are used in the sewerage system for pumping of sewage, sewage sludge, grit matter, etc. as per the suitability:

- a. Radial-flow centrifugal pumps
- b. Axial-flow and mixed-flow centrifugal pumps
- c. Reciprocating pistons or plunger pumps
- d. Diaphragm pumps
- e. Rotary screw pumps
- f. Pneumatic ejectors
- g. Air-lift pumps

UNIT II SEWER DESIGN

- Sewerage
- Hydraulics of flow in sewers
- Objectives
- Design period
- Design of sanitary and storm sewers
- Small bore systems
- Computer applications
- Laying, joining & testing of sewers – appurtenances
- Pumps – selection of pumps and pipe Drainage
- Plumbing System for Buildings
- One pipe and two pipe system.

Design period

The future period for which the provision is made in designing the capacities of the various components of the sewerage scheme is known as the design period.

The design period depends upon the following:

- Ease and difficulty in expansion,
- Amount and availability of investment,
- Anticipated rate of population growth, including shifts in communities, industries and commercial investments,
- Hydraulic constraints of the systems designed, and
- Life of the material and equipment.

Design period

Following design period can be considered for different components of sewerage scheme.

- 1. Laterals less than 15 cm diameter : Full development
- 2. Trunk or main sewers : 40 to 50 years
- 3. Treatment Units : 15 to 20 years
- 4. Pumping plant : 5 to 10 years

Design Discharge of Sanitary Sewage

- The total quantity of sewage generated per day is estimated as product of forecasted population at the end of design period considering per capita sewage generation and appropriate peakfactor.
- The per capita sewage generation can be considered as 75 to 80% of the per capita water supplied per day.
- The increase in population also result in increase in per capita water demand and hence, per capita production of sewage.
- This increase in water demand occurs due to increase in living standards, betterment in economical condition, changes in habit of people, and enhanced demand for public utilities.

Factors Considered for Selecting Material for Sewer

Following factors should be considered before selecting material for manufacturing sewer pipes:

a. Resistance to corrosion

- Sewer carries wastewater that releases gases such as H_2S. This gas in contact with moisture can be converted into sulfuric acid. The formation of acids can lead to the corrosion of sewer pipe.
- Hence, selection of corrosion resistance material is must for long life of pipe.

b. Resistance to abrasion

- Sewage contain considerable amount of suspended solids, part of which are inorganic solids such as sand or grit. These particles moving at high velocity can cause wear and tear of sewer pipe internally. This abrasion can reduce thickness of pipe and reduces hydraulic efficiency of the sewer by making the interior surface rough.

Factors Considered for Selecting Material for Sewer

c. Strength and durability

- The sewer pipe should have sufficient strength to withstand all the forces
- Sewers are subjected to considerable external loads of backfill material and traffic load, if any.

  They are not subjected to internal pressure of water. To withstand external load safely without failure, sufficient wall thickness of pipe or reinforcement is essential.

  In addition, the material selected should be durable and should have sufficient resistance against natural weathering action to provide longer life to the pipe.

Factors Considered for Selecting Material for Sewer

d. Weight of the material

- The material selected for sewer should have less specific weight, which will make pipe light in weight. The lightweight pipes are easy for handling and transport.

e. Imperviousness

- To eliminate chances of sewage seepage from sewer to surrounding, the material selected for pipe should be impervious.

f. Economy and cost

g. Hydraulically efficient

- The sewer shall have smooth interior surface to have less frictional coefficient.

Materials for Sewer

1. *Asbestos Cement Sewers*
2. *Plain Cement Concrete or Reinforced Cement Concrete*
3. **Vitrified Clay or Stoneware Sewers**

1) Asbestos Cement Sewers

- These are manufactured from a mixture of asbestos fibers, silica and cement. Asbestos fibers are thoroughly mixed with cement to act as reinforcement.
- Size 10 to 100 cm internal diameter and length up to 4.0 m.
- These pipes can be easily assembled without skilled labour with the help of special coupling, called 'Ring Tie Coupling' or Simplex joint.
- The pipe and joints are resistant to corrosion and the joints are flexible to permit 12° deflection for curved laying.
- These pipes are used for vertical transport of water. For example, transport of rainwater from roofs in multistoried buildings, for transport of sewage to grounds, and for transport of less foul sullage i.e., wastewater from kitchen and bathroom.

Asbestos Cement Sewers

Advantages

- These pipes are light in weight and hence, easy to carry and transport.
- Easy to cut and assemble without skilled labour.
- Interior is smooth (Manning's n = 0.011) hence, can make excellent hydraulically efficient sewer.

Disadvantages

- These pipes are structurally not very strong.
- These are susceptible to corrosion by sulphuric acid. When bacteria produce H_2S, in presence of water, H_2SO_4 can be formed leading to corrosion of pipe material.

2) Plain Cement Concrete or Reinforced Cement Concrete

- Plain cement concrete (1: 1.5: 3) pipes are available up to 0.45 m diameter and reinforcement
- Cement pipes are available up to 1.8 m diameter. These pipes can be cast in situ or precast pipes.
- Precast pipes are better in quality than the cast in situ pipes.

2) PLAIN CEMENT CONCRETE OR REINFORCED CEMENT CONCRETE

The reinforcement in these pipes can be different such as

- single cage reinforced pipes, used for internal pressure < 0.8 m;
- double cage reinforced pipes used for both internal and external pressure > 0.8 m;
- elliptical cage reinforced pipes are used for larger diameter sewers subjected to external pressure
- and Hume pipes with steel shells coated with concrete from inside and outside. Nominal longitudinal reinforcement of 0.25% is provided in these pipes.

Plain Cement Concrete or Reinforced Cement Concrete

Advantages

- Strong in tension as well as compression.
- Resistant to erosion and abrasion.
- They can be made of any desired strength.
- Easily molded, and can be in situ or precast pipes.
- Economical for medium and large sizes.
- These pipes are available in wide range of size and the trench can be opened and backfilled rapidly during maintenance of sewers.

Plain Cement Concrete or Reinforced Cement Concrete

Disadvantages

- These pipes can get corroded and pitted by the action of H_2SO_4.
- The carrying capacity of the pipe reduces with time because of corrosion.
- The pipes are susceptible to erosion by sewage containing silt and grit.
- The concrete sewers can be protected internally by vitrified clay linings. With protection lining they are used for almost all the branch and main sewers. Only high alumina cement concrete should be used when pipes are exposed to corrosive liquid like sewage.

3) Vitrified Clay or Stoneware Sewers

These pipes are used for house connections as well as lateral sewers.

- The size of the pipe available is 5 cm to 30 cm internal diameter with length 0.9 to 1.2 m.
- These pipes are rarely manufactured for diameter greater than 90 cm.
- These are joined by bell and spigot flexible compression joints.

3) Vitrified Clay or Stoneware Sewers

Advantages

- Resistant to corrosion, hence fit for carrying polluted water such as sewage.
- Interior surface is smooth and is hydraulically efficient.
- The pipes are highly impervious.
- Strong in compression.
- These pipes are durable and economical for small diameters.
- The pipe material does not absorb water more than 5% of their own weight, when immersed in water for 24 h.

3) Vitrified Clay or Stoneware Sewers

Disadvantages

- Heavy, bulky and brittle and hence, difficult to transport.
- These pipes cannot be used as pressure pipes, because they are weak in tension.
- These require large number of joints as the individual pipe length is small.

4) *Brick Sewers*

- This material is used for construction of large size combined sewer or particularly for storm water drains.
- The pipes are plastered from outside to avoid entry of tree roots and groundwater through brick joints.
- These are lined from inside with stone ware or ceramic block to make them smooth and hydraulically efficient.
- Lining also makes the pipe resistant to corrosion.

5) Cast Iron Sewers

- These pipes are stronger and capable to withstand greater tensile, compressive, as well as bending stresses.
- However, these are costly. Cast iron pipes are used for outfall sewers, rising mains of pumping stations, and inverted siphons, where pipes are running under pressure.
- These are also suitable for sewers under heavy traffic load, such as sewers below railways and highways.
- They are used for carried over piers in case of low lying areas.

5) Cast Iron Sewers

- They form 100% leak proof sewer line to avoid groundwater contamination.
- They are less resistant to corrosion; hence, generally lined from inside with cement concrete, coal tar paint, epoxy, etc.
- These are joined together by bell and spigot joint.
- IS:1536-1989 and IS:1537-1976 provides the specifications for spun and vertically cast pipes, respectively.

6) Steel Pipes

- These are used under the situations such as pressure main sewers, under water crossing, bridge crossing, necessary connections for pumping stations, laying pipes over self supporting spans, railway crossings, etc.
- They can withstand internal pressure, impact load and vibrations much better than CI pipes.
- They are more ductile and can withstand water hammer pressure better.

6) Steel Pipes

- These pipes cannot withstand high external load and these pipes may collapse when negative pressure is developed in pipes.
- They are susceptible to corrosion and are not generally used for partially flowing sewers.
- They are protected internally and externally against the action of corrosion.

7) Ductile Iron Pipes

- Ductile iron pipes can also be used for conveying the sewers.
- They demonstrate higher capacity to withstand water hammer. The specifications for DI pipes is provided in IS:12288-1987.
- The predominant wall material is ductile iron, a spheroidized graphite cast iron. Internally these pipes are coated with cement mortar lining or any other polyethylene or poly wrap or plastic bagging/ sleeve lining to inhibit corrosion from the wastewater being conveyed, and various types of external coating are used to inhibit corrosion from the environment.
- Ductile iron has proven to be a better pipe material than cast iron but they are costly.

7) Ductile Iron Pipes

- Ductile iron is still believed to be stronger and more fracture resistant material.
- However, like most ferrous materials it is susceptible to corrosion.
- A typical life expectancy of thicker walled pipe could be up to 75 years, however with the current thinner walled ductile pipe the life could be about 20 years in highly corrosive soils without a corrosion control program like cathodic protection.

8) Plastic sewers (PVC pipes)

- Plastic is recent material used for sewer pipes. These are used for internal drainage works in house.
- These are available in sizes 75 to 315 mm external diameter and used in drainage works.
- They offer smooth internal surface.
- The additional advantages they offer are resistant to corrosion, light weight of pipe, economical in laying, jointing and maintenance, the pipe is tough and rigid, and ease in fabrication and transport of these pipes.

9) High Density Polythylene (HDPE) PIPES

- Use of these pipes for sewers is recent development.
- They are not brittle like AC pipes and other pipes and hence hard fall during loading, unloading and handling do not cause any damage to the pipes.
- They can be joined by welding or can be jointed with detachable joints up to 630 mm diameter (IS:4984-1987).
- These are commonly used for conveyance of industrial wastewater.

9) High Density Polythylene (HDPE) PIPES

- They offer all the advantages offered by PVC pipes.
- PVC pipes offer very little flexibility and normally considered rigid; whereas, HDPE pipes are flexible hence best suited for laying in hilly and uneven terrain.
- Flexibility allows simple handling and installation of HDPE pipes. Because of low density, these pipes are very light in weight.
- Due to light in weight, they are easy for handling, this reduces transportation and installation cost.
- HDPE pipes are non corrosive and offer very smooth inside surface due to which pressure losses are minimal and also this material resist scale formation.

10) Glass Fiber Reinforced Plastic Pipes

- This martial is widely used where corrosion resistant pipes are required.
- Glass fiber reinforced plastic (GRP) can be used as a lining material for conventional pipes to protect from internal or external corrosion. It is made from the composite matrix of glass fiber, polyester resin and fillers.
- These pipes have better strength, durability, high tensile strength, low density and high corrosion resistance.
- These are manufactured up to 2.4 m diameter and up to 18 m length (IS:12709-1989).
- Glass reinforced plastic pipes represent the ideal solution for transport of any kind of water, chemicals, effluent and sewage, because they combine the advantages of corrosion resistance with a mechanical strength which can be compared with the steel pipes.

10) Glass Fiber Reinforced Plastic Pipes

Advantages

- Light weight of pipes that allows for the use of light laying and transport means.
- Possibility of nesting of different diameters of pipe thus allowing additional saving in transport cost.
- Length of pipe is larger than other pipe materials.
- Easy installation procedures due to the kind of mechanical bell and spigot joint.
- Corrosion resistance material, hence no protections such as coating, painting or cathodic are then necessary.

10) Glass Fiber Reinforced Plastic Pipes

Advantages

- Smoothness of the internal wall that minimizes the head loss and avoids the formation of deposits.
- High mechanical resistance due to the glass reinforcement.
- Absolute impermeability of pipes and joints both from external to internal and viceversa.
- Very long life of the material.

11) Lead Sewers

- They are smooth, soft and can take odd shapes.
- This pipe has an ability to resist sulphide corrosion.
- However, these pipes are very costly.
- These are used in house connection.

UNIT II SEWER DESIGN

- Sewerage
- Hydraulics of flow in sewers
- Objectives
- Design period
- Design of sanitary and storm sewers
- Small bore systems
- Computer applications
- Laying, joining & testing of sewers – appurtenances
- Pumps – selection of pumps and pipe Drainage
- Plumbing System for Buildings
- One pipe and two pipe system.

Requirements of Design and Planning of Sewerage System

Following aspects should be considered while designing the system.

☐ The sewers provided should be adequate in size to avoid overflow and possible health hazards.

☐ For evaluating proper diameter of the sewer, correct estimation of sewage discharge is necessary.

☐ The flow velocity inside the sewer should neither be so large as to require heavy excavation and high lift pumping, nor should be so small causing deposition of the solid in the sewers.

☐ The sewers should be laid at least 2 to 3 m deep to carry sewage from basement.

Requirements of Design and Planning of Sewerage System

☐ The sewage in sewer should flow under gravity with 0.5 to 0.8 full at designed discharge, i.e. at the maximum estimated discharge.

☐ The sewage is conveyed to the point usually located in low-lying area, where the treatment plant is located.

☐ Treatment plant should be designed taking into consideration the quality of raw sewage expected and to meet the discharge standards.

The extra space provided in the sewers provides factor of safety to counteract against the following factors:

1. Safeguard against lower estimation of the quantity of wastewater to be collected at the end of design period due to private water supply by industries and public. Thus, to ensure that sewers will never flow full eliminating pressure flow inside the sewer.

2. Large scale infiltration of storm water through wrong or illegal connection, through underground cracks or open joints in the sewers.

3. Unforeseen increase in population or water consumption and the consequent increase in sewage production.

General Considerations

- Design of sewerage system is based on the prospective population at the end of design period which is around 30 years.
- The increase in the capacity of sewers may be kept as 25 percent.

- Sewers in separate system are designed to have a carrying capacity equal to 2-3.5 times the dry weather flow. Generally peak factor of 3 is taken.

- Laterals and sub-main sewers- 3 times
- Main/trunk sewers – 2 times

- Sewers in combined system should be capable of carrying at least 2times the DWF in addition to storm water.

- Sewers are designed to flow 0.8 running full when discharging peak flow.

- Self cleansing velocity – 0.75m/s – Separate System
- 0.6-0.9 m/s – Combined system

Design calculations

Quantities involved: Discharge(q),Velocity(v),Hydraulic mean depth(m) and Gradient(i)

$$Q = AV$$

V is determined by various formulas like manning etc.

m and i will be provided or calculated.

For sewers running partly full, these calculations are cumbersome as for a sewer section, the values of m,A,V,Q vary with depth of sewage in sewer.

To ease the calculations, we use Graph prepared based on Crimp and Burges formula.

For a given sewer reach, design flow is computed from the following relationship.

$$Q = A * P_d * q_m$$

Q = Design flow, litres/day,

A= Tributary Area, hectares(ha),

Pd = population density, Persons/Ha

qm = Max daily sewage flow, lpcd

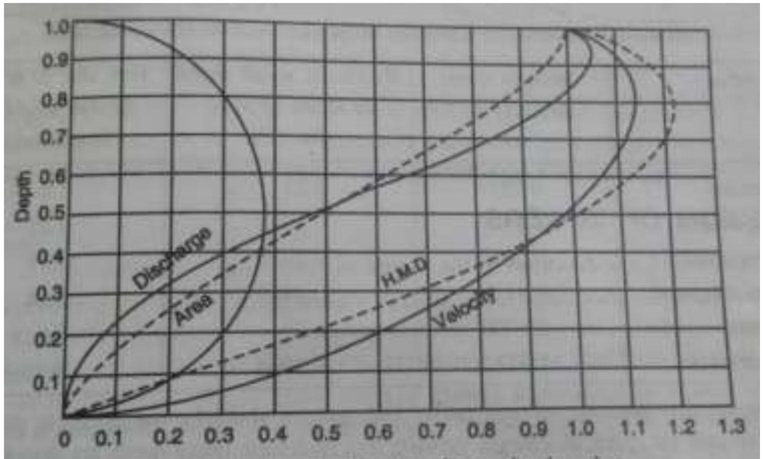


Fig. 2.6. Hydraulic elements for a circular pipe

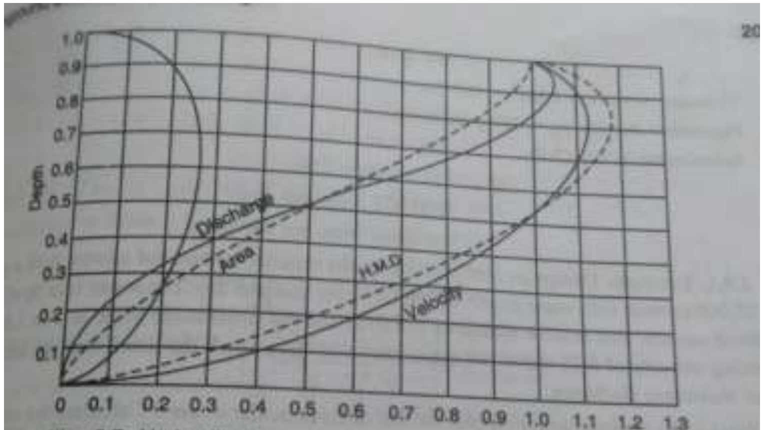
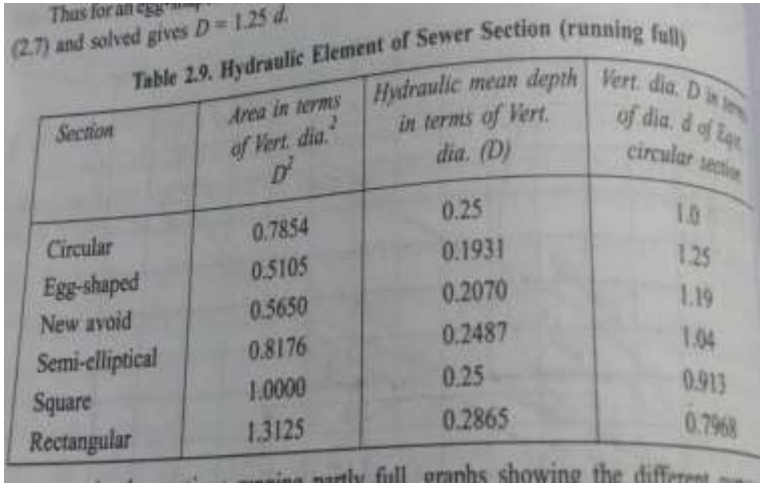


Fig. 2.7. Hydraulic elements curve for standard ovoid sewers


Thus for an egg-

(2.7) and solved gives $D = 1.25\ d$.

Table 2.9. Hydraulic Element of Sewer Section (running full)

Section	*Area in terms of Vert. dia.² D^2*	*Hydraulic mean depth in terms of Vert. dia. (D)*	*Vert. dia. D in ter of dia. d of Equ circular sectio*
Circular	0.7854	0.25	1.0
Egg-shaped	0.5105	0.1931	1.25
New avoid	0.5650	0.2070	1.19
Semi-elliptical	0.8176	0.2487	1.04
Square	1.0000	0.25	0.913
Rectangular	1.3125	0.2865	0.7968

partly full graphs showing the different

Graph prepared based on Crimp and Burges formula.

Q: A main sewer is to be designed to receive a flow of 1km2 area of a community where the population density is 200 persons/ha. The average sewage flow is 150lpcd. What is the design flow for the main sewer?

Sol:

DWF = 150lpcd

Assuming a peak factor of 3,

Max flow,qm = 3*150 = 450lpcd

Tributary area A = 1km2 =100ha

Population density = 200persons/ha

Q = A * Pd*qm

= 100 * 200*450

=9MLD

Design an outfall sewer in the separate system for a town with a population of 125000 with water supply at 180lpcd.The sewer is to be of brickwork rendered smooth with cement mortar(n=0.012) and the permissible slope of 1in 1000.A self cleansing velocity of 0.75 m/s is to be developed ; the dwf may be taken as 1/3 of max discharge.

Sol

Assuming sewage flow to be 80% of water supply per head

DWF = 125000 * 0.8*180/1000*24*60*60 = 0.208m3/s

Max flow = 3 * 0.208 = 0.624m3/s

For circular sewer flowing full,

Q = 0.624 = AV

➔ 0.624 = (πd2)/4 * 1/0.0012 * (d/4)2/3 * (1/1000)1/2

➔ On solving above equation , we get d = 0.825m

➔ Velocity at full flow = v = 0.624/ (πd2)/4 = 1.17m/s

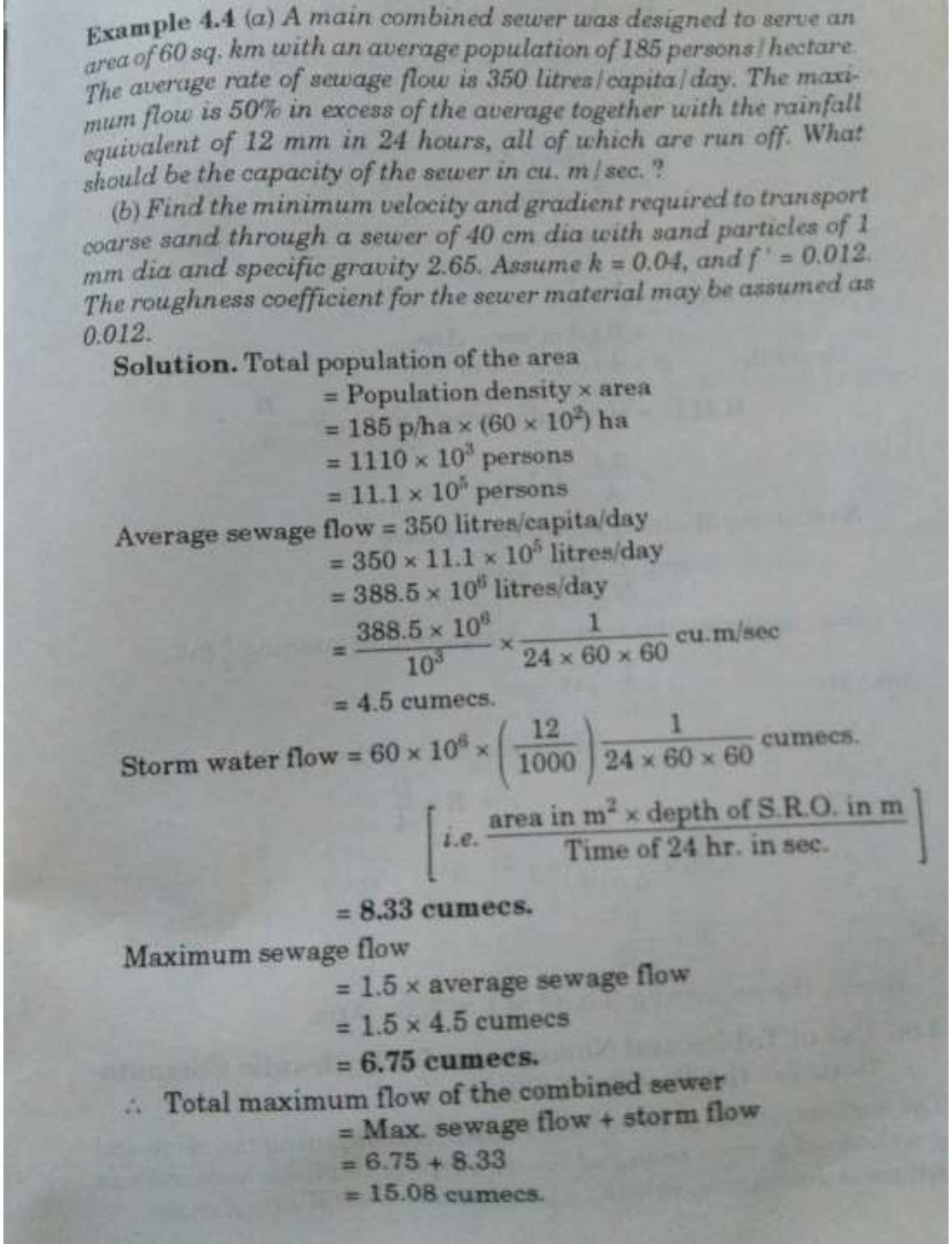
➔ For condition of dwf, discharge ratio = 1/3 = 0.33

➔ From crimps curve, for discharge ratio of 0.33,

➔ Depth ratio = 0.4

➔ Velocity ratio = 0.88

➔ Therefore Velocity at dwf = 0.88 * 1.17 = 1.02m/s



Example 4.4 (*a*) *A main combined sewer was designed to serve an area of 60 sq. km with an average population of 185 persons/hectare. The average rate of sewage flow is 350 litres/capita/day. The maximum flow is 50% in excess of the average together with the rainfall equivalent of 12 mm in 24 hours, all of which are run off. What should be the capacity of the sewer in cu. m/sec.?*

(*b*) *Find the minimum velocity and gradient required to transport coarse sand through a sewer of 40 cm dia with sand particles of 1 mm dia and specific gravity 2.65. Assume k = 0.04, and f' = 0.012. The roughness coefficient for the sewer material may be assumed as 0.012.*

Solution. Total population of the area

$$= \text{Population density} \times \text{area}$$
$$= 185 \text{ p/ha} \times (60 \times 10^2) \text{ ha}$$
$$= 1110 \times 10^3 \text{ persons}$$
$$= 11.1 \times 10^5 \text{ persons}$$

Average sewage flow = 350 litres/capita/day

$$= 350 \times 11.1 \times 10^5 \text{ litres/day}$$
$$= 388.5 \times 10^6 \text{ litres/day}$$
$$= \frac{388.5 \times 10^6}{10^3} \times \frac{1}{24 \times 60 \times 60} \text{ cu.m/sec}$$
$$= 4.5 \text{ cumecs.}$$

$$\text{Storm water flow} = 60 \times 10^6 \times \left(\frac{12}{1000}\right)\frac{1}{24 \times 60 \times 60} \text{ cumecs.}$$

$$\left[\textit{i.e.} \frac{\text{area in m}^2 \times \text{depth of S.R.O. in m}}{\text{Time of 24 hr. in sec.}}\right]$$

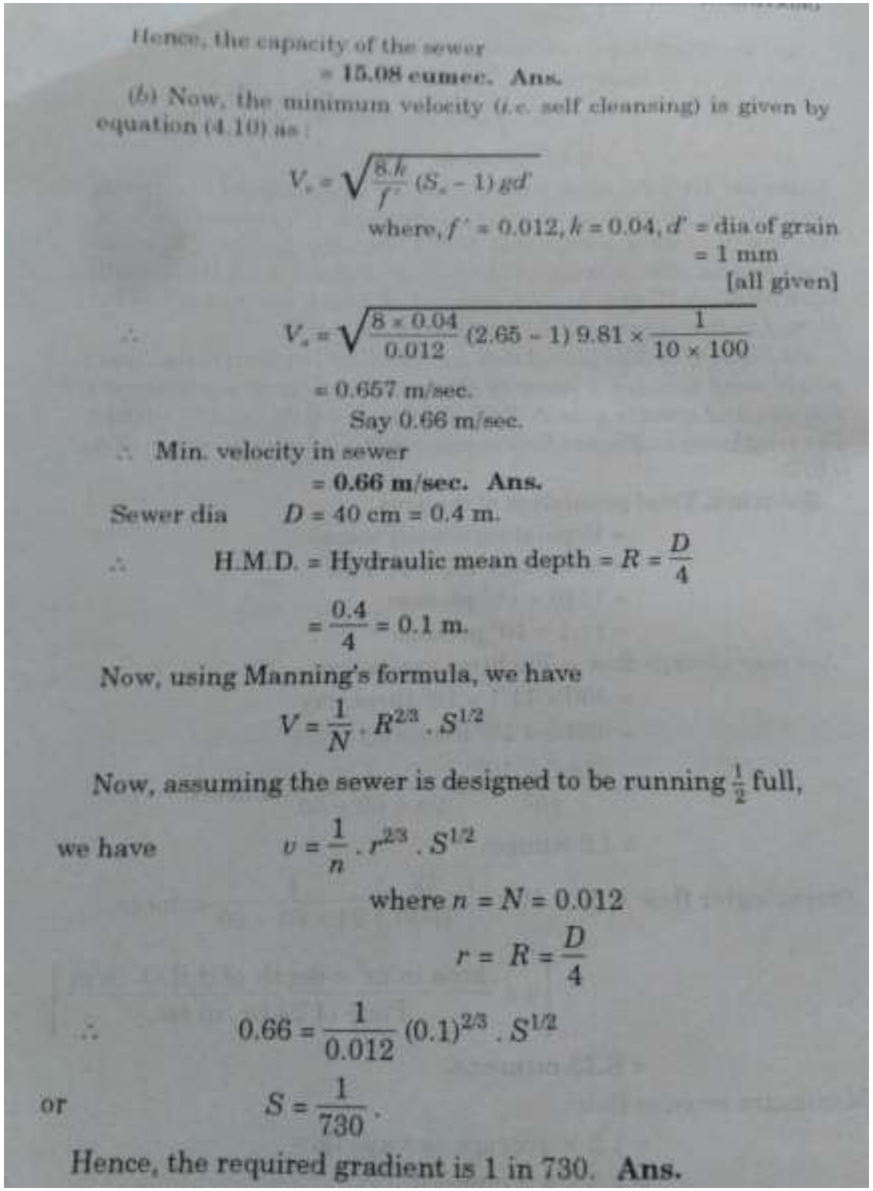
$$= \mathbf{8.33 \text{ cumecs.}}$$

Maximum sewage flow

$$= 1.5 \times \text{average sewage flow}$$
$$= 1.5 \times 4.5 \text{ cumecs}$$
$$= \mathbf{6.75 \text{ cumecs.}}$$

∴ Total maximum flow of the combined sewer

$$= \text{Max. sewage flow} + \text{storm flow}$$
$$= 6.75 + 8.33$$
$$= 15.08 \text{ cumecs.}$$



Hence, the capacity of the sewer

= **15.08 cumec. Ans.**

(*b*) Now, the minimum velocity (*i.e.* self cleansing) is given by equation (4.10) as :

$$V_s = \sqrt{\frac{8.k}{f'}(S_s - 1)\,gd'}$$

where, $f' = 0.012$, $k = 0.04$, d' = dia of grain
= 1 mm
[all given]

$$\therefore \quad V_s = \sqrt{\frac{8 \times 0.04}{0.012}(2.65 - 1)\,9.81 \times \frac{1}{10 \times 100}}$$

= 0.657 m/sec.
Say 0.66 m/sec.

∴ Min. velocity in sewer

= **0.66 m/sec. Ans.**

Sewer dia $D = 40$ cm = 0.4 m.

$$\therefore \quad \text{H.M.D.} = \text{Hydraulic mean depth} = R = \frac{D}{4}$$

$$= \frac{0.4}{4} = 0.1 \text{ m.}$$

Now, using Manning's formula, we have

$$V = \frac{1}{N} . R^{2/3} . S^{1/2}$$

Now, assuming the sewer is designed to be running $\frac{1}{2}$ full,

we have $$v = \frac{1}{n} . r^{2/3} . S^{1/2}$$

where $n = N = 0.012$

$$r = R = \frac{D}{4}$$

$$\therefore \quad 0.66 = \frac{1}{0.012}(0.1)^{2/3} . S^{1/2}$$

or $$S = \frac{1}{730}.$$

Hence, the required gradient is 1 in 730. **Ans.**

Surface and Storm Water Drainage

- When rain fall over the ground surface a part of it percolate in the ground a part is evaporated in the atmosphere and remaining part overflows as storm and flood water.
- The quantity of storm water reaching the sewer is very large as compared to sanitary sewer (DWF)

Factor Affecting Storm Water Drainage

- Quantity of storm water from an area depend upon
  - Intensity and duration of rain fall- an increase in this result in increase in storm water
- Topography of water shed

This includes

Extent of area drain- bigger the area commended by a storm of sufficient duration grater would be the extend of area drain

Shape of area- fan shaped areas drain away discharge more quickly then oblong shaped area

Slope of area- on steeper slope, rate of storm water rate of flow would be greater

Nature of soil-permeability, vegetation and built-up area also influence flow. Run-off normally increases with increase in imperviousness and decreases with forest and vegetation growth

Factor Affecting Storm Water Drainage

- Number of available ditches in the area- if number is large part of storm water may be retained or removed thus decreasing quantity available for providing storm water drainage

- Humidity, Wind and temperature
  - Greater humidity, high wind and warm temperature tend to reduce storm water flow.

Determination of Storm water flow

Rational Method

- Based on the area of watershed to be drained, impermeability of the ground surface and the rainfall intensity over the surface, the rational formula is given by

Q = CAIR

Q = rate of runoff

A = Area of watershed being drained

I = Relative imperviousness

C = constant(1/360)

R = Rainfall intensity

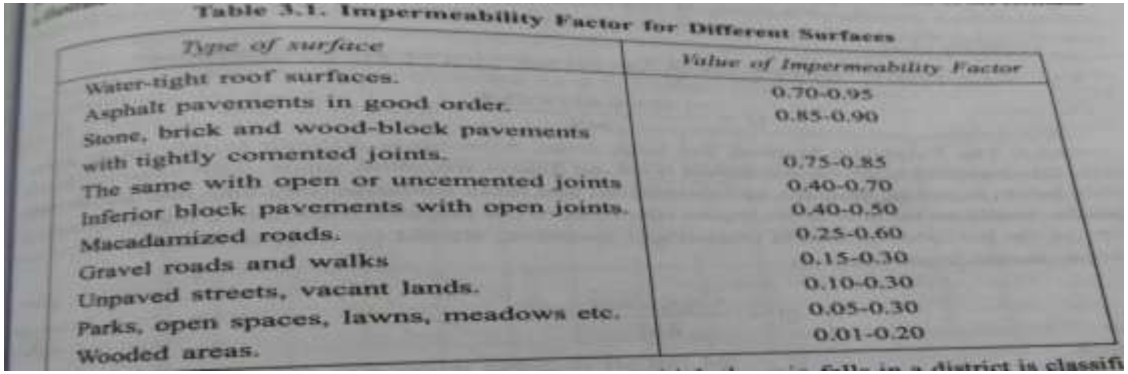


Table 3.1. Impermeability Factor for Different Surfaces

Type of surface	*Value of Impermeability Factor*
Water-tight roof surfaces.	0.70-0.95
Asphalt pavements in good order.	0.85-0.90
Stone, brick and wood-block pavements with tightly comented joints.	0.75-0.85
The same with open or uncemented joints	0.40-0.70
Inferior block pavements with open joints.	0.40-0.50
Macadamized roads.	0.25-0.60
Gravel roads and walks	0.15-0.30
Unpaved streets, vacant lands.	0.10-0.30
Parks, open spaces, lawns, meadows etc.	0.05-0.30
Wooded areas.	0.01-0.20

Q: Assuming that the surface on which the rail falls in a district is classified as follows:

20% of the area consists of roofs for which the runoff ratio is taken as 0.90,25% of the area consists of pavements for which the runoff ration is 0.85,50% of the area consists of lawns, gardens for which the runoff ratio is 0.10 and remaining 5% of the area is wooded for which the runoff ratio is 0.05. Determine the coefficient of runoff.

If the total area of the district is 1.62 hectares and the max intensity is taken as 62.5mm, what is the runoff for the district.

Sol:

Runoff coefficient I may be computed as

$I = A_1I_1 + A_2I_2 + A_3I_3 \ldots\ldots.. A_NI_N/(A_1+A_2+A_3+\ldots.A_N)$

A1I1 = 20A * 0.90/100; A2I2 = 25A*0.85/100 ; A3I3 = 50A*0.1/100

A4I4 = 5A*0.05/100

➔ I = 0.445

➔ Q = AIR/360 = > 1.62*0.445*62.5/360 = 0.125m3/s

Design of Storm water Sewers

Following procedure is commonly used:

A) Divide the map of a district to be drained into a number of tributary areas, each to be served by one sewer. Mark sewer lines on the plan and calculate the area served by each sewer.

B) Reduce each sewered area in to its equivalent impermeable area(Area * Impermeability factor)

C) Draw Sections along line of sewers and determine the gradients at which the sewers are proposed to be laid.

D) Assume probable size of the sewer and find the velocity of flow through the sewer at available gradient by using hydraulic formulae.

E) Find out the time of concentration by adding to the time to flow already determined, an assumed value of inlet time.

F) Determine the rainfall intensity by using Ministry of Health formula

$$R = A/t^n \quad \text{and} \qquad R = A/(t+B)$$

R = intensity of rainfall in mm/hr in min

t = duration of storm in min

A,B,n are constants

A = 30, 40 for 5-20min and 20-30 min duration storms

B = 10,20 for 5-20min and 20-30 min duration storms.

R = 30/(t+10) for 5-20 min storm

R = 40/(t+20) for 20-100 min storm

Where R is in inches/hr and t in minutes

R = 760/(t+10) for 5-20min storm

R = 1020/(t+20) for 20-100 min storm

Where R is in mm/hr(metric units)

- Calculate the quantity of storm water flow per unit time using Lloyd Davis formula

Q = 60.5(60r/T)AI = 60.5RAI

Q = discharge in cubic feet /min

A = area in acres

R = total rainfall in inches

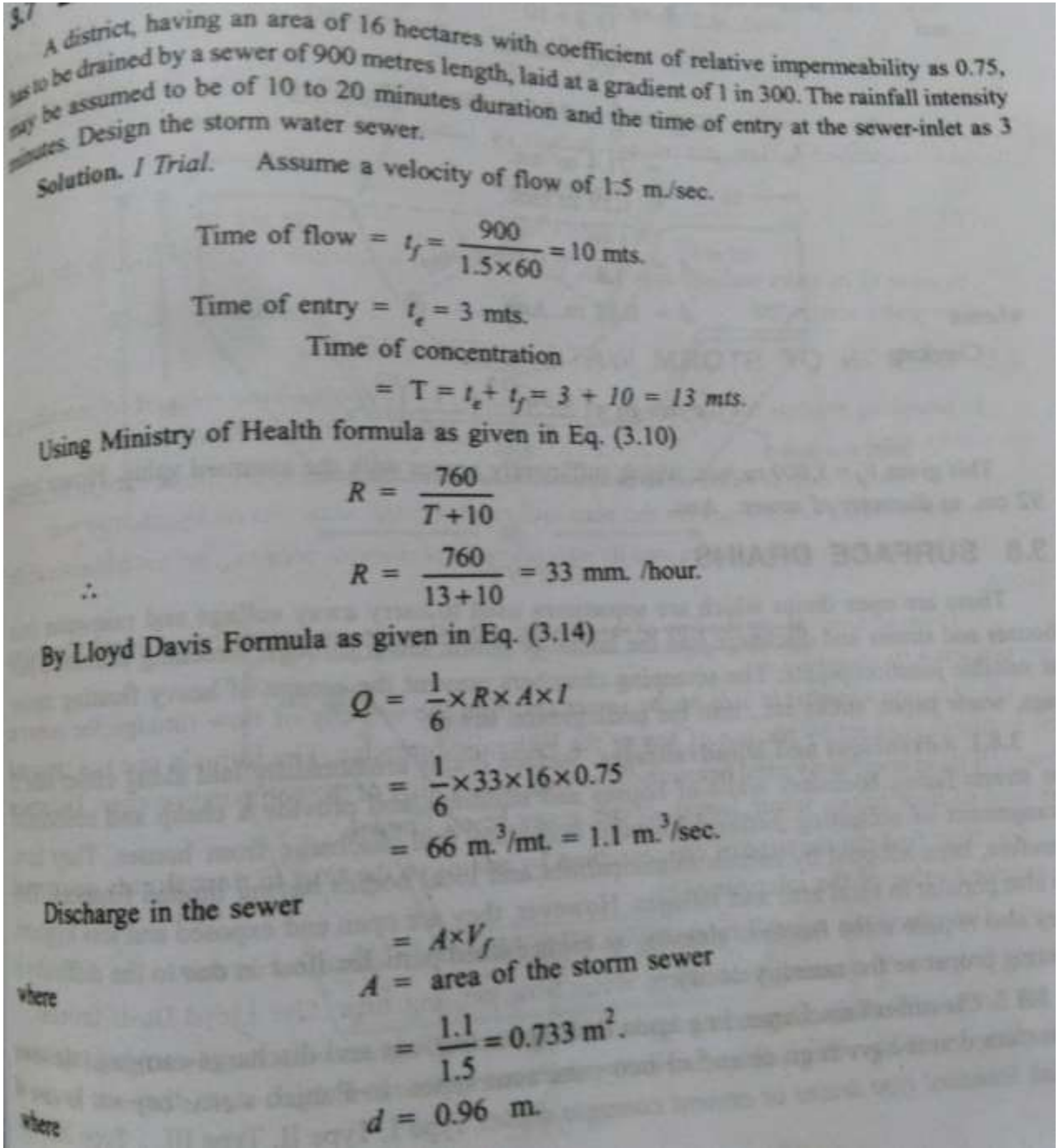
T = time of concentration in minutes

I = Impermeability factor

60.5 a constant expressed in cu.ft per mt per acre of 1 inch rainfall

Q = RAI/6(Metric units)

- If the runoff discharge as calculated above agrees with the discharge of the sewer when carried at the given grade and velocity, the assumed size of the sewer is correct.
- In case of deviation, fresh size must be selected and the process should be repeated using trial and error method.



3.7 A district, having an area of 16 hectares with coefficient of relative impermeability as 0.75, as to be drained by a sewer of 900 metres length, laid at a gradient of 1 in 300. The rainfall intensity ay be assumed to be of 10 to 20 minutes duration and the time of entry at the sewer-inlet as 3 minutes. Design the storm water sewer.

Solution. *I Trial.* Assume a velocity of flow of 1.5 m./sec.

$$\text{Time of flow} = t_f = \frac{900}{1.5 \times 60} = 10 \text{ mts.}$$

$$\text{Time of entry} = t_e = 3 \text{ mts.}$$

$$\text{Time of concentration}$$

$$= T = t_e + t_f = 3 + 10 = 13 \text{ mts.}$$

Using Ministry of Health formula as given in Eq. (3.10)

$$R = \frac{760}{T+10}$$

$$\therefore \quad R = \frac{760}{13+10} = 33 \text{ mm. /hour.}$$

By Lloyd Davis Formula as given in Eq. (3.14)

$$Q = \frac{1}{6} \times R \times A \times I$$

$$= \frac{1}{6} \times 33 \times 16 \times 0.75$$

$$= 66 \text{ m.}^3\text{/mt.} = 1.1 \text{ m.}^3\text{/sec.}$$

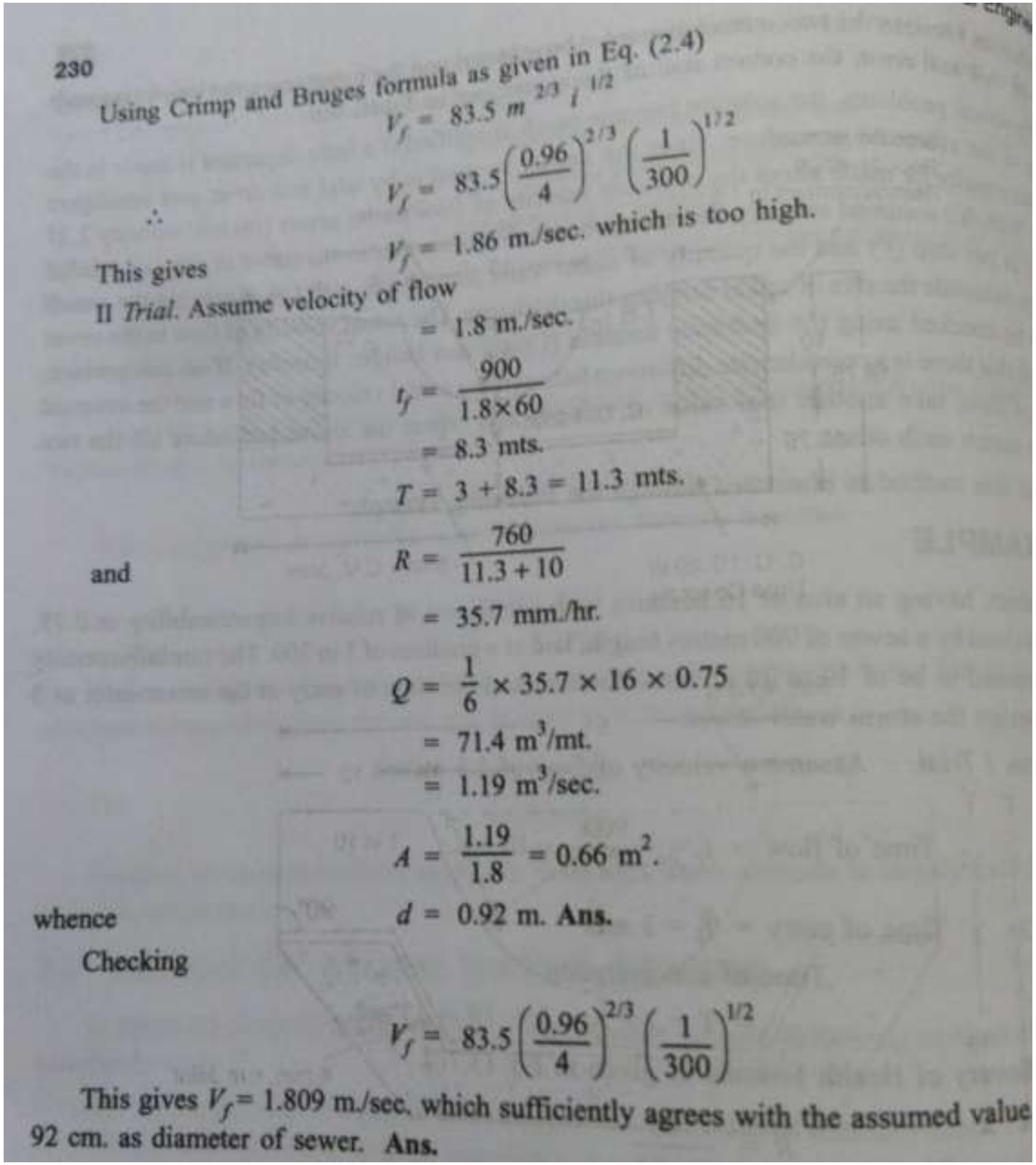
Discharge in the sewer

$$= A \times V_f$$

where A = area of the storm sewer

$$= \frac{1.1}{1.5} = 0.733 \text{ m}^2.$$

where $d = 0.96$ m.



Using Crimp and Bruges formula as given in Eq. (2.4)

$$V_f = 83.5\ m^{2/3}\ i^{1/2}$$

$$V_f = 83.5\left(\frac{0.96}{4}\right)^{2/3}\left(\frac{1}{300}\right)^{1/2}$$

$\therefore$

This gives $V_f = 1.86$ m./sec. which is too high.

II *Trial.* Assume velocity of flow

$$= 1.8 \text{ m./sec.}$$

$$t_f = \frac{900}{1.8\times 60}$$

$$= 8.3 \text{ mts.}$$

$$T = 3 + 8.3 = 11.3 \text{ mts.}$$

and $$R = \frac{760}{11.3+10}$$

$$= 35.7 \text{ mm./hr.}$$

$$Q = \frac{1}{6}\times 35.7\times 16\times 0.75$$

$$= 71.4 \text{ m}^3\text{/mt.}$$

$$= 1.19 \text{ m}^3\text{/sec.}$$

$$A = \frac{1.19}{1.8} = 0.66 \text{ m}^2.$$

whence $d = 0.92$ m. **Ans.**

Checking

$$V_f = 83.5\left(\frac{0.96}{4}\right)^{2/3}\left(\frac{1}{300}\right)^{1/2}$$

This gives $V_f = 1.809$ m./sec. which sufficiently agrees with the assumed value 92 cm. as diameter of sewer. **Ans.**

SEWAGE TREATMENT

Why treatment ???

OBJECTIVE

- Remove suspended and floating matter, inorganic grit
- To stabilize biodegradable organic substances
- Destruction of pathogenic bacteria
- For safe disposal
- To reduce nuisance or health hazards
- Various organic and inorganic pollutants presented as suspended colloidal and dissolved solids are removed or reduced by physico – chemical and biological methods which are grouped as physical, chemical and biological unit processes.

Sewage treatment consists of three phases

- **Primary Treatment**
- **Secondary or biological and**
- **Tertiary treatment.**

Physical operations are those in which application of physical forces are predominant – consists of screens, grit removal, oil and grease removal, plain sedimentation and flotation.

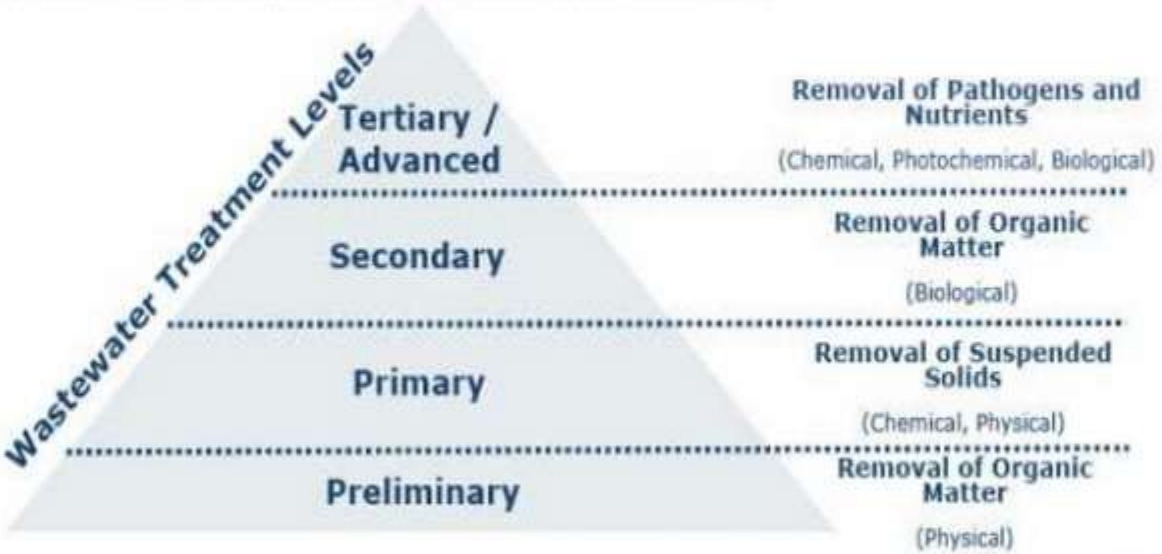
Chemical unit processes – reduction /removal of pollutants is achieved by addition of chemicals/chemical reactions – precipitation – gas transfer – disinfection – adsorption are few processes. Generally used for industrial waste water.(Used in primary/tertiary treatment)

Biological unit processes – reduction/removal of contaminants is brought by biological activity or by micro organisms. – useful for removing biodegradable organic substances present as colloidal/dissolved solids.

Biodegradable organic substances are converted to water, CO2,Ammonia and inert residue.

With proper processes and maintenance and good environmental conditions it is possible to treat any type of waster water.

Water and Wastewater Treatment Technologies: Levels of Wastewater Treatment

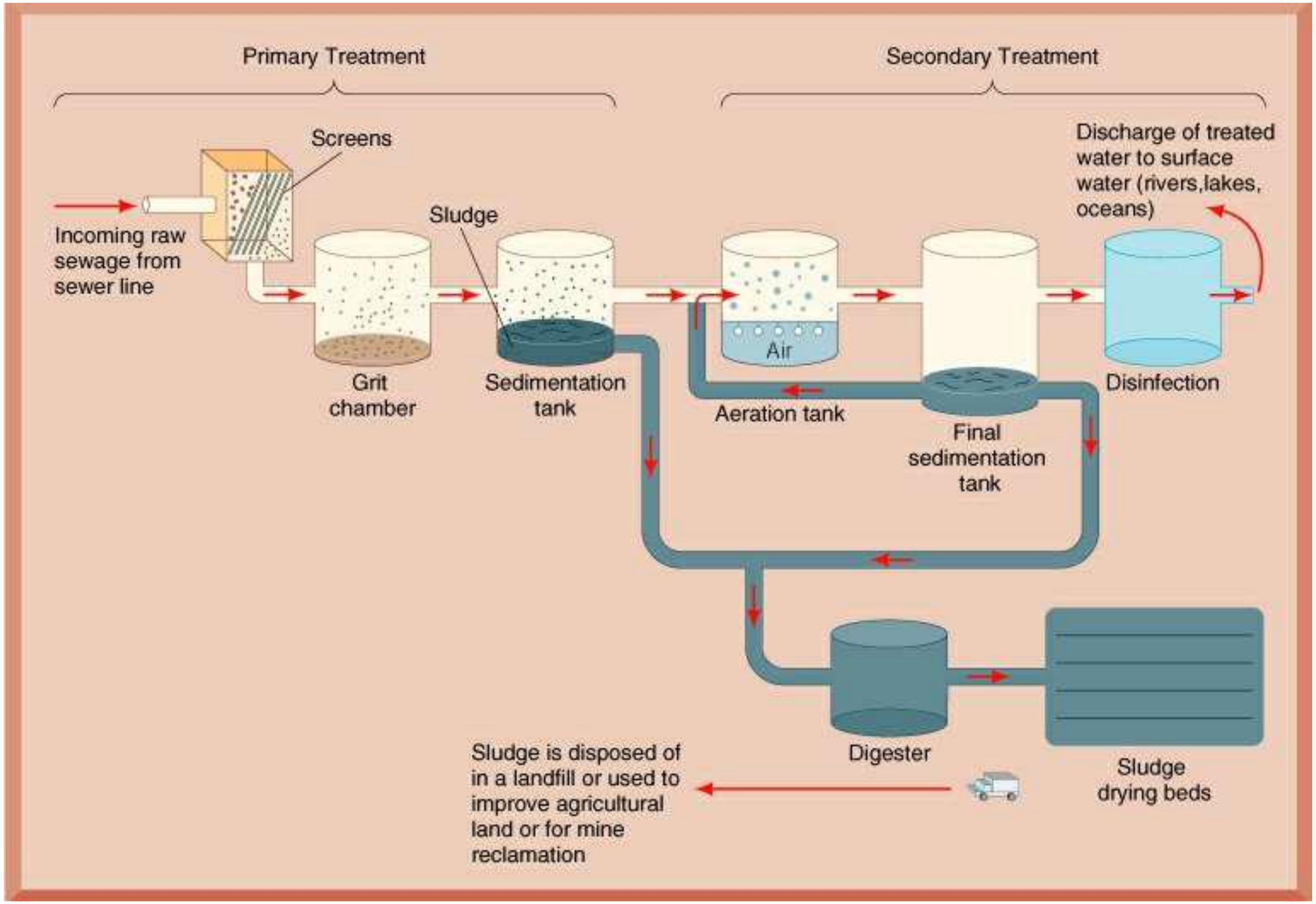


Source: Frost & Sullivan

Sewage Treatment Methods

Primary Treatment	Secondary /Biological	Tertiary
Screens	Activated Sludge Process and its modifications	Adsorption
Grit Chambers	Trickling Filter	Nitrification and Denitrification
Primary Sedimentation Tank	Aerated Lagoon	Chlorination
Oil Separators	Waste Stabilization Pond	
Flotation	Rotating Biological Contractor	

Wastewater Treatment



Screens

- Screening is a first and essential step in sewage treatment.
- Used for removal of suspended, floating matter like wooden pieces, plastic material, fibers, cloth, paper etc.
- Screens may consists of parallel bars, rods/wires, wire meshes, perforated plates

Objectives:

- To prevent objectionable shoreline conditions
- To avoid the formation of sludge blankets in the receiving water
- To prevent the damage of equipment like pumps, valves etc
- To avoid interference in the satisfactory functioning of
- subsequent treatment units
- To prevent clogging of sprinkler nozzles in trickling filters.

Screens may be coarse, medium or fine depending upon the size of the openings and the purpose for which it has been provided.

Coarse Screens:

- Serve as protective devices(75-150mm) provided ahead of raw sewage pumps to prevent entry of floating matter like logs of timber etc.
- Consists of vertical/inclined bars spaced at equal intervals across the channel through which sewage flows - Cleaned manually

Medium Screens:

- Made up of rectangular rods/bars with a clear opening of 20-50mm(10mm*50mm) - Depth is equal to flow depth
- Can be cleaned either manually or mechanically

Fine Screens

- Clear openings of less than 20mm with mechanically cleaned devices.
- Used for treating industrial waste water and not for domestic sewage due to clogging problems.

BAR SCREEN

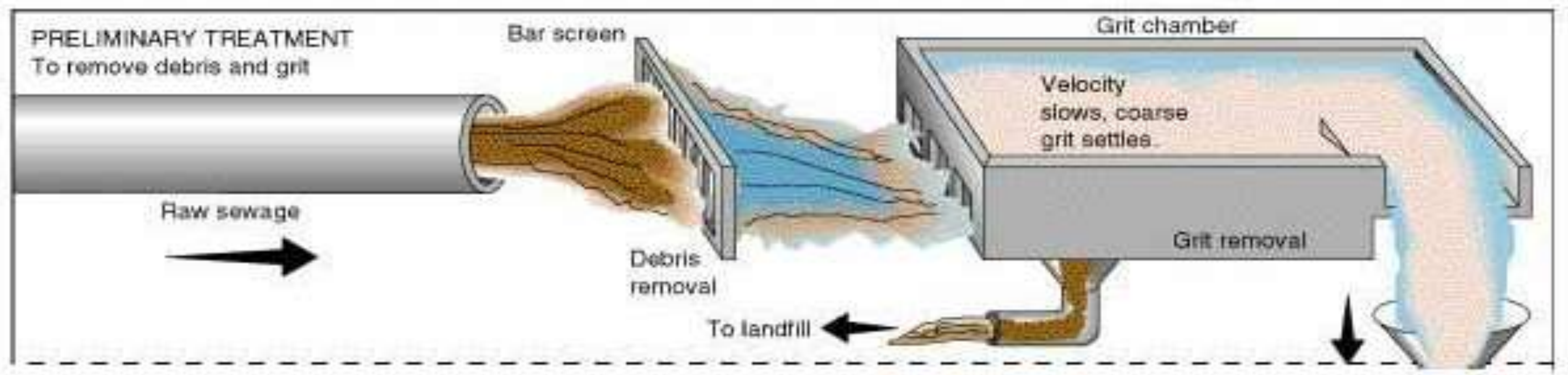
GRIT CHAMBER

Grit chambers are provided to remove inorganic grit

Objective:

- To prevent the pumps, mechanical equipment from abrasion and abnormal wear or tear
- To reduce the load on primary settling tank and sludge digesters
- Grit – coarse particles of ash,sand,clinkers, inert substance – inorganic in nature
- Size of the grit varies between 0.1 - 0.2mm with specific gravity in the range of 2.4 – 2.65
- Grit is non putrescible and possesses a high hydraulic subsidence
- A velocity of flow through the grit chamber will be in the range of 0.15m/s – 0.3 m/s **(Velocity should ne neither slow nor so high) ($V_h = 3 \text{ to } 4.5\sqrt{gd(S_s-1)}$)**
- Detention period of 60 seconds is usually adopted.
- Control sections are used to control velocity with in the required range with +- 5-10%
- The cross sectional area of the device is in direct proportion to the flow

- Grit chambers are cleaned manually/mechanically
- Loss of head ranges from 0.05m to 0.6m depending on the type of velocity control device provided
- Grit can be disposed off by dumping in low lying areas or by burial



SKIMMING TANKS

- Removes floating matter like oil, fats and grease
- During the flow of sewage, oil and other floating substances like fat, grease rises to the top which are subsequently removed.
- Now a days skimming tanks are provided in primary sedimentation tanks itself.

- A grit chamber is designed to remove particles with a diameter of 0.2mm,specific gravity 2.65. Settling velocity for these particles has been found to range from 0.016 to 0.020m/s . A flow through velocity of 0.3m/s will be maintained by proportioning weir. Determine the channel dimensions for a maximum wastewater flow of 10000cu m/day

Sol:

Hor velocity of the flow = 0.3m/s

Settling velocity is between 0.016 to 0.020m/s. Let us assume it as 0.020m/s.

Q = Velocity * Cross section = Vh * A

➔ 10000/24*60*60 = 0.30*A

➔ A = 0.385m2

➔ Assuming a depth of 1m, we have

➔ 1 * B = 0.385 = 0.385m ==0.4m(Say)

➔ Detention time = Depth of the basin/Settling velocity = 1/0.02 = 50 sec.

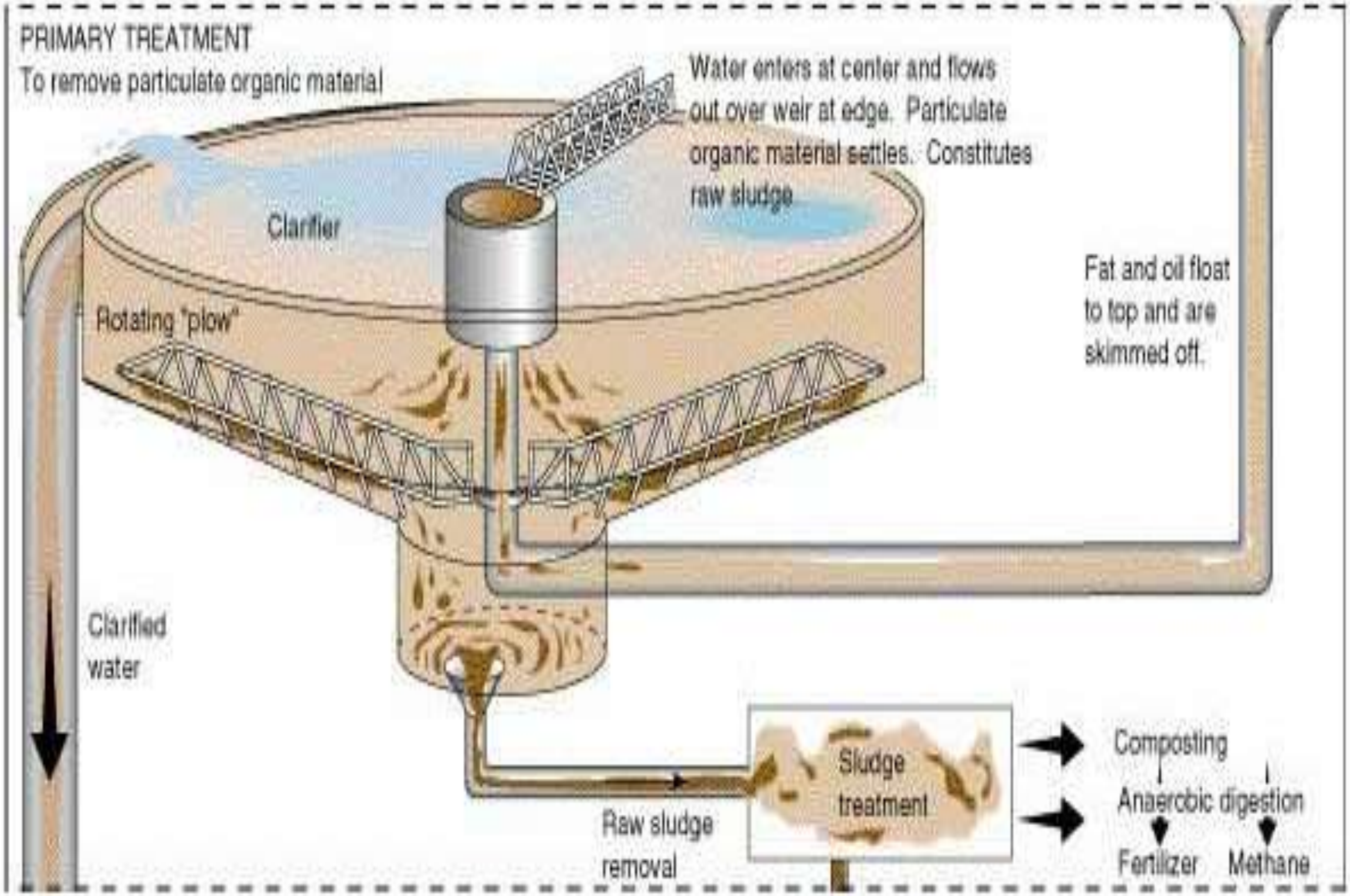
➔ Length of the tank = Vh * Detention time

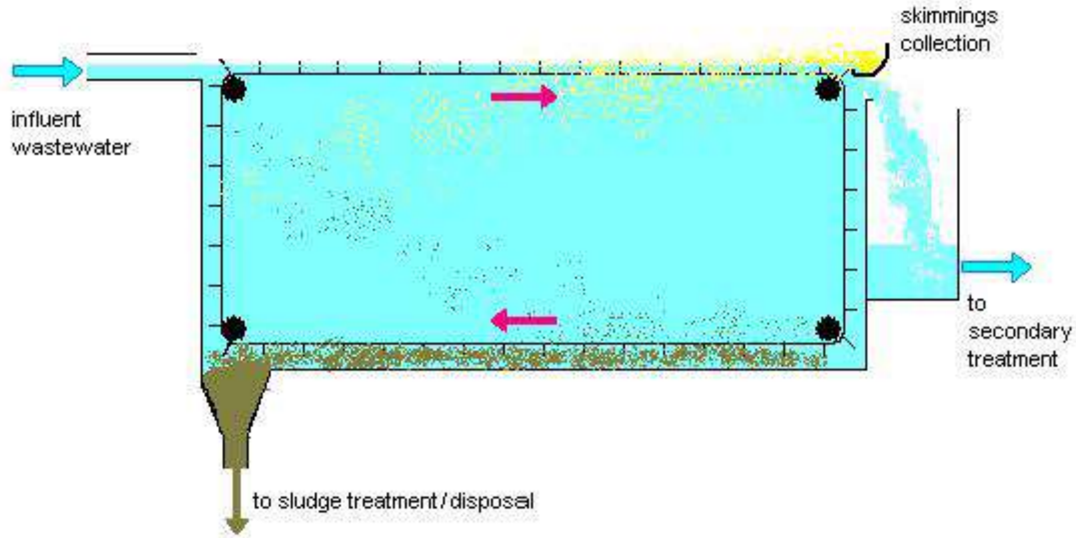
➔ = 0.3 * 50 = 15m

➔ Hence use a rectangular tank of Length 15m, Width of 0.4m and Depth of 1m.

Primary Sedimentation

- Objective is to separate the settleable organic solids so that if discharged to water bodies does not form sludge deposits and if used for irrigation does not results in excessive organic loading.
- Reduces the organic load to the extent of 30-35% and suspended solids load to the extent of 60-65% on secondary treatments.
- Design of sedimentation tanks depend on several factors like flow variations, solids concentration, detention time, surface loading rate .
- Principle of sewage sedimentation is same as sedimentation of water.


PRIMARY TREATMENT
To remove particulate organic material
Water enters at center and flows out over weir at edge. Particulate organic material settles. Constitutes raw sludge
Clarifier
Fat and oil float to top and are skimmed off.
Rotating "plow"
Clarified water
Sludge treatment
Raw sludge removal
Composting
Anaerobic digestion
Fertilizer
Methane



Primary settling tank

Settling Velocity

$Vs = 418(Ss-1)d^2(3T+70/100)$ for $d<0.1mm$, Vs in m/s and T in degree centigrade.

$Vs = 1.8\sqrt{gd(Ss-1)}$ for $d>1mm$

$Vs = 418(Ss-1)d(3T+70/100)$ for d between 0.1 and 1 mm.

Modified Hazen Formula:

$Vs = 60.6d(Ss-1)(3T+70/100)$ for d between 0.1 and 1mm.

$V = Q/BH$ or $Vs = Q/BL$

Detention time = BLH/Q(Rectangular tank)

Detention time = $d^2(0.011d + 0.785H)/Q$ (circular tank)

- Detention time of 1-2 hours is usually adopted
- 1 hour is adopted when activated sludge process is used in secondary treatment
- 2 hour is adopted when trickling filters are used in secondary treatment
- Larger detention period increases efficiency but at the same increases septic conditions – should be avoided
- In cases , where only primary treatment is involved 2.5 – 3hours is generally adopted.
- Width = Generally kept as 6M, not to exceed 7.5m
- Length = 4-5 times of width
- Effective Depth = 2.4 – 3.6m (3m generally)
- Diameter of circular tank = 60m

Over flow rates/surface loading

= 40000 – 50000litres/sqm/day for plain sedimentation

= 50000 – 60000 litres/sqm/day for coagulation sedimentation

= 25000 – 35000 litres/sqm/day for secondary sedimentation tanks

Design a suitable rectangular sedimentation tank for treating the sewage from a city provided with an assured public water supply system with max daily demand of 12million litres per day. Assume suitable values of detention period and velocity of flow in the tank. Make any assumptions , wherever needed.

Assuming 80% of water supplied as sewage, we have quantity of sewage required to be treated per day
= 0.8 * 12ML = 9.6MLD

Assuming the detention period of 2hours,
Capacity of the tank required = 9.6 * 2/24ML = 0.8ML = 800Cu.m.
Assuming the flow velocity through the tank is maintained at 0.3m/min, we have
Length of the tank required = Velocity of flow * Detention time
= 0.3 * 2*60= 36m
Cross sectional area of the tank required = Capacity of tank/Length of tank
= 800/36 = 22.2m^2
Assuming the water depth in the tank as 3m,
Width of the tank = 22.2/3 = 7.4m

Hence a rectangular sedimentation tank with an overall size of 36m * 7.5m *3.5m(0.5m free board) can be used.

Design a circular settling tank unit for a primary treatment of sewage at 12mld. Assume suitable values of detention (presuming that trickling filters are to be used) and surface loading

- Assuming detention period as 2 hours and surface loading as 40000 l/sqm/day
- Quantity of sewage to be treated in 2hours = 12*2/24 = 1MLD = 1000m^3
- Capacity of tank = 1000m^3

- Surface loading = Q/Surface area of tank

  $Q/(\pi/4)(d^2)$

  $40000 = 12*1000000/ (\pi/4)(d^2)$

  = d= 19.6m
- Effective depth of tank = Capacity/Area of cross section

  $=1000/ (\pi/4)(19.6^2)$

  = 3.2m
- Hence use a circular tank with 19.6m dia and 3.2+0.5 free board depth

The sludge which settles in the sedimentation basin is pumped to the sludge digesters *where a temperature of 30–35ºC is maintained. This is the optimum temperature for the anaerobic bacteria (bacteria that live in an environment that does not contain oxygen). The usual length of digestion is 20–30 days but can be much longer during winter months. Continual adding of raw sludge is necessary and only well-digested sludge should be withdrawn, leaving some ripe sludge in the digester to acclimatise the incoming raw sludge.*

Sludge digestors

Drying beds

Digested sludge is placed on drying beds of sand *where the liquid may evaporate or drain into the soil. The dried sludge is a porous humus-like cake which can be used as a fertiliser base.*

Drying beds

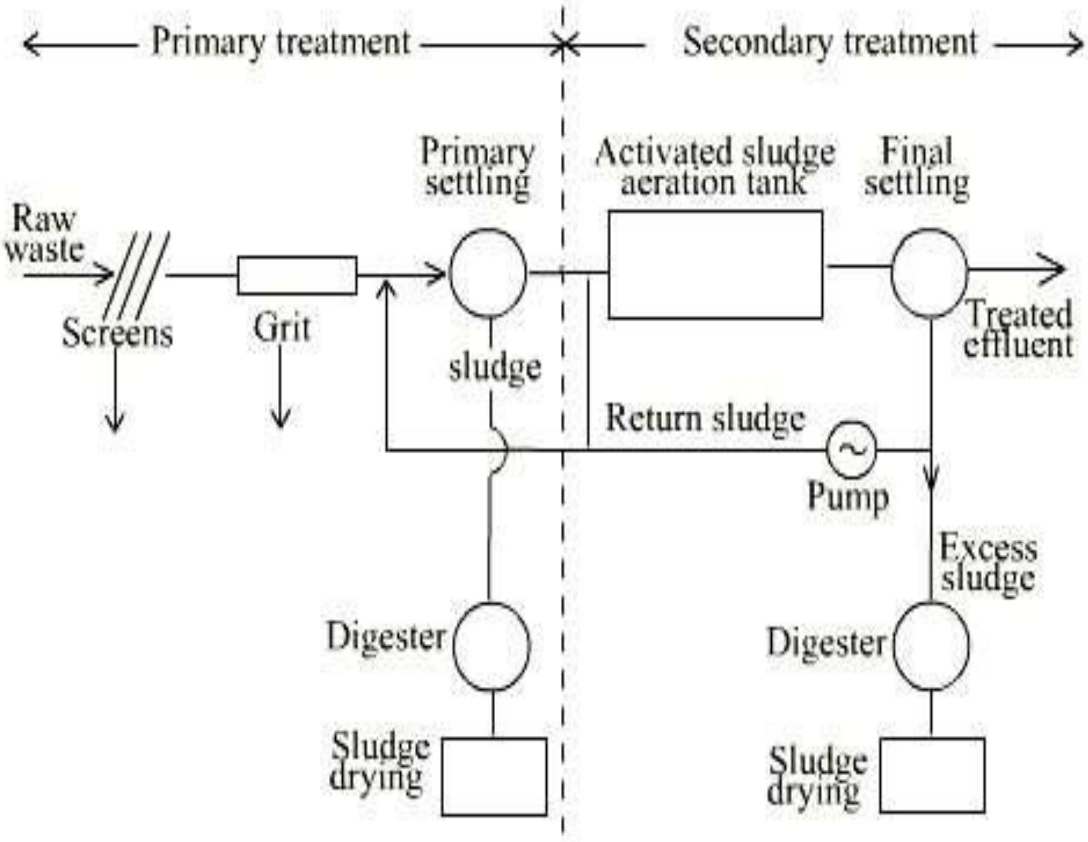
Secondary Treatment

Secondary Treatment through Activated Sludge Process (Aerobic Suspended Culture)

- Sewage effluent from primary sedimentation tank is mixed with 20-30 percent f activated sludge.
- **Activated Sludge** – sludge consisting of large concentration of highly active aerobic micro-organisms.
- Sewage effluent + activated sludge is mixed intimately in a aeration tank for 4-8 hours(micro organisms are coated around sludge solids)
- The moving organisms(due to agitation) will oxidize the organic matter and the suspended and colloidal matter tend to coagulate and form a precipitate, which settles down readily in secondary settling tank.
- The settled sludge(activated sludge) is recycled to the aeration tank to be mixed with sewage to be treated.
- New activated sludge which is continuously produced by this process, a portion of it is resent to aeration tank and remaining disposed properly after digestion.

- BOD removal is up to 80-95 percent and bacteria removal is around 90-95 percent
- Proper supervision is required to ensure ample supply of oxygen us present
- Intimate and continuous mixing of the sewage and activated sludge
- Ratio of volume of activated sludge added to volume of sewage being treated is kept practically constant
- For a new plant, minimum of 4 weeks may be required to form a suitable return sludge or activated sludge from another plant can be used.
- Removal of grit and larger solids by screening, grit chambers and primary sedimentation tanks is to be done before aeration.
- Detention time should be very less in order to keep the sewage fresh. Generally 1.4 hours is maintained.(40,000 overflow rata and 2.4m depth)

Flow sheet of an activated sludge system



Aeration tanks:

- Aeration tanks are normally rectangular chambers of 3 - 4.5 m deep and 4 - 6m wide and Length 20 – 200m and Detention period of 4 – 8 hours
- Air can be introduced in to the tanks either by the method of **Air diffusion or mechanical aeration.**

Diffused Air Aeration:

- Compressed air under a pressure of 35-70 KN/m2 is introduced through diffusers.
- Diffusers should be capable of diffusing air in small bubbles to provide better efficiency of aeration.
- Porous plates(30 * 30 *25mm) and tubes(60cm long and 75mm thick) made up of quartz and aluminium oxide are used as diffusers.

- Ridge and furrow type and spiral flow type of tanks are generally used.
- Air is forced upward through diffuser plates placed at bottom of ridge and furrow type whereas air is introduced near the side of the tank in such a way that spiral flow is obtained in tank. This requires compressed air at low pressures.
- 4000 – 8000 m3 of air is required to treat one MLD(Depends on sewage parameters)
- Usually 100m3/day of air is required to remove one kg of BOD.

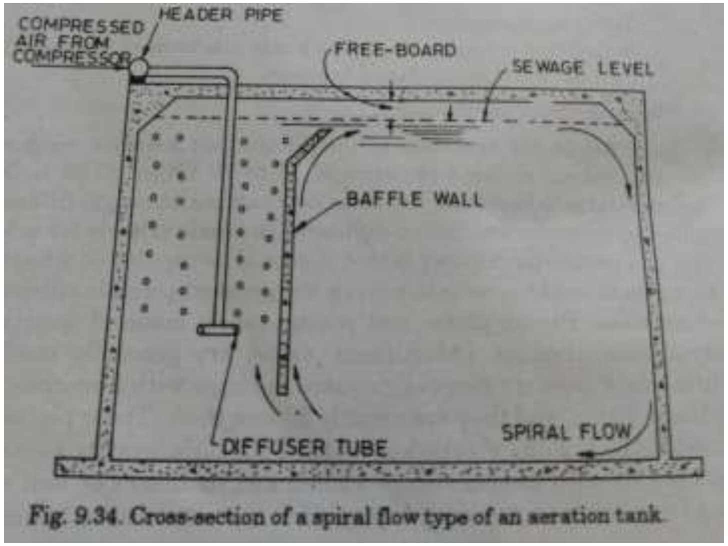


Fig. 9.34. Cross-section of a spiral flow type of an aeration tank

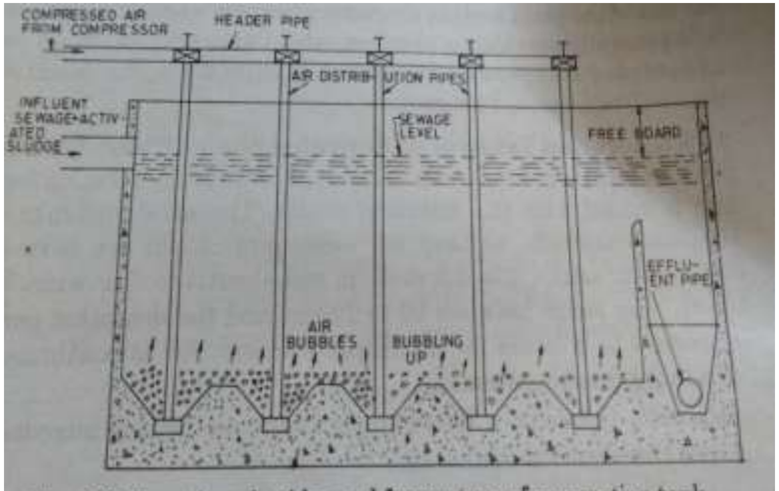
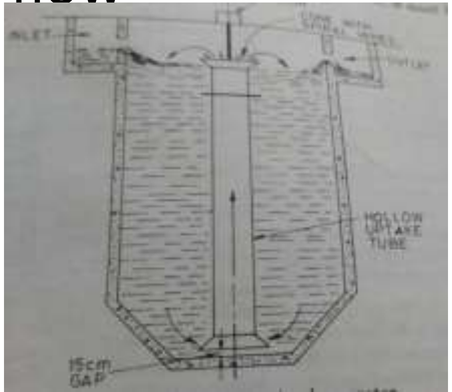
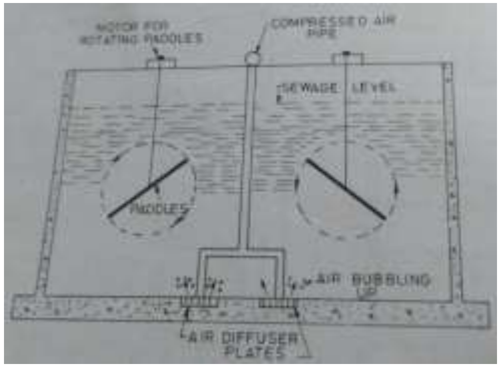


Fig. 9.33. L-section of a ridge and furrow type of an aeration tank.

Mechanical Aeration:

- 90-95% of air gets wasted in air diffusion method as it simply escapes through the tank without giving oxygen to sewage(it helps in agitation)
- Atmospheric air is brought in contact with the sewage in mechanical aeration method by means of stirring using devices like paddles(surface aerators) continuously by changing the surface of sewage by circulation of sewage from bottom to top
- Detention time is around 6-8 hours
- Quantity of returned sludge is around 25-30 percent of sewage flow





Secondary Sedimentation tank

- Sewage flows from aeration tank to sedimentation tank(similar to primary with some modifications)
- As there are no floating solids, provision for removal of scum are not needed.
- As Suspended particles in aeration tank effluent are light in weight considerable length of overflow weir is desirable to reduce the velocity of approach.
- Weir overflow rate not exceeding 150m3/day per linear meter
- Solids loading rate is around 100-150kg/m^2 per day and should not exceed 250kg/m^2 at peak flows(ensures adequate sludge thickening)
- Detention time is around 1.5 – 2 hours
- Length to depth ratio is around 5 for circular tanks and 7 for rectangular tanks
- Depth may be around 3.5 – 4.5m
- Velocity of flow is about 30cm/min

Loading rates for Settling tanks

Design Parameter	**Primary Settling Tank**		**Secondary Settling Unit**	
	Primary Settling Only	Primary Settling followed by Secondary treatment	Secondary Settling after trickling filter	Secondary Settling after activated sludge process
Overflow rate (litres/m^2/day	25000 – 50000	35000 - 80000	15000 - 50000	15000 - 50000
Solid Loading (kg/m^2/day)	--	--	70-180	70-210
Weir Loading (litres/m/day)	Not to exceed 1,50,000		Not to exceed 1,85,000	

Design a circular settling tank for the secondary treatment of sewage(activated sludge process) with the following data Average Flow = 6MLD, Peak Flow = 13.5MLD, Concentration of solid Sludge in mixed liquor, MLSS = 3000mg/l

1) **Determine surface area considering surface loading**.

Assuming overflow rate of 20000 $l/m^2/day$ at average flow

$$\text{Surface area} = 6 * 10^6/20000 = 300m^2$$

Check:

Surface loading at peak flow = Peak flow/Surface area

= 13.5 * 106/300

= 45000 l/m2/day < 50000 l/m2/day. (with in limits, hence ok)

2) **Determine surface area considering solid loading**

Assuming a solid loading of 90kg/m2/day at average flow,

$$\text{Surface area} = 6 * 10^6 *3000/1000*90*1000 = = 200\ m^2$$

For a max solid loading of 210 $kg/m^2/day$

$$\text{Surface area required} = 13.5*10^6*3000/1000*210*1000 = 192.8m^2$$

Adopt higher surface area of above i.e 300m^2

3) Work out tank size

$$\text{Area of the tank} = \pi d^2/4$$

$$\Rightarrow 300 = \pi d^2/4$$

$$\Rightarrow d = \surd(300 * 4)/\ \pi$$

$$\Rightarrow d = 19.54\ m = 20m(\text{say})$$

$\Rightarrow$ If we Assume effective depth as 3m,

$\Rightarrow$ Weir loading is given by

$$\Rightarrow \text{Weir loading} = 6*106/\pi d$$

$$\Rightarrow = 6\ *106/\pi*20$$

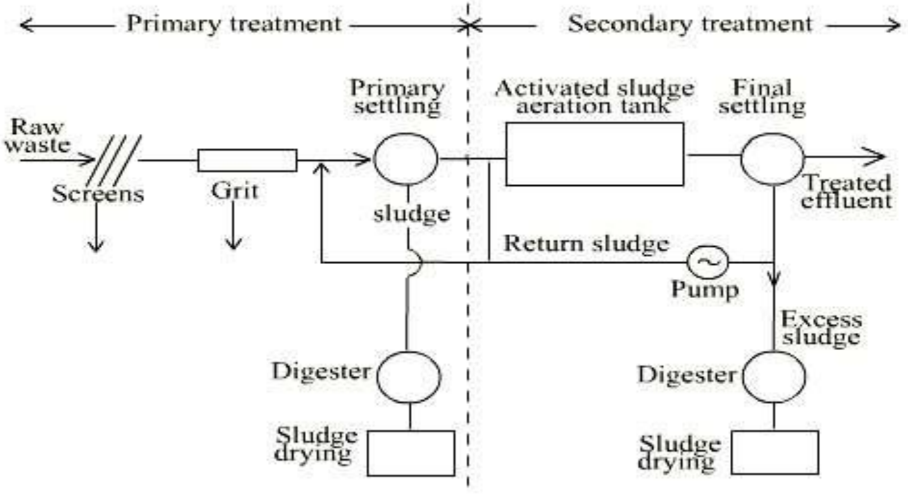
$$\Rightarrow = 95490\ l/m/d$$

which is with in permissible limits, hence ok.

Activated Sludge Process

The most common suspended growth process used for municipal wastewater treatment is the activated sludge process .

- Activated sludge plant involves:
- wastewater aeration in the presence of a microbial suspension,
- solid-liquid separation following aeration,
- discharge of clarified effluent,
- wasting of excess biomass, and
- return of remaining biomass to the aeration tank.



Flow sheet of an activated sludge system

- In activated sludge process wastewater containing organic matter is aerated in an aeration basin in which micro-organisms metabolize the suspended and soluble organic matter.

- Part of organic matter is synthesized into new cells and part is oxidized to CO_2 and water to derive energy.

- In activated sludge systems the new cells formed in the reaction are removed from the liquid stream in the form of a flocculent sludge in settling tanks.

- A part of this settled biomass, described as activated sludge is returned to the aeration tank and the remaining forms waste or excess sludge.

Activated Sludge Process Variables

The main variables of activated sludge process are the mixing regime, loading rate, and the flow scheme.

Mixing Regime

- Generally two types of mixing regimes are of major interest in activated sludge process: ***plug flow*** and ***complete mixing***. In the first one, the regime is characterized by orderly flow of mixed liquor through the aeration tank with no element of mixed liquor overtaking or mixing with any other element. There may be lateral mixing of mixed liquor but there must be no mixing along the path of flow.
- In complete mixing, the contents of aeration tank are well stirred and uniform throughout. Thus, at steady state, the effluent from the aeration tank has the same composition as the aeration tank contents.
- The type of mixing regime is very important as it affects (1) oxygen transfer requirements in the aeration tank, (2) susceptibility of biomass to shock loads, (3) local environmental conditions in the aeration tank, and (4) the kinetics governing the treatment process.

Loading Rate

- A loading parameter that has been developed over the years is the ***hydraulic retention time*** (HRT), q, d

$$q = V / Q$$

- V= volume of aeration tank, m^3, and Q= sewage inflow, m^3/d
- Another empirical loading parameter is ***volumetric organic loading*** which is defined as the BOD applied per unit volume of aeration tank, per day.
- A rational loading parameter which has found wider acceptance and is preferred is ***specific substrate utilization rate***, q, per day.

$$q= \frac{Q\ (S_O - S_e)}{V\ X}$$

- A similar loading parameter is ***mean cell residence time*** or ***sludge retention time*** (SRT), q_c, d

$$q_c = VX \;/\; Q_w X_r + (Q - Q_w X_e)$$

- where S_O and S_e are influent and effluent organic matter concentration respectively, measured as BOD_5 (g/m^3)
- X, X_e and X_r are MLSS concentration in aeration tank, effluent and return sludge respectively, and Q_w= waste activated sludge rate.
- Under steady state operation the mass of waste activated sludge is given by

$$Q_w X_r = YQ\,(S_O - S_e) - k_d\, XV$$

- where Y= maximum yield coefficient (microbial mass synthesized / mass of substrate utilized) and k_d = endogenous decay rate (d^{-1}) .
- From the above equation it is seen that $1/q_c = Yq - k_d$
- If the value of S_e is small as compared S_O, q may also be expressed as ***Food to Microorganism ratio***, F/M

$$F/M = Q(S_O - S_e) / XV = QS_O / XV$$

- The q_c value adopted for design controls the effluent quality, and settleability and drainability of biomass, oxygen requirement and quantity of waste activated sludge.

Flow Scheme

The flow scheme involves:

- the pattern of sewage addition
- the pattern of sludge return to the aeration tank and
- the pattern of aeration.
- Sewage addition may be at a single point at the inlet end or it may be at several points along the aeration tank. The sludge return may be directly from the settling tank to the aeration tank or through a sludge reaeration tank. Aeration may be at a uniform rate or it may be varied from the head of the aeration tank to its end.

Design Considerations

Aeration tank loadings

The important terms which define the loading rates of an activated sludge plant include:

- Aeration period(Hydraulic Retention time-HRT)
- BOD loading per unit volume of aeration tank(Volumetric loading)
- Food to Micro Organism Ratio(F/M Ratio)
- Sludge age

Aeration Period/HRT

Decides the loading rate at which the sewage is applied to aeration tank

Detention period(t) = Vol of tank/Rate of sewage flow in tank

= **V m^3/Qm^3/day = V/Q day**

= V/Q * 24 hours

Where t = aeration period in hours

V = Volume of aeration tank

Q = Quantity of waste water flow in to aeration tank excluding the quantity of recycled sludge.

Volumetric BOD Loading

Is defined as BOD5 load applied per unit volume of aeration tank.(Organic loading)

Organic loading = Mass of BOD applied per day to the aeration tank through influent sewage in gm/Volume of aeration tank in m^3

$$\mathbf{Q.Y_o/V}$$

Q = Sewage flow into the aeration tank in m3

Y_o = BOD5 in mg/l

V = Volume of aeration tank in m3

Food to Micro Organisms Ratio(F/M Ratio)

- Expressing BOD loading with regard to microbial mass in the system.
- BOD applied is represented as food(F) and microbial suspended solids in mixed liquor of the aeration tank is represented by M
- F/M ratio = Daily BOD load applied to aerator system in gm/Total microbial mass in the system in gm
- If Y_o represents the 5 day BOD of the influent sewage flow of Qm^3/day, then the BOD applied to aeration system =

$$\mathbf{F = Q.Y_o\ gm/day}$$

The total microbial mass in the aeration system(M) is computed by multiplying the average concentration of solids in the mixed liquor of the aeration tank called Mixed Liquor Suspended Solids(MLSS) with the volume of the aeration tank

$$\mathbf{M = MLSS * V = X_t * V, \text{ where } X_t = MLSS \text{ in mg/l}}$$

$$\mathbf{F/M = Q.Y_o/X_t.V}$$

Lower the F/M value, the higher will be the BOD removal.

F/M ratio can be varied by altering the MLSS concentration in the aeration tank.

Sludge Age:the average time for which particles of suspended solids remain under aeration. – residence time of biological solids in the system.

While sewage passes through the aeration tank only once and rather quickly the resultant biological growths and extracted waste organics(solids) are repeatedly recycled from the secondary clarifier back to aeration tan thereby increasing the retention time of solids, which is called as Solids Retention Time(SRT) or Mean cell Residence Time(MCRT) or Sludge age.

Sludge age(Ɵc) = Mass of suspended solids(MLSS)/Mass of solids leaving the system per day.

Sludge age = Ɵc = $V.X_T/(Q_w.X_R)+(Q-Q_w)X_E$

X_t = Concentration of solids in the influent of aeration tank(MLSS)

V = volume of aerator, Q_w = Vol of waste sludge per day

X_r = concentration of solids in returned sludge , Q = Sewage inflow per day

X_E= concentration of solids in the effluent in mg/l

If X_E value is less, then sludge age is given by

$$\Theta c = V.X_T/(Q_w.X_R)$$

Sludge Volume Index is defined as the volume occupied in ml by one gm of solids in the mixed liquor after settling fo 30min and is determined experimentally.

Required to decide the rate of recycle of sludge to maintain desired MLSS and F/M ratio in the aeration tank.

Specific substrate utilization rate(U) per day is defined as

$$\mathbf{U = Q(Y_o - Y_E)/V.X_t}$$

Under steady state operation, the mass of wasted activated sludge is futher given by

$$\mathbf{Q_w.X_r = \alpha_y.Q(Y_o-Y_E) - K_e.X_t.V}$$

Where αy = max yield coefficient = microbial mass synthesized/mass of substrate utilized

K_e = endogenous respiration rate constant per day

α_y =1.0(MLSS) = 0.6(MLVSS), Ke = 0.06

From the above equations we can write

$$\mathbf{1/ \Theta_c = \alpha_y.U - K_e}$$

An average operating data for conventional activated sludge treatment plant is as follows

Wastewater flow = 35000m3/d

Volume of aeration tank = 10900m3

Influent BOD = 250mg/l

Effluent BOD = 20mg/l

MLSS = 2500mg/l

Effluent suspended solids = 30mg/l

Waste sludge suspended solids = 9700mg/l

Quantity of waste sludge = 220m3/d.

Based on the above information determine (a)Aeration period (b) F/M ratio(kg BOD per day/kg MLSS ©Percentage efficiency of BOD removal

Given values are

- $Q = 35000m3/d$ $V = 10900m3$ $Y_o = 250mg/l$
- $Y_E = 20mg/l$ $X_t = 2500mg/l$ $X_E = 30mg/l$
- $X_r = 9700mg/l$ $Q_w = 220m3/d$

Aeration period (t) in hours is given by

$t = V.24/Q = 10900*24/35000 = 7.47$ hr = 7.5 (say)

F/M ratio

F = Mass of BOD removed = $Q.Y_o$

= 35000 * 250 gm/day = 35000*250/1000 Kg/day

= 8750 kg/day

M = Mass of MLSS = $V.X_t$ = 10900 *2500 gm/m^3

= 10900 * 2500/1000 kg

= 27250 kg

F/M ratio = 8750/27250

= 0.32 kg of BOD per day/Kg of MLSS

Percentage efficiency of BOD removal

= (Incoming BOD-Outgoing BOD)/Incoming BOD

= (250 – 20)*100/250 = 92%

Sludge Age

$\theta c = V.X_T/(Q_w.X_R)+(Q-Q_w)X_E$

= 27250kg /(220m3/day*9700mg/l) +(35000m3/day-220m3/day)30mg/l

= 27250 kg/(220*9700/1000) +(35000-220)*30/1000)

= 8.58 Days

Conventional System and its Modifications

- The conventional system maintains a plug flow hydraulic regime. Over the years, several modifications to the conventional system have been developed to meet specific treatment objectives. In ***step aeration*** settled sewage is introduced at several points along the tank length which produces more uniform oxygen demand throughout. ***Tapered aeration*** attempts to supply air to match oxygen demand along the length of the tank. ***Contact stabilization*** provides for reaeration of return activated sludge from the final clarifier, which allows a smaller aeration or contact tank. ***Completely mixed*** process aims at instantaneous mixing of the influent waste and return sludge with the entire contents of the aeration tank. Extended aeration process operates at a low organic load producing lesser quantity of well stabilized sludge.

Activated Sludge Modified Systems

Conventional Activated Sludge treatment systems have been modified to increase the efficiency . Few of them are

1) Tapered Aeration

2) Step Aeration

3) Contact Stabilization or Sludge Reaeration

4) Complete Mix Process

5) Extended Aeration

Tapered Aeration

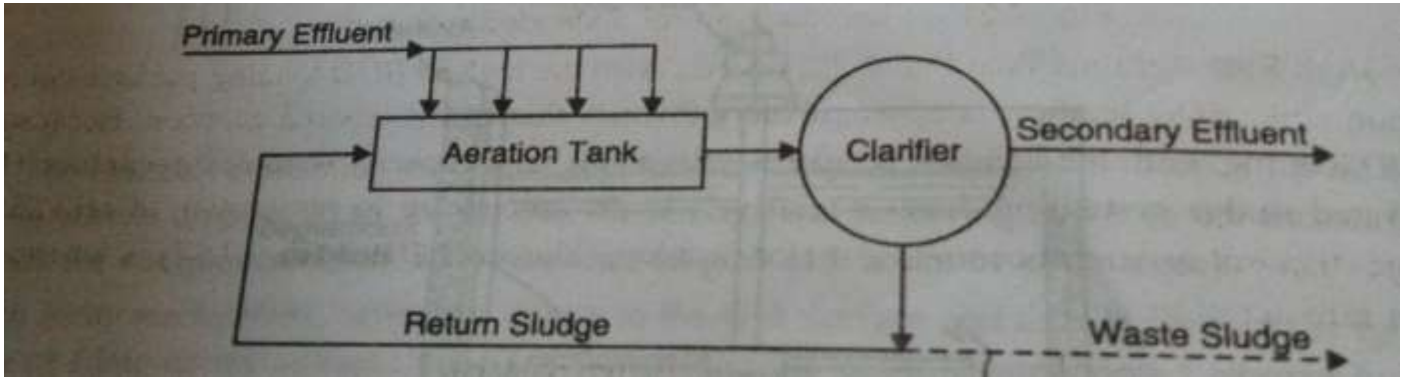
- Oxygen demand will be higher at the inlet end of aeration tank
- when the primary effluent enters the tank due to high BOD. Oxygen demand gradually decreases as the distance from the inlet of the aeration tank increases.
- In tapered system, compressed air is supplied at higher rates near the inlet end of the tank and is gradually decreased as sewage moves towards the outlet end – which ensures optimal application of air in the aeration tank.
- Generally 45% of air is supplied to first one-third length of tank

  30% to second one third length of the tank

  25% to last one third length of the tank

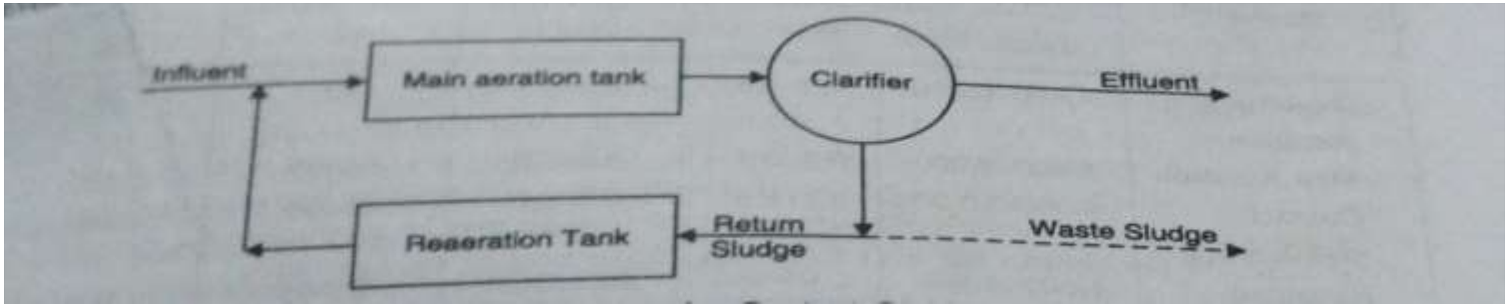
Step Aeration

- Sewage is introduced along the length of the aeration tank in several steps while the returned sludge is introduced at the head.
- This arrangement results in uniform air requirement along the entire length of the tank
- The process enables reduction in the volume of tank without
- lowering BOD removal efficiency
- Can absorb shock organic loadings also
- Useful for larger plant capacities of the order of 1000MLD



Contact Stabilization process or Biosorption process

- Designed for treating colloidal wastewaters
- Sewage and Recycled/returned sludge are mixed and aerated for a comparatively shorter period of 0.5-1.5 hour in a special tank called contact tank.(this period is sufficient for micro organisms to absorb organic pollutants without stabilization)
- Activated sludge is recycled for aeration in reaeration tank for a period of 3hours during which the absorbed organic matter gets decomposed
- Since the volume to be stabilized in main tank is less, we can reduce the size of the main aeration tank
- Can handle higher BOD loadings because of pre-reaeration received by the return sludge
- Even the use of primary sedimentation may be dispensed with.



Complete Mix Process

- Developed for smaller cities where the hourly variations in sewage were quite high.(25MLD where municipal and industrial waste waters flow together)
- Complete mixing pattern is followed .
- Sewage and return sludge are distributed uniformly along one side of the tank and the aerated sewage is withdrawn uniformly along the opposite side
- Complete mix plant can hold much higher MLSS concentration of the order of 3000 – 4000mg/l as against 1500-3000 mg/l of conventional plant.
- This helps in adopting smaller volume for aeration tank, can handle shock loadings, and increased capacity to treat toxic biodegradable wastewaters like phenols.

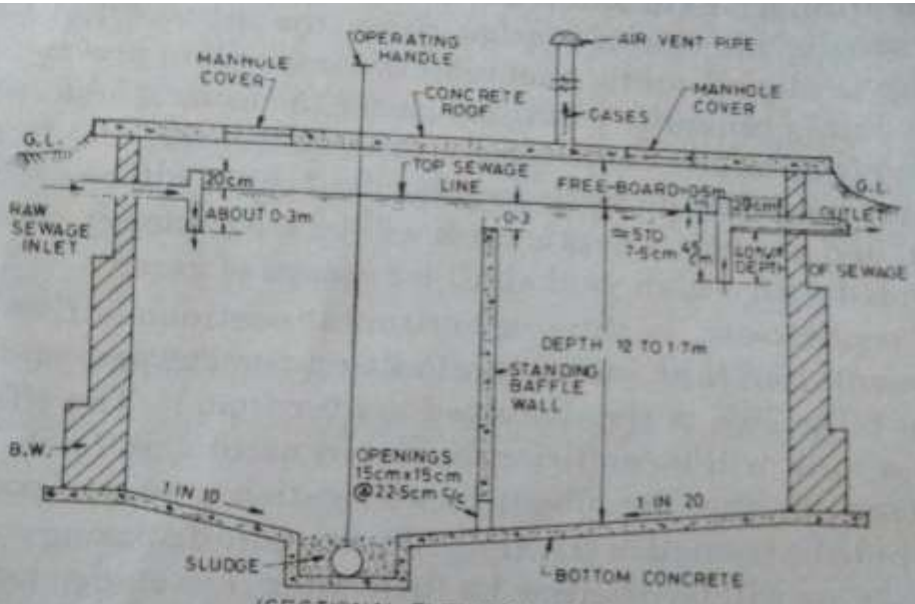
Extended Aeration Process

- Aeration period is quite large and is around 12-24 hours as against 4-6 hours of conventional plant.
- Bod removal is of the order of 95-98% as compared to 85-92% of conventional plant.
- Oxygen requirement is quite high which increases the running cost of the plant.
- No sludge digester is required as sewage gets well stabilized due to long detention periods(Oxidation ponds)
- Useful for small communities having 4MLD sewage flows.

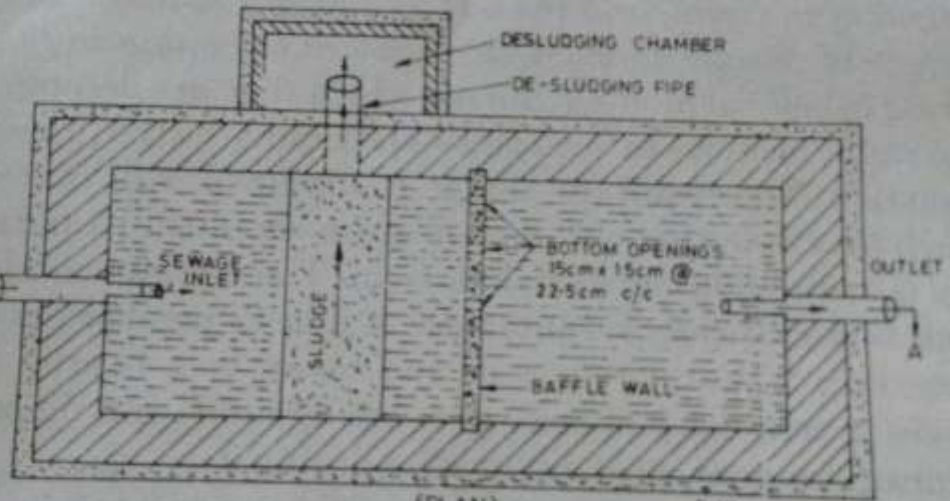
SEPTIC TANKS

- Primary Sedimentation with longer detention period of the order of 12-36 hours with extra provisions for digestion of settled sludge.
- A septic tank is thus a horizontal continuous flow type of sedimentation tank directly admitting raw sewage and removes around 60-70% of dissolved matter.
- Sludge digestion is carried out under anaerobic conditions which leads to formation of foul gases which are let out in to atmosphere through high vent shafts(2m above the top of building)
- The sludge settled at the bottom of the tank, and the oils and greasy matter rising to the top surface of sewage as cum are allowed to remain in the tank for a period of several months .
- The digested sludge is periodically removed at an interval of 6 – 12 months and in no case exceeding 3 years.

- Septic tank effluent should be disposed of properly in a sanitary manner preferably after drying it.
- Septic tanks are generally provided in area where sewers have not been laid.
- Mostly used for isolated communities ,schools, hospitals and other public institutions.
- Generally not recommended for communities having more than 300 population.
- Waste water containing excessive detergents and disinfectants are not suitable for treatment in septic tanks as they adversely affect the biological activity.
- Continuous water supply is prerequisite for effective working of septic tank.



(SECTIONAL ELEVATION A-A)



(PLAN)

Fig. 9.50. Septic Tank.

Design considerations of septic tank

1) **Capacity of septic tanks**: should be capable of storing the sewage flow during detention period and an additional volume of sludge for 6months to 3 years depending upon periodicity of cleaning.

- If only water closets are connected to septic tank , sewage flow is about 40-70 lpcd
- If sullage is also discharged into septic tank, sewage flow is around 90 – 150lpcd
- Accumulation of sludge and scum depends on characteristics of raw sewage at varying rates and efficiency of digestion.
- Rate of accumulation of sludge has been recommended as 30 litres/person/year.
- Minimum capacity of septic tank for about 8-10 people may be kept as 2250 litres when all liquid wastes are discharged in to it and 1400 litres when only water closets wastes are discharged.
- Free board of 0.3m may be provided for accommodating scum in the tank.

Inlet and Outlet baffles:

- The baffles/tees should extend up to the top level of scum(about 22cm above the top sewage line) but stop a little below the bottom of the covering slab(by at least 7.5cm in order to allow free movement of gases.)
- Inlet should penetrate by about 30cm below top sewage line and outlet should penetrate to about 40% of sewage depth
- The outlet invert level should be kept 5 – 7.5cm below the inlet invert level.

Detention time

Varies between 12 – 36 hours but generally adopted as 24 hours.

Length to width ratio : 2 – 3

Depth: 1.2 – 1.8m.

Disposal of Effluent from Septic Tanks

- Effluent contains large amount of putrescible organic matter of the order of 200 – 250 mg/l
- Effluent has BOD of the order 100 – 200mg/l
- This has to be disposed carefully so as to reduce nuisance or risk to health of people.

Following three methods are generally adopted for disposing in addition to its usage for gardening, farms etc.

- Soil absorption system
- Biological filters
- Up flow Anaerobic filters

Soil absorption system

- Involves disposal of effluent on land
- Can be adopted when sufficient porous land is available(percolation rate not to exceed 60minutes)

Soak Pit/Seepage Pit

- Circular covered pit through which the effluent is allowed to be soaked in to surrounding soil.
- Soak pit can be either filled with aggregate or kept empty
- When empty, the pit is lined with brick/stone/concrete blocks with dry open joints. Lining below the inlet level is supported by 7.5cm thick coarse aggregate backing and above inlet level is plastered with cement mortor
- Inlet pipe may be taken to a depth of 0.9m from top as an anti-mosquito
- measure.
- Soil should be highly porous with percolation rate not exceeding 30 minutes.(**Percolation rate of soil is defined as the time in minutes required for seepage of water through that ground by 1cm)**

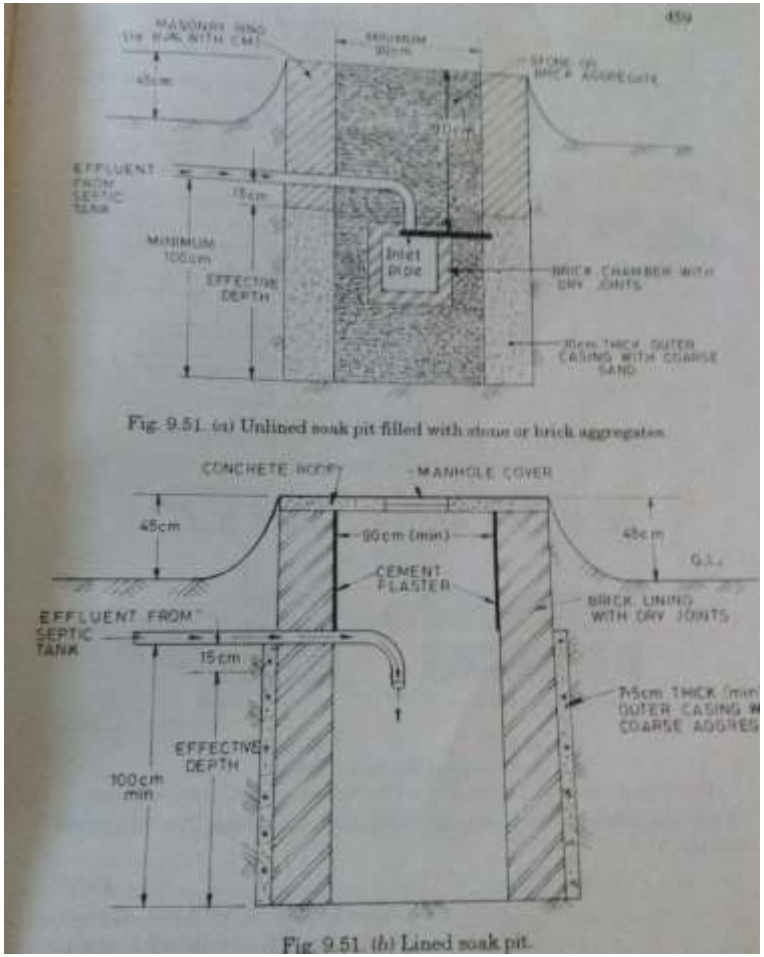
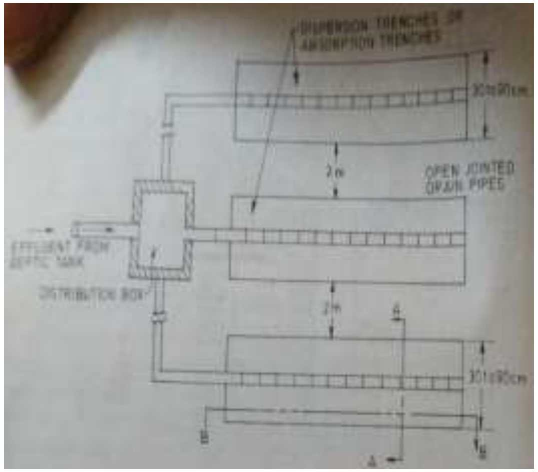
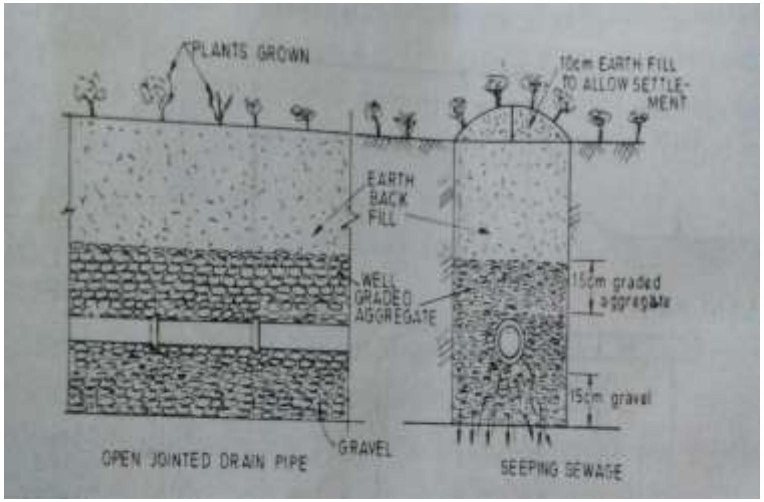


Fig. 9.51. (a) Unlined soak pit filled with stone or brick aggregates.

Fig. 9.51. (b) Lined soak pit.





Soak Pits

Absorption Trenches

Absorption trenches

- Septic tank effluent is allowed to enter a masonry chamber(distribution box) from where it is uniformly distributed through an underground network of open jointed pipes into absorption trenches called dispersion trenches.
- The suspended organic matter present in the effluent will be absorbed in the absorption trenches which consists of gravel and well graded aggregate and water will seep down to the water table.
- Plants are usually grown on the top of trenches which get their irrigation water from seeping water .

Biological filters

- Used where soil is relatively impervious(percolation rate>60min) or water logged areas or where limited land is available.
- Effluent is brought in contact with a suitable medium , the surfaces of which become coated with organic film which oxidizes much of the organic matter through agency of micro organisms.

Up flow anaerobic filters(reverse filters)

- Septic tank effluent is introduced from bottom and microbial growth is retained on the stone media leading to efficient digestion
- BOD removal is around 70% and effluent is clear from odour and nuisance.

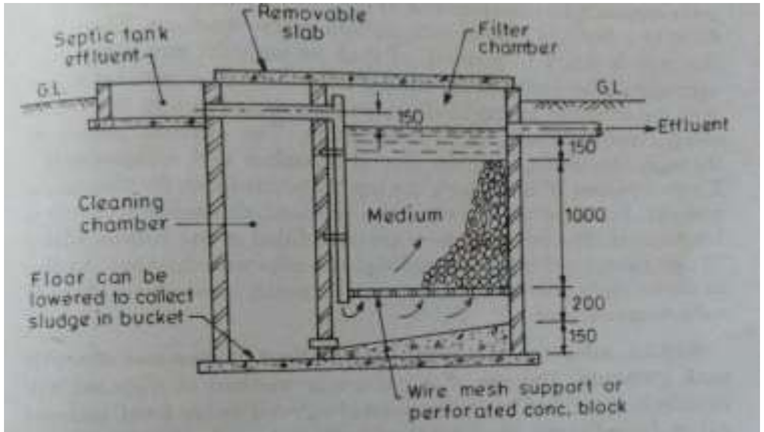


Fig. 9.54. (*a*) Single chambered rectangular upflow anaerobic filter.

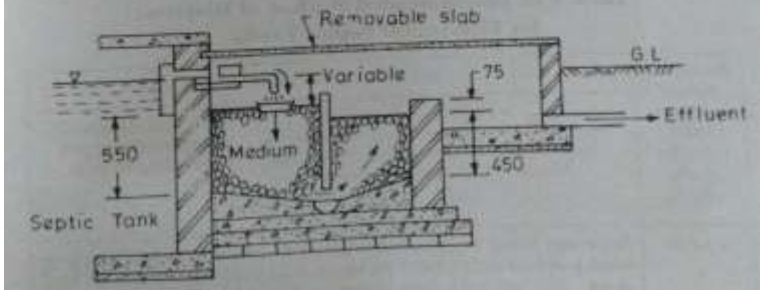


Fig. 9.54. (*b*) Double chambered rectangular upflow anaerobic filter.

Table 9.13. Recommended Method of Disposal for Effluents of Septic Tanks

Position of Subsoil water level (SSWL) below the ground level	*Soil and Subsoil Condition*		
	Porous soil with percolation rate		*Dense and clayey soils with percolation rate exceeding 60 min.*
	not exceeding 30 min.	*exceeding 30 min. but not exceeding 60 min.*	
≤ 1.8 m	*Dispersion trench* located partly or fully above the ground level in a mound.	*Dispersion trench* located partly or fully above ground level in a mound.	*Biological filter* partly or fully above ground level with under drains ; or *Upflow anaerobic filter*. The final effluent is discharged in to a city sewer or a drain, or used for gardening purposes.
> 1.8 m	*Soak pit* or *Dispersion trench*	Dispersion trench	*Sub-surface biological filter* with under-drains or *Upflow anaerobic filter*. The final effluent is discharged into a city sewer or used for gardening purposes.

Advantages of Septic tanks

- Septic tanks can be easily constructed and do not require any skilled supervision during construction. Moreover there is no maintenance problem except periodical cleaning as there is no moving part in it.
- Cost is reasonable compared to the advantages and sanitation they offer in rural or urban areas, where no sewage system has been laid.
- An exceptionally functioning septic tank can considerably reduce the suspended solids and BOD from sewage
- The sludge volume to be disposed of is quite less as compared to that in a normal sedimentation tank. The quantity is reduced due to digestion taking place in the tank itself. The reduction in volume is about 60% and reduction in weight is about 30%
- The effluent from septic tank can be disposed of on load in a soak pit with out much trouble
- Best suited for isolated rural areas and for isolated hospitals and buildings.

Disadvantages of septic tanks

- If the tank is not functioning properly, the effluents will be very foul, dark and even worse than the influent.
- They require too large sizes for serving many people
- Leakage of gases from top cover may cause bad smells and environmental pollution
- Periodical cleaning, removal and disposal of sludge remains a tedious problem
- The working of a septic tank is unpredictable and non-uniform.

Design the dimensions of a septic tank for a small colony of 150 persons provided with an assured water supply from the municipal head works at a rate of 120 lpcd. Assume any data you may need.

- Quantity of water supplied = per capita * population

  = 120 * 150 litres/day

  = 18000 litres/day

Assuming 80% of water supplied becomes sewage, we have quantity of sewage produced = 80 * 18000/100 = 14400 litres/day

Assuming the detention period as 24 hours,

Capacity of the tank = 14400 * 24/24

=14400 litres.

Assuming the rate of deposited sludge as 30 litres/capita/year and also assuming period of cleaning as 1 year, we have

Volume of sludge deposited = 30 * 150 * 1 = 4500 litres.

Total required capacity of the tank = Capacity of sewage + Capacity of sludge

= 14400 + 4500

=18900 litres or 18.9 cu.m

Assuming 1.5m as the depth of the tank, we have

Surface area of the tank = 18.9/1.5

= 12.6m2

If the ratio of the length to width is kept as 3:1, we have

3B * B = 12.6

B = √(12.6)/3

= 2.05m = 2.1m(say)

Provide length of the tank as 6m so that area of cross section provided will be 12.6m2(6*2.1 same as required)

Therefore the dimensions of the septic tank will be

6m * 2.1m * 1.8m (assuming free board of 0.3m)

- Design a septic tank for the following data
  No of people = 100
  Sewage Capacity/day = 120 litres
  Desludging period = 1 year
  Length: width = 4:1
- What would be the size of its soak well if the effluent from this tank is to be discharged in to it. Assume percolation rate through the soak well to be 1250l/m3/d

Solution for second part

Percolation rate = 1250l/m3/day

Sewage outflow = 12000 litres/day

Volume of filtering media required for soak well = 12000 / 1250
= 9.6m3

If depth of the soak well is taken as 2m, then area of the soak well required = 9.6/2 = 4.8m2

Therefore diameter of soak well required = $\pi d^2/4 = 4.8$
=> d = 2.47m = 2.5m(say)

SEWARAGE AND SEWAGE TREATMENT

SANITATION

It is the prevention of the outbreak of diseases dangerous for the general health of public.

Achieved by controlling or eliminating environmental factors which contribute to the spread of diseases

- Water Supply
- Carriage or disposal of human excreta and other wastes from communities, industries and trades
- The menace of insects-mosquitoes, flies and rodents with regards to food/other services
- Ventilation and air-conditioning
- Atmospheric pollution and methods of purification
- Plumbing in case of buildings

SEWAGE,SEWER,SEWERAGE

Sewage –
used water or liquid waste of a community, which includes human and household wastes together with street-washings, industrial waste and ground water and storm Water

Sewage

Domestic Sewage
Discharges from
kitchens,
baths,
lavatories

Industrial waste
Mills
Chemical plants
Distilleries

Ground water entering sewers through leaks

Storm water

- Sewer is an underground conduit for removal of sewage
- Sewerage is the general process of removing sewage(entire system of conduits and appurtenances involved is called sewerage system/sewer system.

SECONDARY TREATMENT

- Effluent from primary clarifiers contains about 45% to 50% of unstable organic matter originally present in sewage.
- Larger solids are removed by settlement in sedimentation tank and organic matter present in solution or in suspension or in colloidal matter is carried away by effluent from settling tank.
- FUNCTION:
  - To convert remaining organic matter into stable forms by oxidation or by nitrification.
- METHODS:

  -FILTERATION

  -ACTIVATED SLUDGE PROCESS

Biological Treatment Techniques

- Attached Growth Processes (fixed film processes)
  - Micro organism responsible for conversion of organic matter in waste water to gases and cell tissue are attached to some inert medium such as rock, slag or specially design ceramic or plastic materials. Such processes include
    - Intermittent sand filter
    - Trickling filter
    - RBC
    - Anaerobic lagoons

Biological Treatment Techniques

- Suspended growth processes
  - Micro organism responsible for conversion of organic matter in waste water to gases and cell tissue are maintain in suspension within the liquid in the reactor by employing either natural or mechanical mixing.
  - The required volume is reduced by returning bacteria from secondary clarifier in order to maintain high solid concentration.

Suspended growth process includes:

1. Activated sludge processes
2. Aerated lagoons

FILTERATION

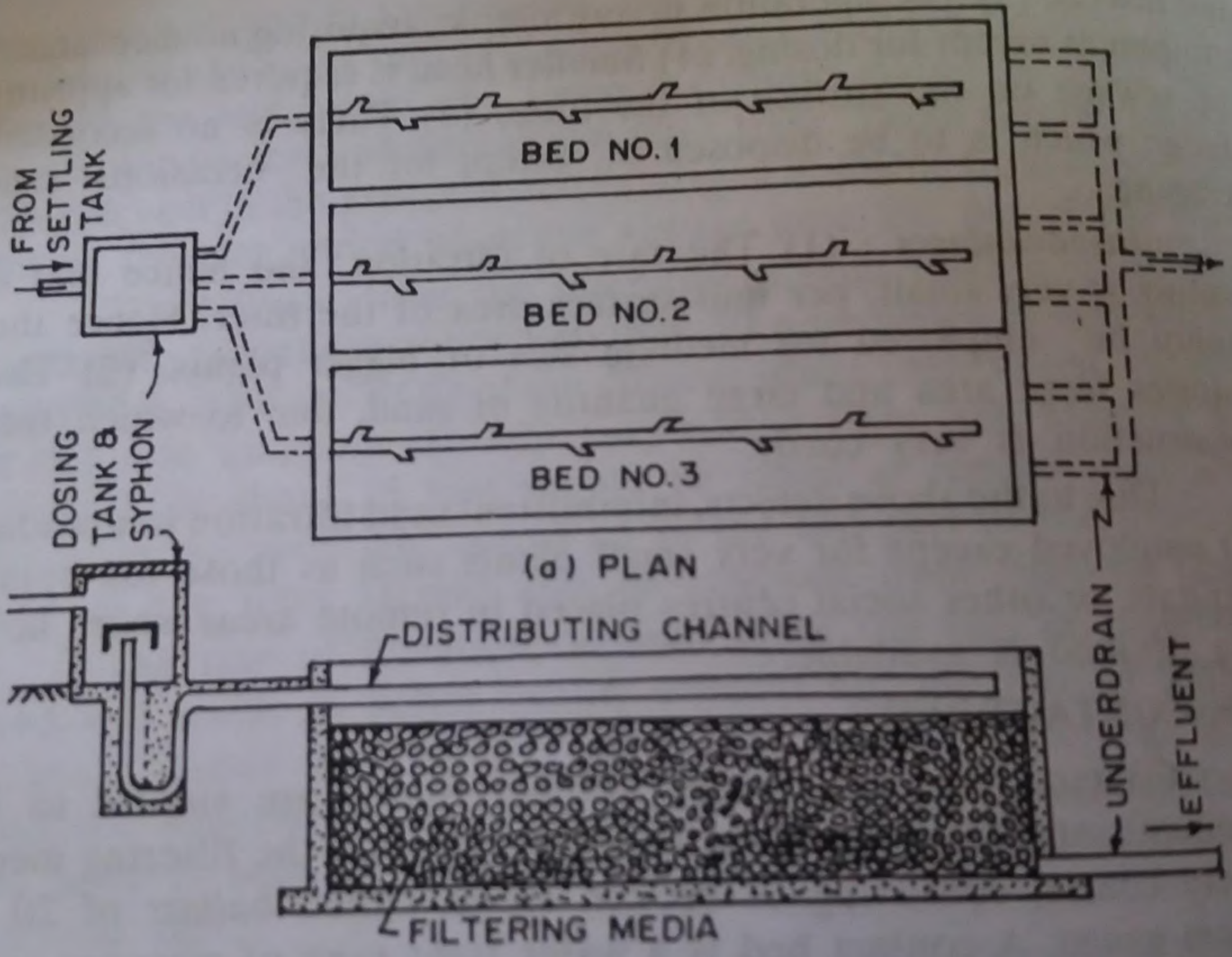
- Filters commonly used in secondary treatment of sewage are:

1. Contact bed
2. Intermittent sand filters
3. Trickling filters

CONTACT BED FILTER

- The sewage effluent is kept in contact with filtering media for some period.
- As sewage effluent passes through filtering media an organic film is produced around the particles of filtering media.
- A large number of aerobic bacteria present in this film carries out oxidation of organic matter.
- In second contact period when bed is standing empty filter obtains oxygen from atmosphere and organic matter caught in the voids of filtering media gets oxidized.

Contact Bed



(a) PLAN

(b) L-SECTION

WORKING OF CONTACT BED

- Tank is filled with sewage effluent which may take about 2 hours or so.
- Sewage effluent is allowed to stand on filtering media for period of about 2 hours or so.
- Tank is then emptied and sewage effluent is allowed to flow through effluent pipe without disturbing the organic film of bed.
- Contact bed is then allowed to stand empty for a period of about 6 hour.
- Actual contact period will depend on quality and type of effluent required. Cycle of operation is generally completed in 12 hrs.

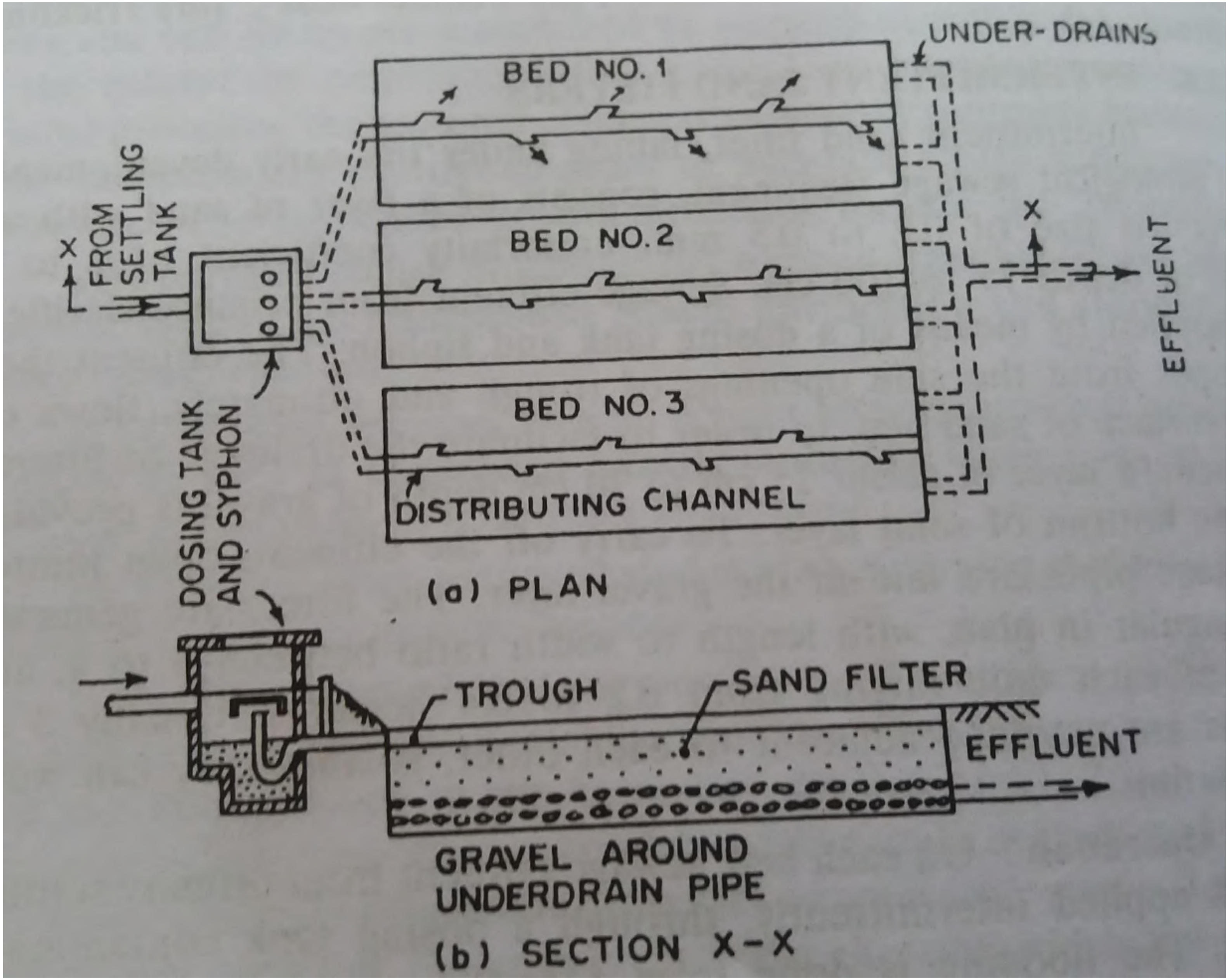
INTERMITTENT SAND FILTERS

- In this process sewage effluent is applied at regular interval on specially prepared bed of sand filter.
- As it passes through filtering media of sand the purification of sewage effluent is affected by following two actions:
  - Mechanical straining
  - Bacterial action taking place in voids of sand particles.
- During period of rest, atmospheric air will be carried up to the voids of sand particles so as to establish favorable conditions of aerobic bacteria.

Working

- Sewage effluent from PST is applied intermittently through dosing tank containing siphon.
- Sewage effluent percolates through sand bed, in this process suspended organic matter gets trapped in the voids of top portion of sand through ***straining action***.
- Trapped organic matter is acted upon by aerobic bacteria. These aerobic bacteria flourish well in presence of oxygen available from atmosphere during rest period.

Intermittent sand filter



- FILTER MEDIA:
  - Consists of sand layer at top (750mm-900mm).
  - In order to facilitate drainage of effluent layer of about 150mm to 300mm depth of gravel is provided at bottom.
- In order to maintain efficiency of intermittent sand filter topmost layer of depth about 25mm is raked at regular intervals to break up the materials caught in the top part of filter.
- USES: it is best suited for small isolated institutions such as hotels, hospitals, isolated commercial and industrial units.

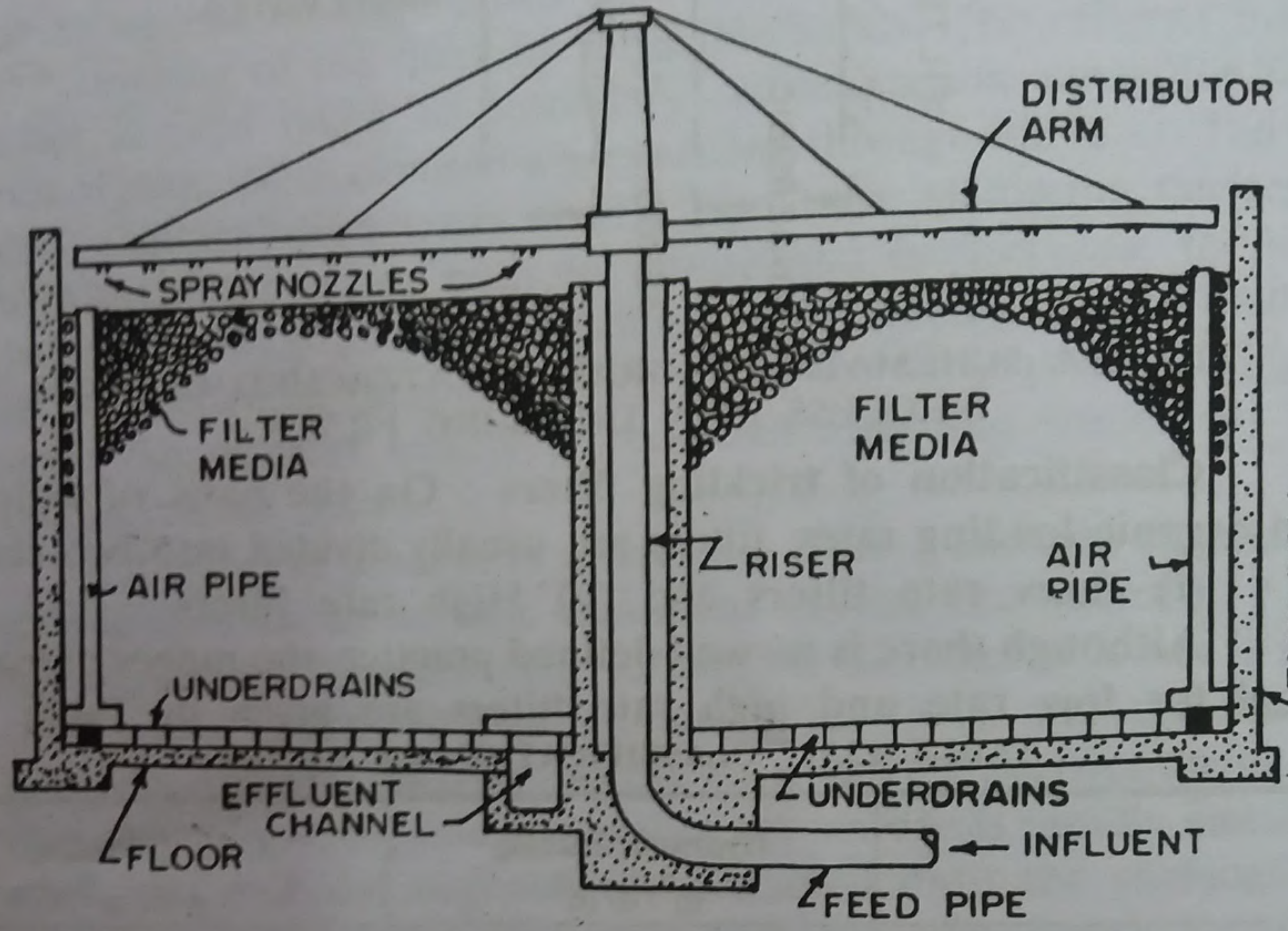
TRICKLING FILTER

- Trickling filter is an ***attached growth process.***
- Process in which microorganisms responsible for treatment are attached to an inert packing material. Packing material used in attached growth processes include rock, gravel, slag, sand, redwood, and a wide range of plastic and other synthetic materials.

TRICKLING FILTER (Location)

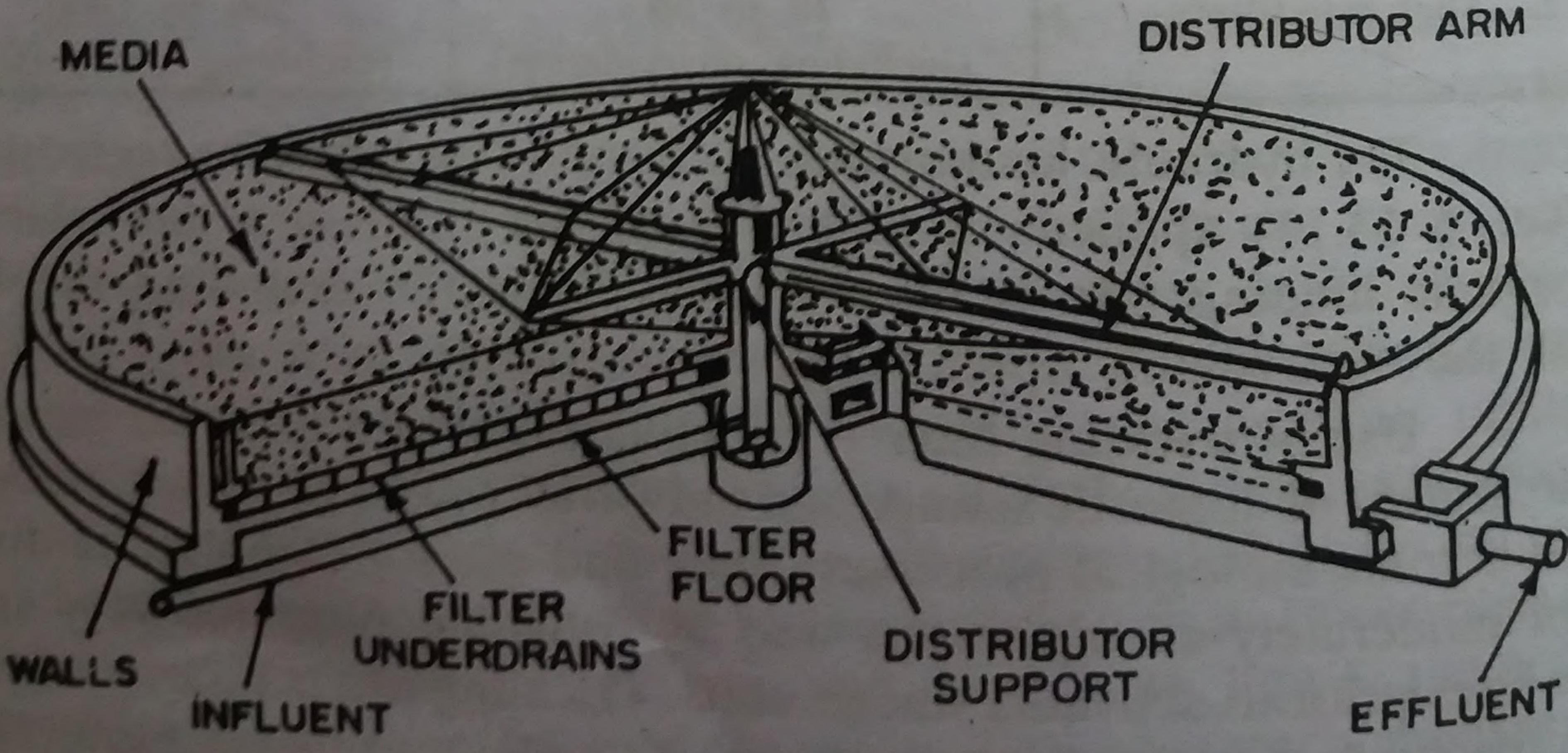
- Trickling filter are used for biological treatment of domestic sewage and industrial waste which are amenable to aerobic biological process.
- They possess a unique capacity to handle shock loads and provide dependable performance with minimum supervision.
- It is always preceded by primary sedimentation so that settle able solid may not clog the filter
- It is always followed by final settling tank to remove the settable organic solid produced in the filtration.
- Skimming devices should be provided for final settling tank as they serve both to oxidize and bio flocculate the organic materials in sewage and their efficiency is assets on total reduction in BOD effected to the filter and subsequent settling tank.

TRICKLING FILTER



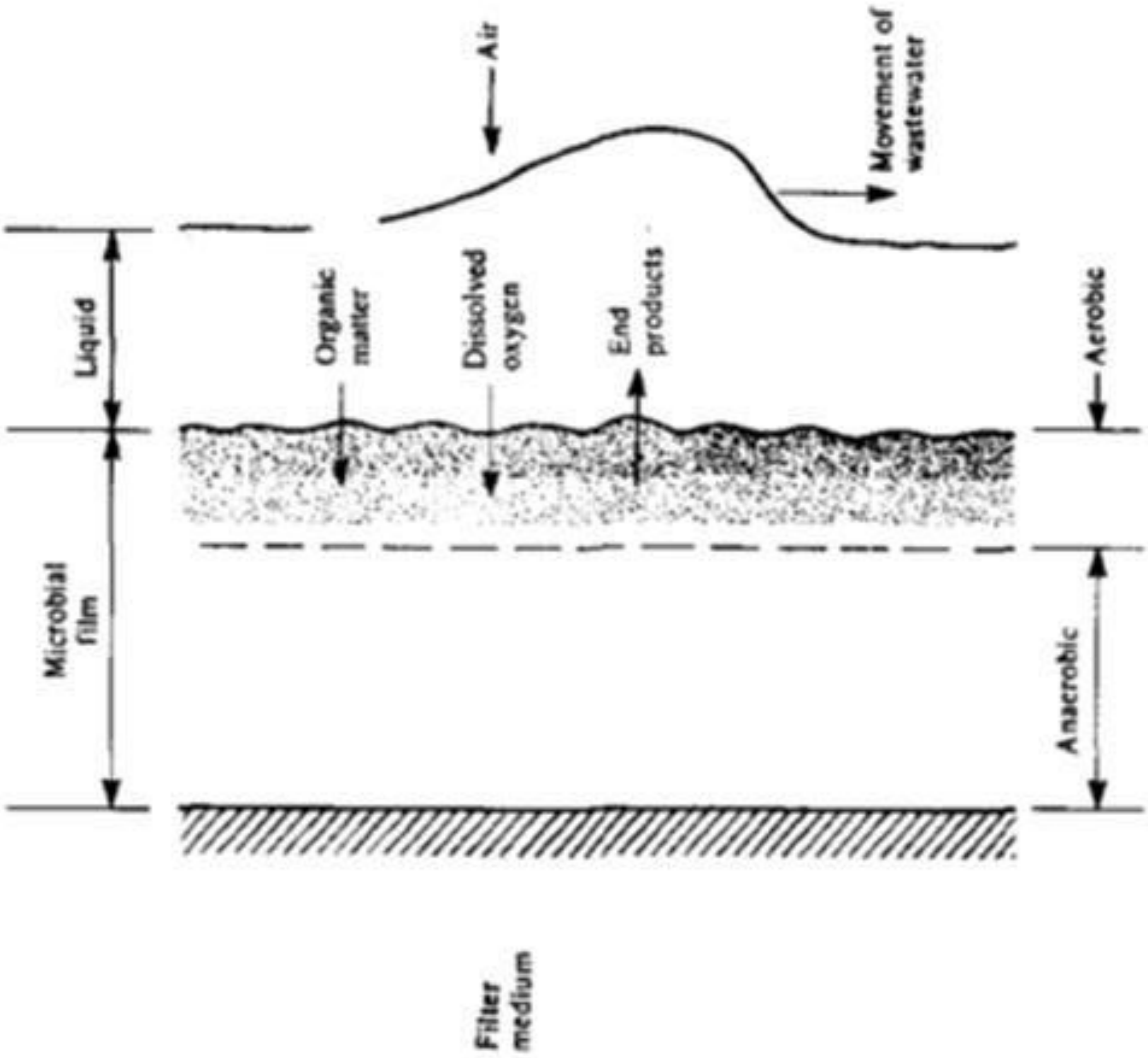
(*a*) TYPICAL CROSS-SECTION

TRICKLING FILTER

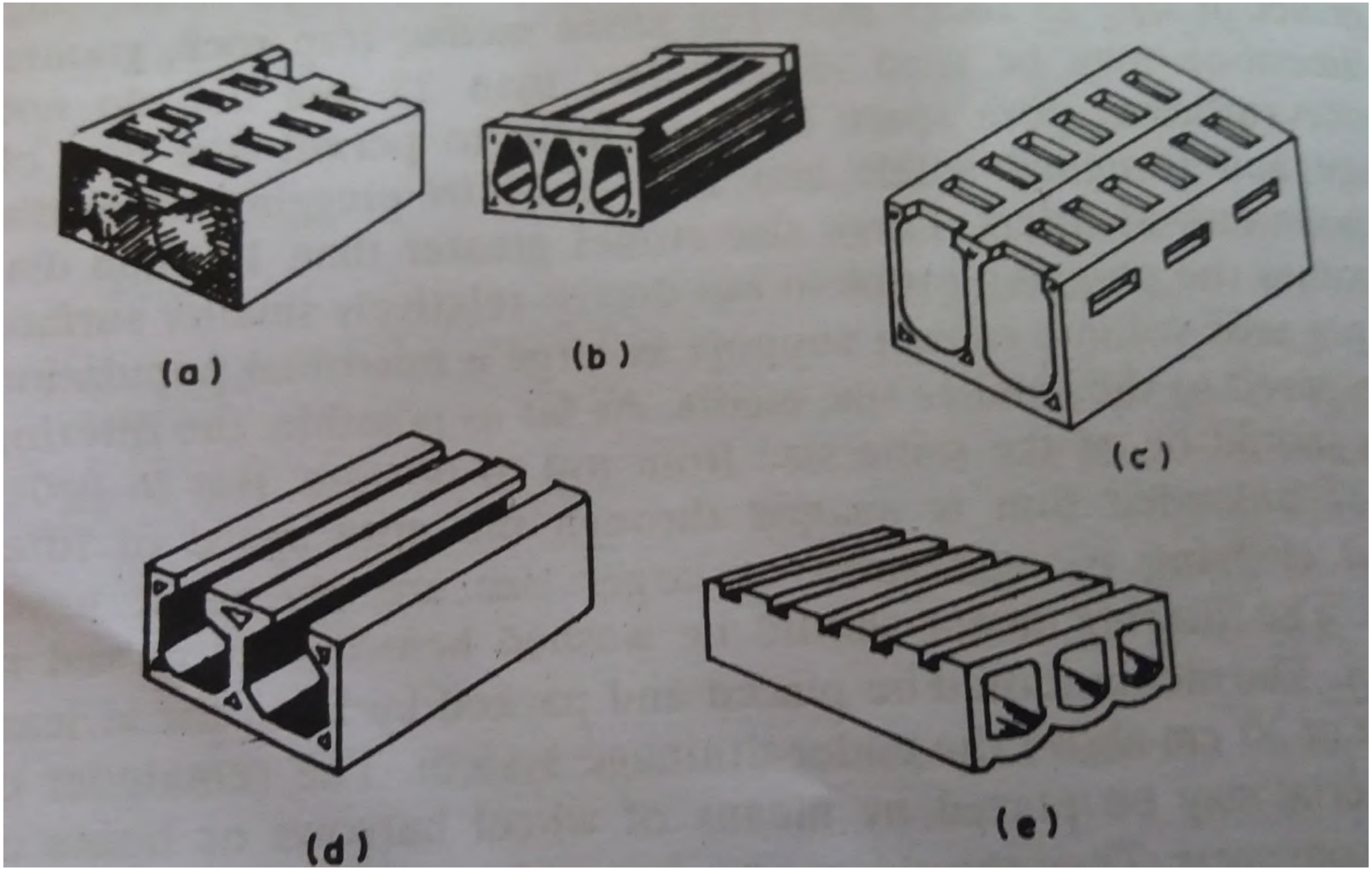


(*b*) PICTORICAL SECTION
FIG. 13.5 TRICKLING FILTER

SLIME LAYER FIGURE



Commercially Available Blocks for Under Drainage System



WORKING

- As sewage trickles to filter media a biological slime consisting of aerobic bacteria and other biota built up around the media surface, normally in 2 weeks periods making filter ready for use.
- Organic material is absorbed on this biological slime where they are degraded by biota thus increasing weight and thickness of slime. The colour of this film is blackish greenish and yellowish consisting of bacteria, fungi, algae, lichens, protozoa etc.
- It loose their ability to cling to the media surface.
- Eventually there is scoring of slime and fresh slime layer begins to grow on media. This phenomenon of scoring is called slogging or unloading of filter.

WORKING

- The sloughed off film and treated wastewater are collected by an under drainage which also allows circulation of air through filter. The collected liquid is passed to a settling tank used for solid- liquid separation.
- Slogging helps ventilation by keeping the filter media open, reviewing the biota, maintaining it active for efficient functioning of filter.
- The degree of filter slogging to be given depends on organic loading and hydraulic loading which will influence its scour.

BIOLOGICAL PROCESS

- Though TF is classified as an aerobic treatment device, the slime layer form on filter media is aerobic upto depth of 0.1 to 0.2 mm and remaining part is anaerobic.
- As waste water flows over the microbial film the soluble organic material in sewage is rapidly metabolized while colloidal organics are adsorbed on to the surface.
- In the outer portion of biological film organic matter is degraded by aerobic microorganism. Since food concentration is higher at outer layer, micro organism near the outer surface are in a rapid growth phase and due to this thickness of layer increases and diffused oxygen is consumed before it can penetrate full depth of slime layer.

BIOLOGICAL PROCESS

- Hence lower zone of the film is in state of starvation due to which anaerobic environment is established near the surface of the media.
- As a result it enter endogenous phase of growth and lose their ability to cling to the media surface and result in sloughing or unloading of filter

CONSTRUCTION FEATURES

- It consists of water type tank having a bed of filter media, sewage distribution system and under drain system.

1. **Shape of filter**-It may have circular or rectangular shape, in which circular shape is most common. Here rotary distribution system is adopted for spreading or spraying sewage on surface of filter bed. Circular shape has also advantage of structural economy.
2. **Filter walls-**It may be of either RCC or fully plastered brick or stone masonry or hollow concrete block
3. **Filter Floor-**It is design to support under drain system and fully loaded super imposed filter media. Normally RCC slab 100 to 150mm thick over a proper leveling course is proved. The flow should slope towards main collecting channels.
4. **Under drainage System-**It is used to collect trickling sewage and sloughed solids and to convey them to main collecting channel and also to ventilate filter media. It consists of V shaped or half round channels cast in concrete floor. These drains are covered by concrete blocks as shown in figure. The compressed air is also passed through these under drainage lines

CONSTRUCTION FEATURES

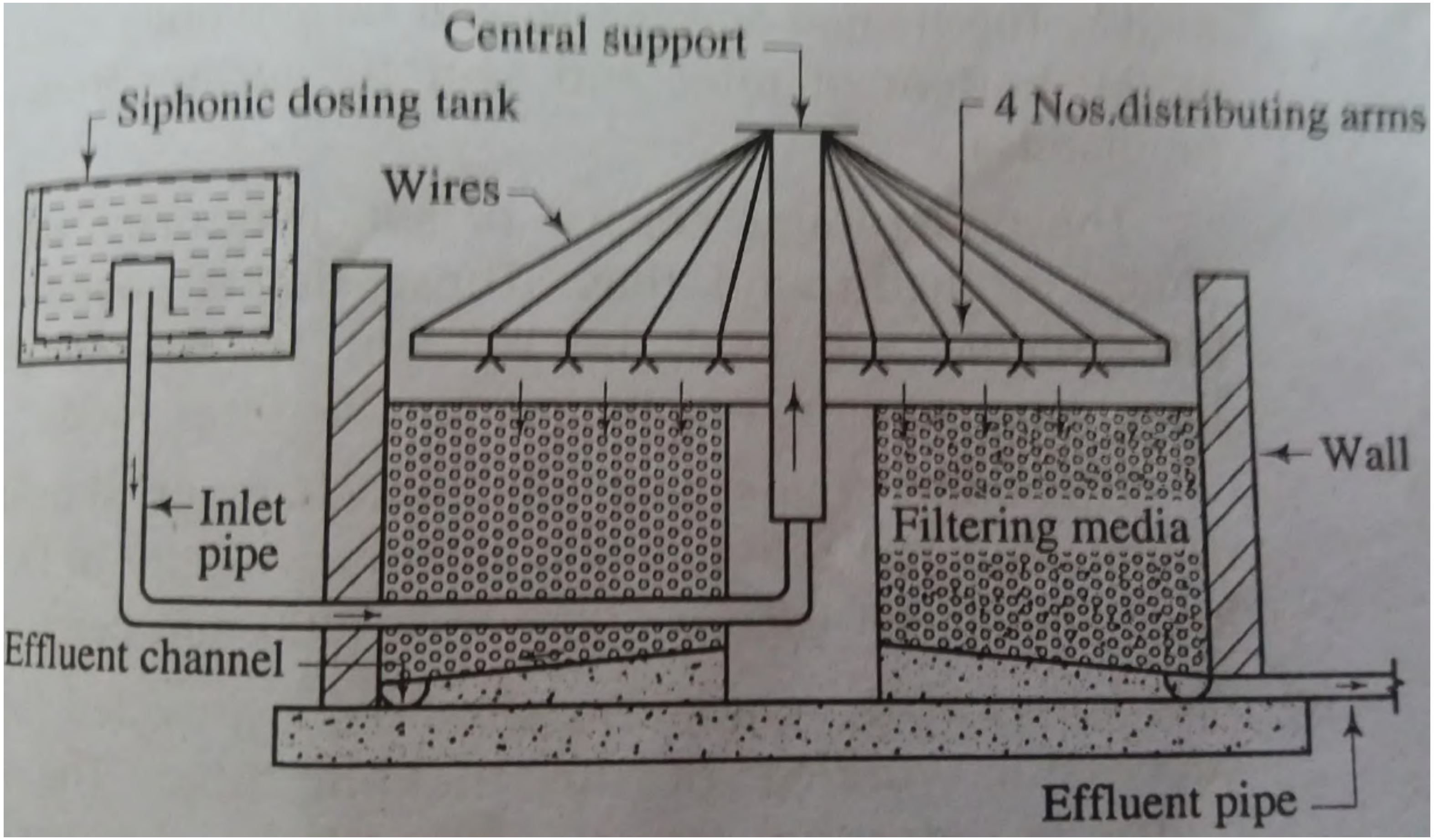
5. **Ventilation-** Efficiency of filter is increased if filter is properly designed and sufficient natural ventilations there.
   - Forced ventilation may be provided in case of deep filter, it consists of forcing air vertically upward by used of fan or other suitable mechanical equipment.
   - Natural draft ventilation may be provided in following ways
     - By connecting the ends of under drains to a chimney for circulation of air.
     - By constructing filters above ground with open sides.
     - By keeping ends of under drainage open
     - By providing vent pipe at periphery of filter

CONSTRUCTION FEATURES

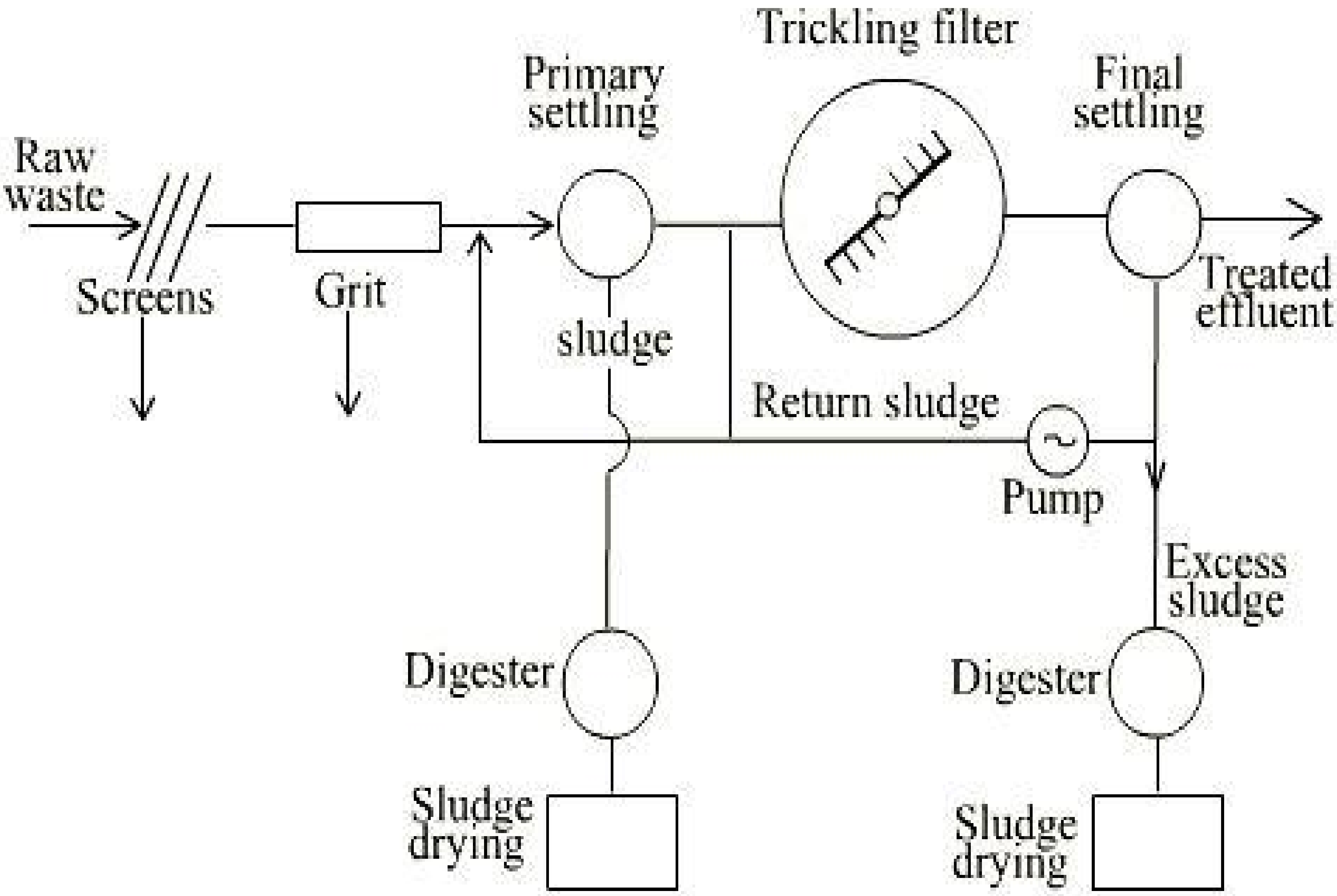
6. Filter Media-
   - It may consists of crushed rock or clinker ,Anthracite coal, blast furnace slag etc.
   - Shape should be preferably cubical and not flat or elongated.
   - It should be free from dirt and of uniform size. It must be weather resistant and storm enough.
   - Size between 30mm to 80mm.
7. Distribution system-The function of distributer is to spread effluent evenly on the filter media.
   - Two types -movable distributor and fixed distributor
   - Movable distributor-sewage is distributed through the arms which is rotated around the central support.
   - Fixed distributor- these are in the form of spray nozzles which are fixed on the surface of filters at appropriate distance.

CONSTRUCTION FEATURES

8. Dosing tank- sewage is generally not applied on the surface continuously. It is applied for 3 to 5 mins and then discontinue for a period of 3 to 10 mins or more. Hence automatic siphonic dosing tanks are provided.



Flow sheet of a trickling filter system



TYPES OF TRICKLING FILTERS

- Classified as
  - Low rate TF (standard rate TF)
  - High rate TF

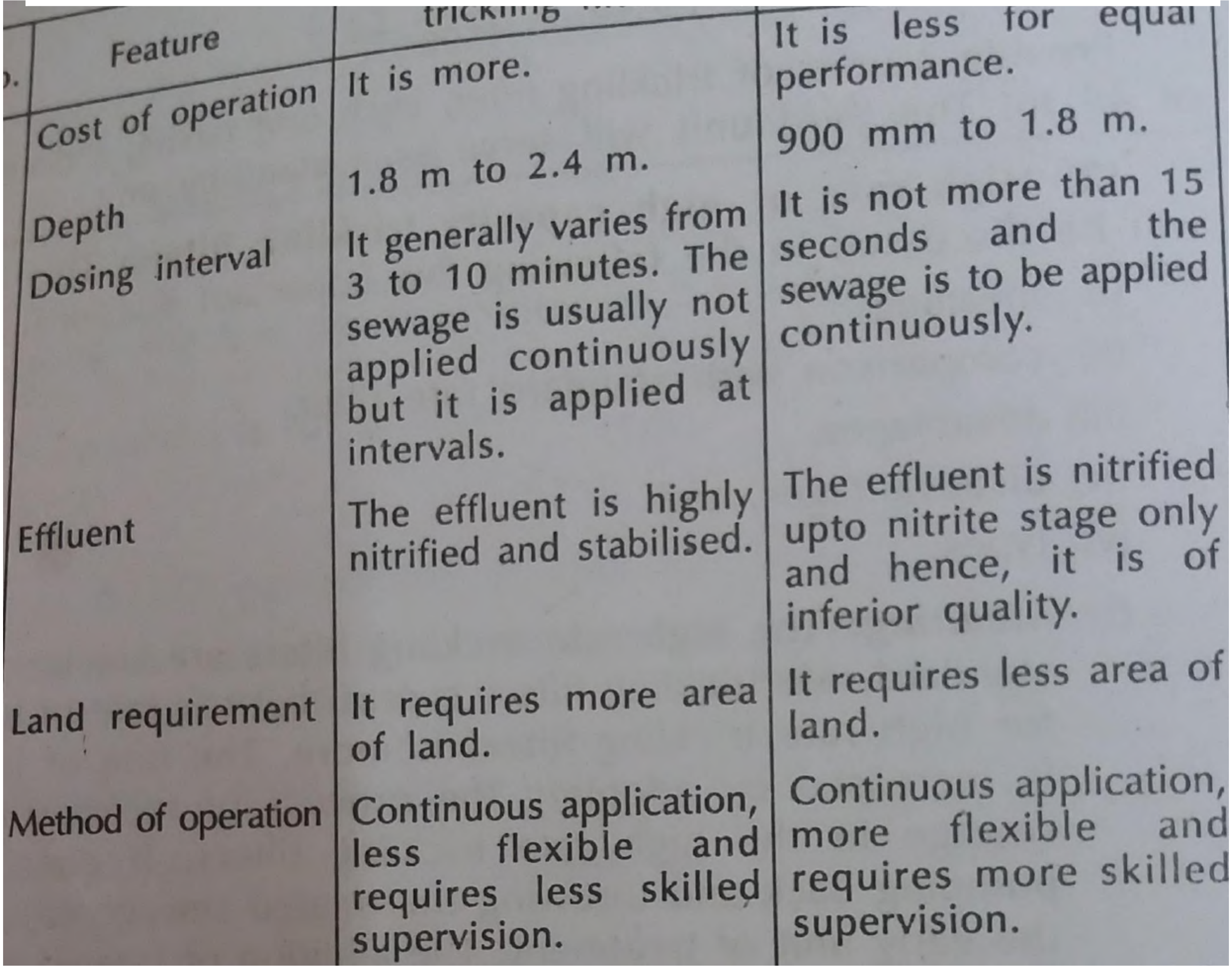
	Type of filter	Hydraulic loading in $m^3/d/m^2$	Organic loading as BOD mg/d/m^3
1	Low rate TF	1 to 4	80 to 320
2	High rate TF	10 to 30 (including recirculation)	500 to 100 (excluding recirculation)

HIGH RATE FILTER

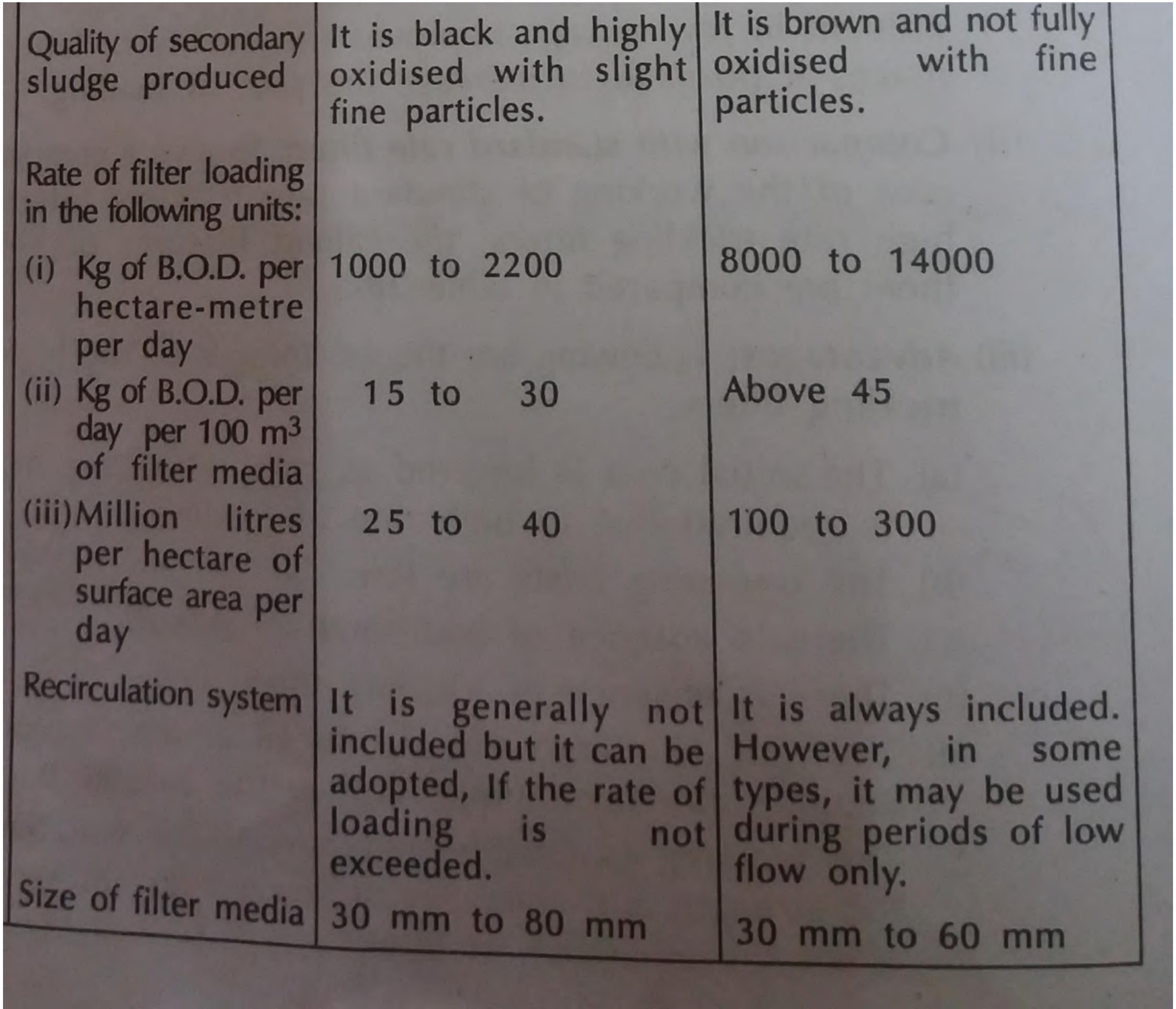
- Normal rate trickling filter have high efficiency in BOD removal and other organic matter.
- Main drawback is higher initial cost and large area and large filter media requirement.
- To overcome above drawbacks the rate of flow was increased and following observation were made.
  - With increase in rate of flow thickness of bio film was reduced and materials deposited in filtering media are continuously washed away with effluents.
  - Thinner film is more efficient and supply continuous food to aerobic bacteria.
  - As contact period for bacteria to act upon sewage is less, less oxidation takes place. Hence load on secondary settling tank is increased.
  - The quality of sludge is not so easily digestible as that of low rate trickling filter.

MODIFICATION OVER SRTF

- Depth of filter media is reduced to 170 to 120 cm for better aeration and for high rate of biological activity.
- Size of under drain are increased and their slope are made more steeper for quick collection of effluent.
- Speed of rotating arm is increased to 2rpm for supplying sewage and high rate
- Size of secondary settling tank is increased for collecting more quantity of sewage and flocculent solids coming with effluent of trickling filter.



Features	Standard rate TF	High Rate TF
Feature		
Cost of operation	It is more.	It is less for equal performance.
Depth	1.8 m to 2.4 m.	900 mm to 1.8 m.
Dosing interval	It generally varies from 3 to 10 minutes. The sewage is usually not applied continuously but it is applied at intervals.	It is not more than 15 seconds and the sewage is to be applied continuously.
Effluent	The effluent is highly nitrified and stabilised.	The effluent is nitrified upto nitrite stage only and hence, it is of inferior quality.
Land requirement	It requires more area of land.	It requires less area of land.
Method of operation	Continuous application, less flexible and requires less skilled supervision.	Continuous application, more flexible and requires more skilled supervision.



Features	Standard rate TF	High Rate TF
Quality of secondary sludge produced	It is black and highly oxidised with slight fine particles.	It is brown and not fully oxidised with fine particles.
Rate of filter loading in the following units:		
(i) Kg of B.O.D. per hectare-metre per day	1000 to 2200	8000 to 14000
(ii) Kg of B.O.D. per day per 100 m^3 of filter media	15 to 30	Above 45
(iii) Million litres per hectare of surface area per day	25 to 40	100 to 300
Recirculation system	It is generally not included but it can be adopted, If the rate of loading is not exceeded.	It is always included. However, in some types, it may be used during periods of low flow only.
Size of filter media	30 mm to 80 mm	30 mm to 60 mm

RECIRCULATION

- It is return of portion of treated or partly treated sewage to the treatment process. It is important feature of high rate filter
- Expressed in term of recirculation ratio R
- Advantages
  - The thickness of bio film on contact media is reduced by forced film sloughing
  - Filter influent is fresh and due to which foul odor is prevented
  - Applied sewage is seeded with active organism and enzyme of effluent due to which efficiency of filter is increased.
  - The filter influent is diluted and weakened so that filter works at constant efficiency and quality of effluent is improved
- Recirculation ratio is ratio of recirculated flow to the total flow of raw sewage.
- It is used for calculation of
  - Capacity of pump
  - Increased load on trickling filter

Recirculating pump capacity

=(influent sewage flow)x(recirculation ratio)

Hydraulic load on trickling filter

=(influent sewage) x (1+recirculation ratio).

- **Recirculation factor:** The number of effective passes through filter is known as recirculation factor (F)

$$F = \frac{1+R}{[1+(1-f)R]^2} \qquad = \frac{1+R}{(1+0.1R)^2}$$

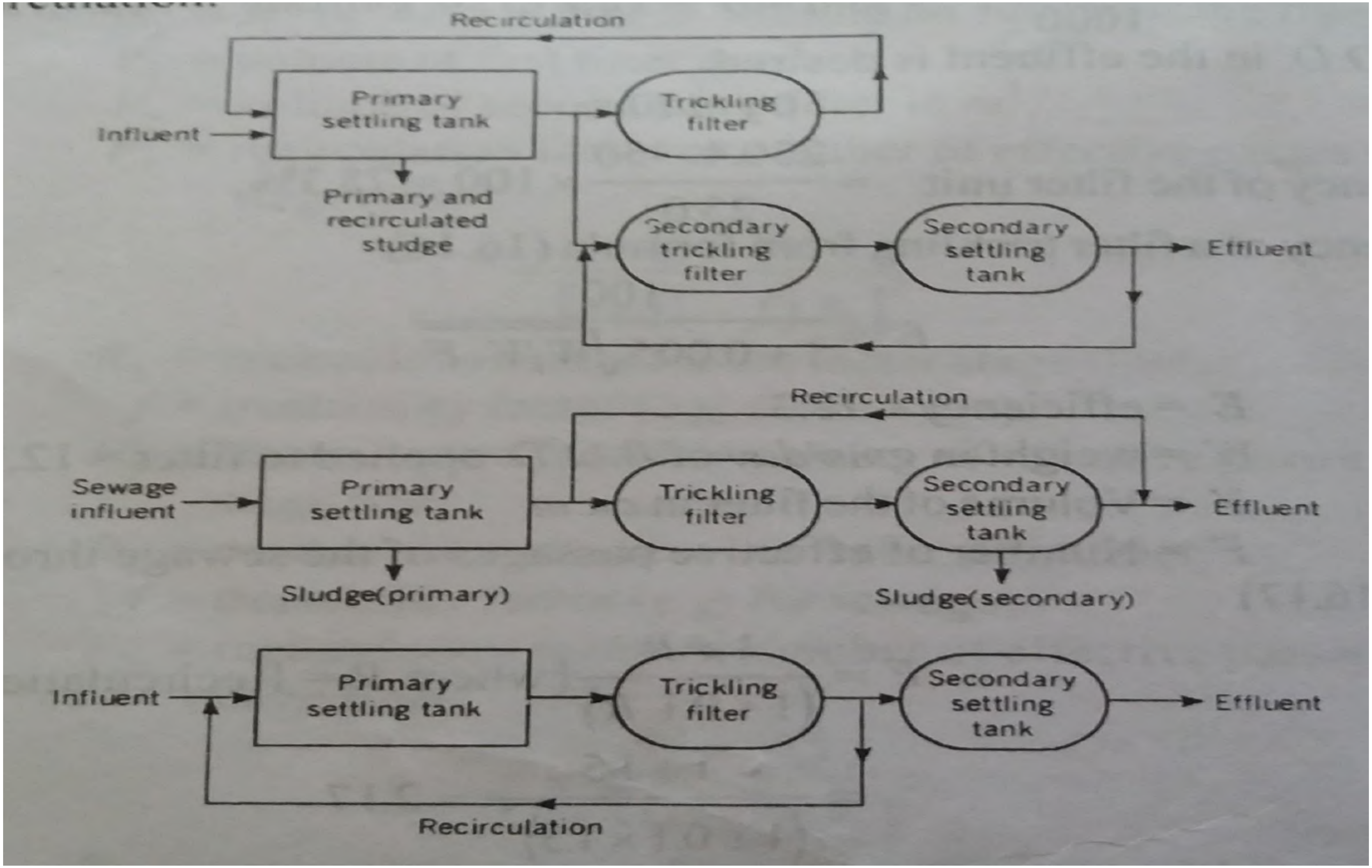
where f = treatability factor =0.9 for sewage

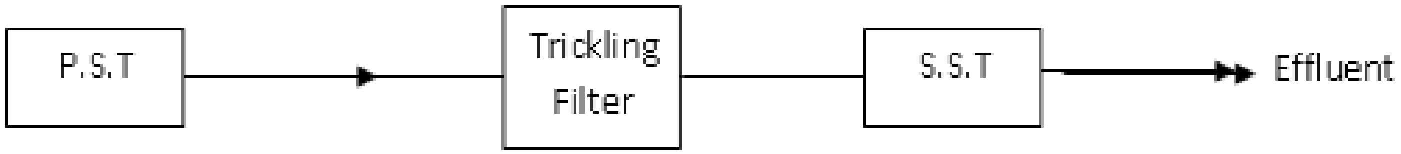
- **Hydraulic recirculation factor :** The no of hydraulic passes of recirculated sewage through the filter

F_h = (Inflow +recirculation)/ inflow = 1+R

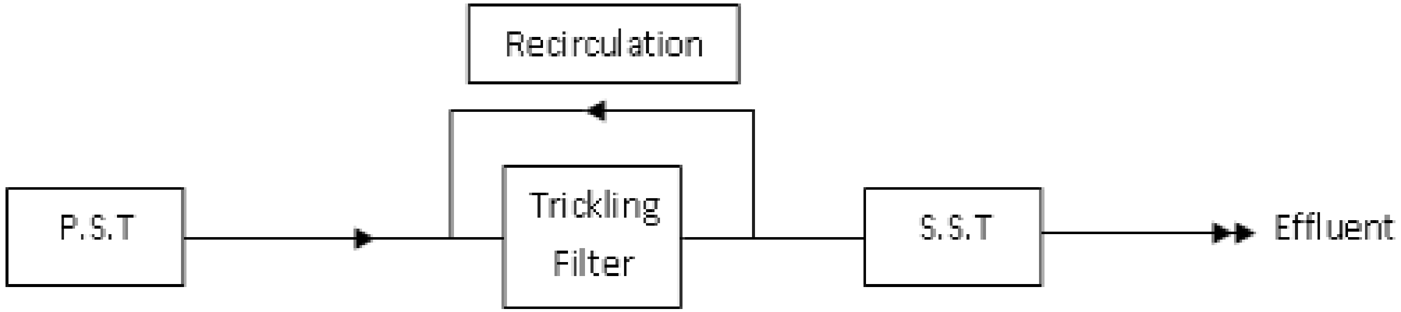
- If sewage has high concentration of BOD it can be recirculated by passing no. of times through trickling filter and settling tanks.

*It should not be more than 2-3 times as it reduces efficiency***.**

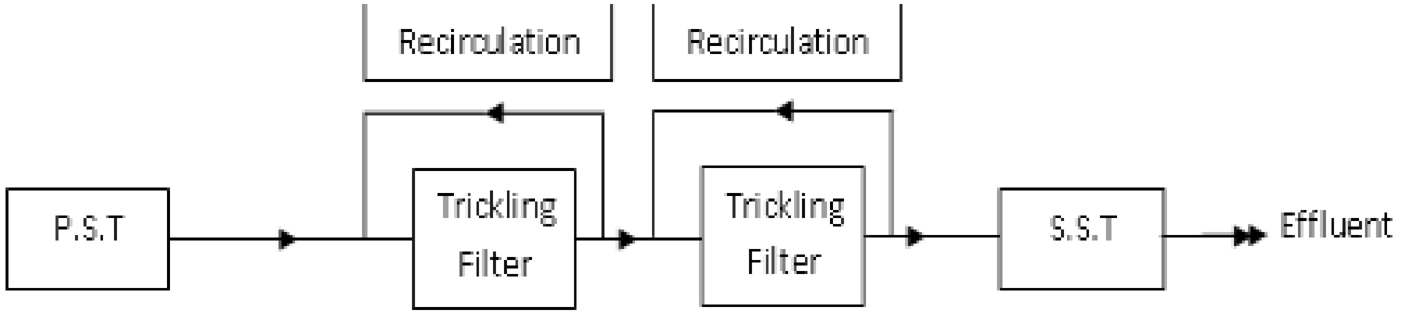




Low Rate/Standard Trickling Filter (No Recirculation)



Single Stage High Rate Trickling Filter



Two Stage High Rate Trickling Filter

- The high rate trickling filter, single stage or two stage are recommended for medium to relatively high strength domestic and industrial wastewater. The BOD removal efficiency is around 75 to 90% but the effluent is only partially nitrified.
- ***Single stage unit*** consists of a primary settling tank, filter, secondary settling tank and facilities for recirculation of the effluent.
- ***Two stage filters*** consist of two filters in series with a primary settling tank, an intermediate settling tank which may be omitted in certain cases and a final settling tank.
- 2 stage units are used for strong sewage when effluent BOD has to be less than 30mg/l.

Advantage and disadvantage of Trickling Filter

Advantages of Trickling Filter

- Rate of Filter loading is high as required less land areas and smaller quantities of filter media for their installations.
- Effluent obtained from the trickling filter is sufficient stabilized.
- Working of Trickling filter is simple and does not require any skilled supervision.
- They are flexible in operation.
- They are self cleaning
- Mechanical wear and tear is small as they contain less mechanical equipment.

Advantage and disadvantage of Trickling Filter

Disadvantages of Trickling Filter

- The beds loss through these filters is high.
- Construction cost is high
- These filters cannot treat raw sewage and primary sedimentation is must.
- Fly nuisance and odour nuisance may prevail.

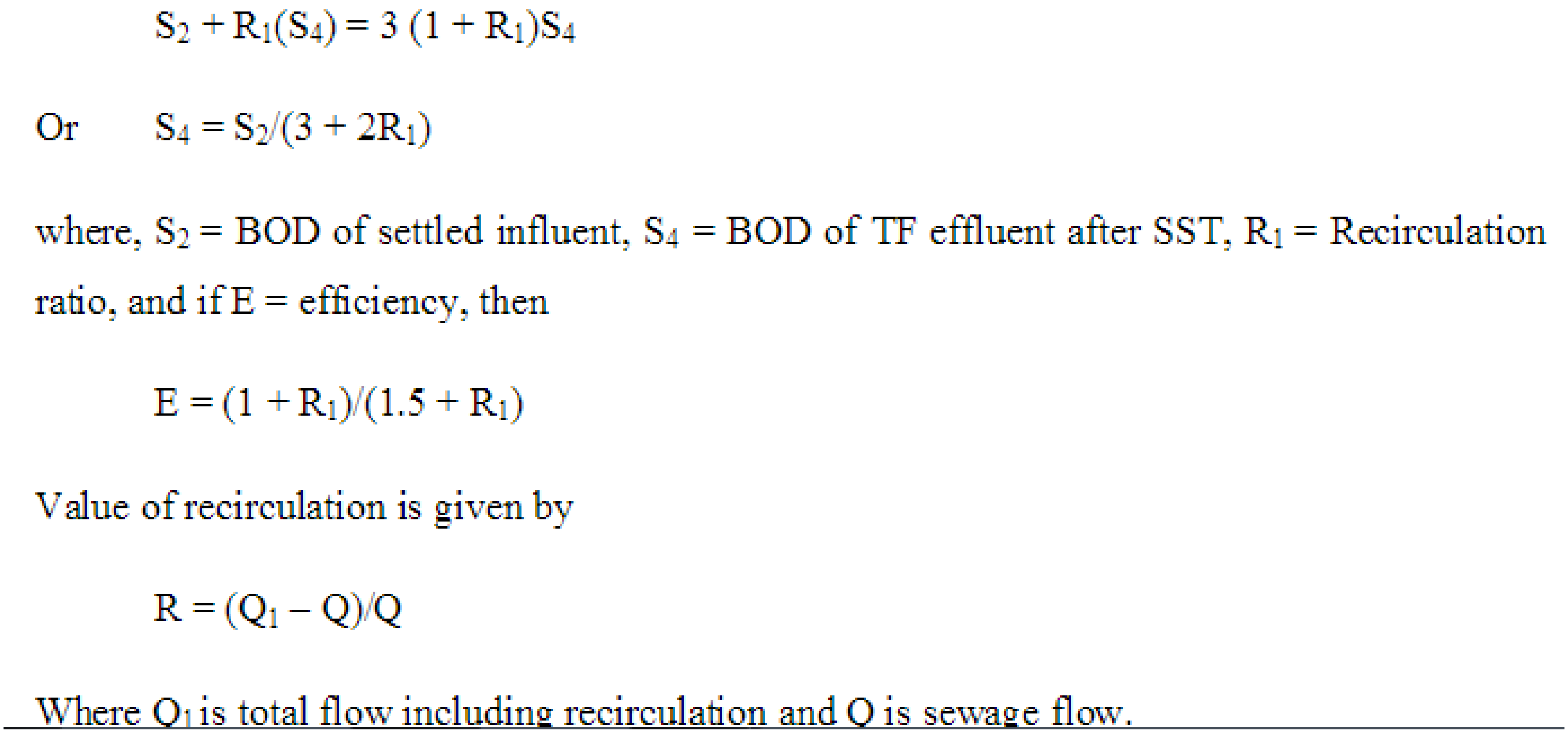
DESIGN ASPECTS OF TF

1. Depth- effective depth is generally kept between 1.4m to 2.4m
2. No of filters-provision for standby unit hence minimum two filter should be provided
3. Rate of filter loading-following units are most commonly used to express rate of loading in TF
   - Kg of BOD per volume of filter bed -according to this unit rate varies form 1000to 2200 kg of BOD per hectare meter per day
   - Kg of BOD per volume of filter media- according to this unit rate varies from 15 to 30 kg of BOD per day per 100 m^3 of filter material
   - Surface area of filter bed- according to this unit rate varies from 25 to 40 million liters/hectare/day of surface area
   - Volume of filter bed-according to this unit rate varies from 7.5 to 22.5 million liters/hectare-meter/day

- Number of equations are available for determining efficiency of plant based on organic loading rates and recirculation ratios. Types of equations:
  - NRC equations (National Research Council of USA)
  - Rankins equation
  - Eckenfilder equation
  - Galler and Gotaas equation

1.RANKINES FORMULA

- For single stage filters, Ten state standard states that the BOD of influent to the filter(including recirculation) shall not exceed three times the BOD required for settled effluent.



$$S_2 + R_1(S_4) = 3\ (1 + R_1)S_4$$

Or $$S_4 = S_2/(3 + 2R_1)$$

where, S_2 = BOD of settled influent, S_4 = BOD of TF effluent after SST, R_1 = Recirculation ratio, and if E = efficiency, then

$$E = (1 + R_1)/(1.5 + R_1)$$

Value of recirculation is given by

$$R = (Q_1 - Q)/Q$$

Where Q_1 is total flow including recirculation and Q is sewage flow.

- These eq. are applicable only when organic loading rate on the filter including recirculation is less than 1800 g/d/m^3 and 10-30 m3/d/m^2 hydraulic loading is maintained

- When organic loading ranges between 1800 to 2800 gm/d/m^3

$$S4 = \frac{S2}{2.78 + 1.78R1}$$

- For all loading in excess of 2800 g/m3 BOD removal is assumed to be 1800 g/d/m^3
- When effluent of first stage filter is applied to 2nd stage filter without settling following equations are applied.

$$S4 = \frac{S2}{2 + R1}$$

$$E3 = \frac{1 + R1}{2 + R1}$$

- In case 1st stage effluent consist of settle sewage which does not pass through 1st stage filter following eq. is used

$$S4 = \frac{1.5 + S2}{2.5 + r}$$

$$value\ of\ recirculation = \frac{Q1 - Q}{Q}$$

Where Q1 = total flow through 1st stage filter

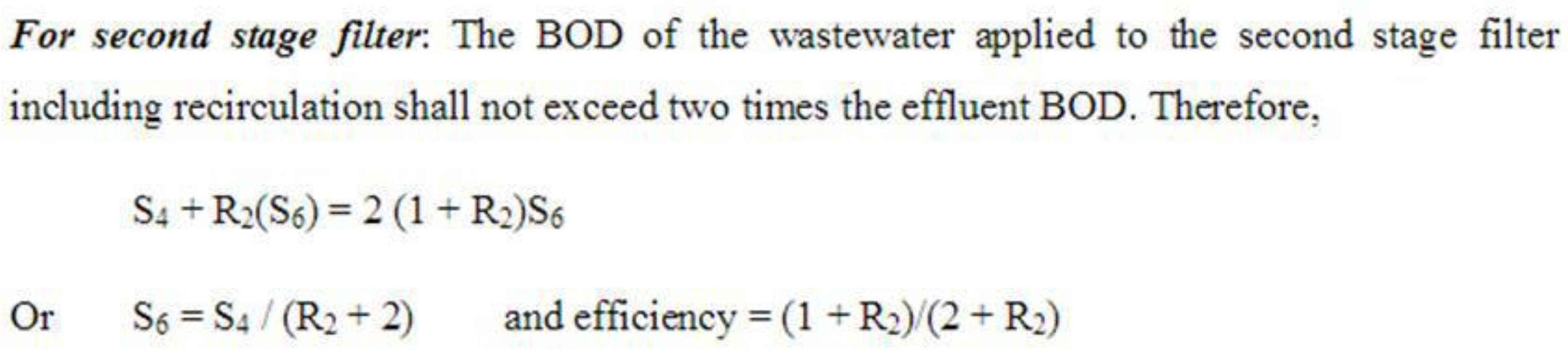
Q = Row sewage flow

BOD loading on filter is determine by

La1 = Q (S2+R1S4)

Where La1= BOD loading in Kg/day

Q= sewage flow in mld



For second stage filter: The BOD of the wastewater applied to the second stage filter including recirculation shall not exceed two times the effluent BOD. Therefore,

$$S_4 + R_2(S_6) = 2\,(1 + R_2)S_6$$

Or $S_6 = S_4 / (R_2 + 2)$ and efficiency = $(1 + R_2)/(2 + R_2)$

Where S6 = BOD of settle effluent from 2nd stage mg/lt

R2 = recirculation ration in 2nd stage

NRC EQUATIONS

- These equations are applicable to both low rate and high rate filters. The efficiency of single stage or first stage of two stage filters, E is given by

$$E = \frac{100}{1 + 0.44(W/VF)^{1/2}}$$

For the second stage filter, the efficiency E' is given by

$$E' = \frac{100}{1 + \frac{0.44}{1-e}(W'/V'F')^{1/2}}$$

Where E= % efficiency in BOD removal of 1st stage

E' = % efficiency in BOD removal in 2nd stage filter

e = E/100

W= BOD loading of settled raw sewage in 1st stage (Kg/day)

V= vol of 1st stage filter (m^3)

F= Recirculation factor

Q. The sewage is flowing @4.5 million litres per day from primary clarifier to a standard rate trickling filter. The 5-day BOD of influent is 160mg/l. The value of the adopted organic loading is to be 160gm/m3/day, and surface loading 2000l/m^2/day. Determine volume of filter and its depth. Also calculate the efficiency of this filter unit.

Total 5 Day BOD present in sewage = $160*4.5*10^{6}/10^{3}$ gm/day

= 7,20,000 gm/day

Volume of filter media required = Total BOD/Organic Loading

(= 7,20,000 gm/day)/(160 gm/m3.day)

= 4500m^3

Surface area required for the filter = Total flow/Hydraulic loading

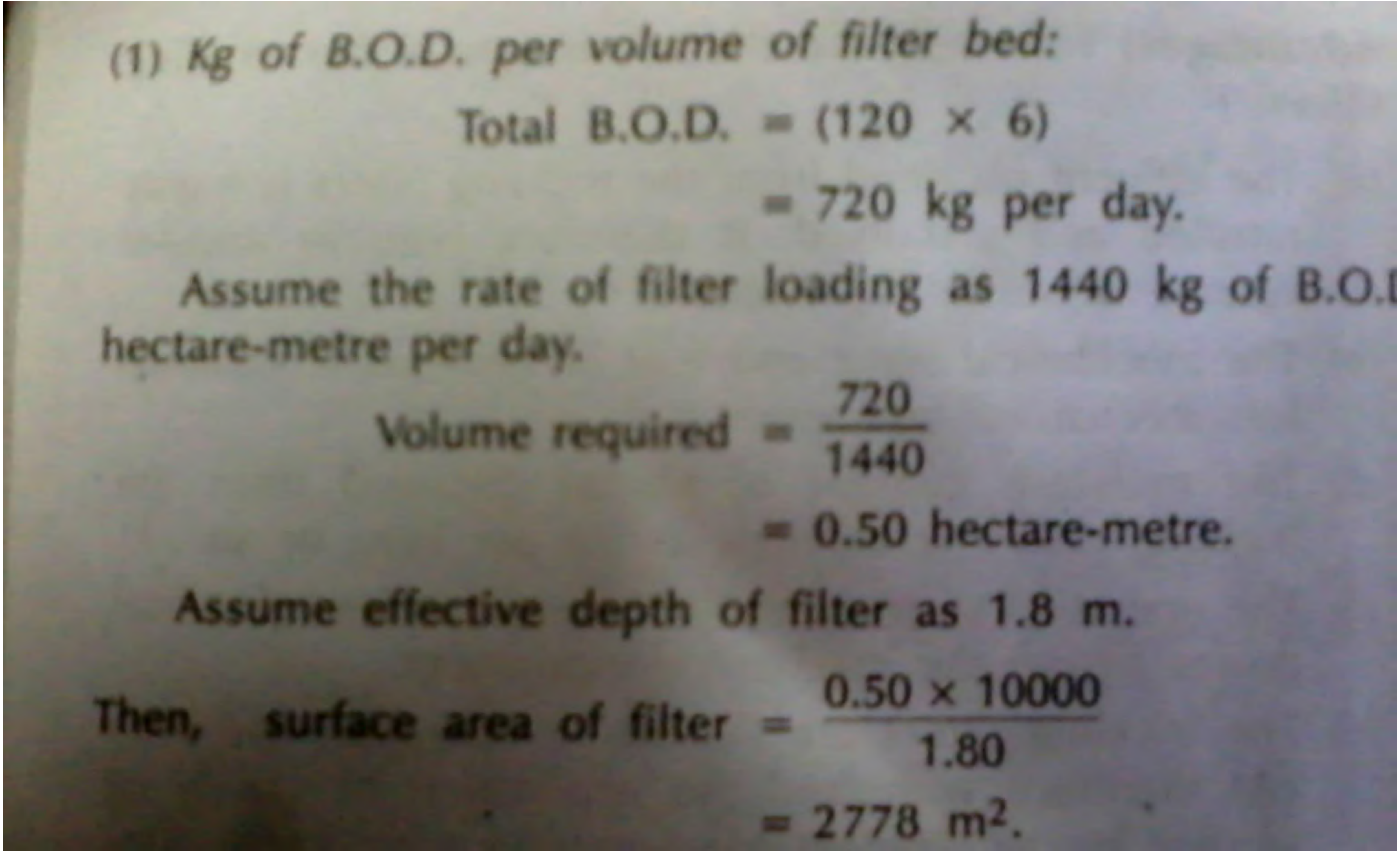
= $(4.5 * 10^{6}$ l/d)/2000 l/m^2.d

= 2250 m^2

Depth of the bed required = 4500/2250 = 2m

Efficiency of the filter is given by ή =

- Question- Design a TF for treating 6 million liter of sewage per day. BOD of sewage is 120 ppm
- Solution-It can be solved by taking different unit of rate of filter loading



(1) *Kg of B.O.D. per volume of filter bed:*

$$\text{Total B.O.D.} = (120 \times 6)$$

$$= 720 \text{ kg per day.}$$

Assume the rate of filter loading as 1440 kg of B.O.
hectare-metre per day.

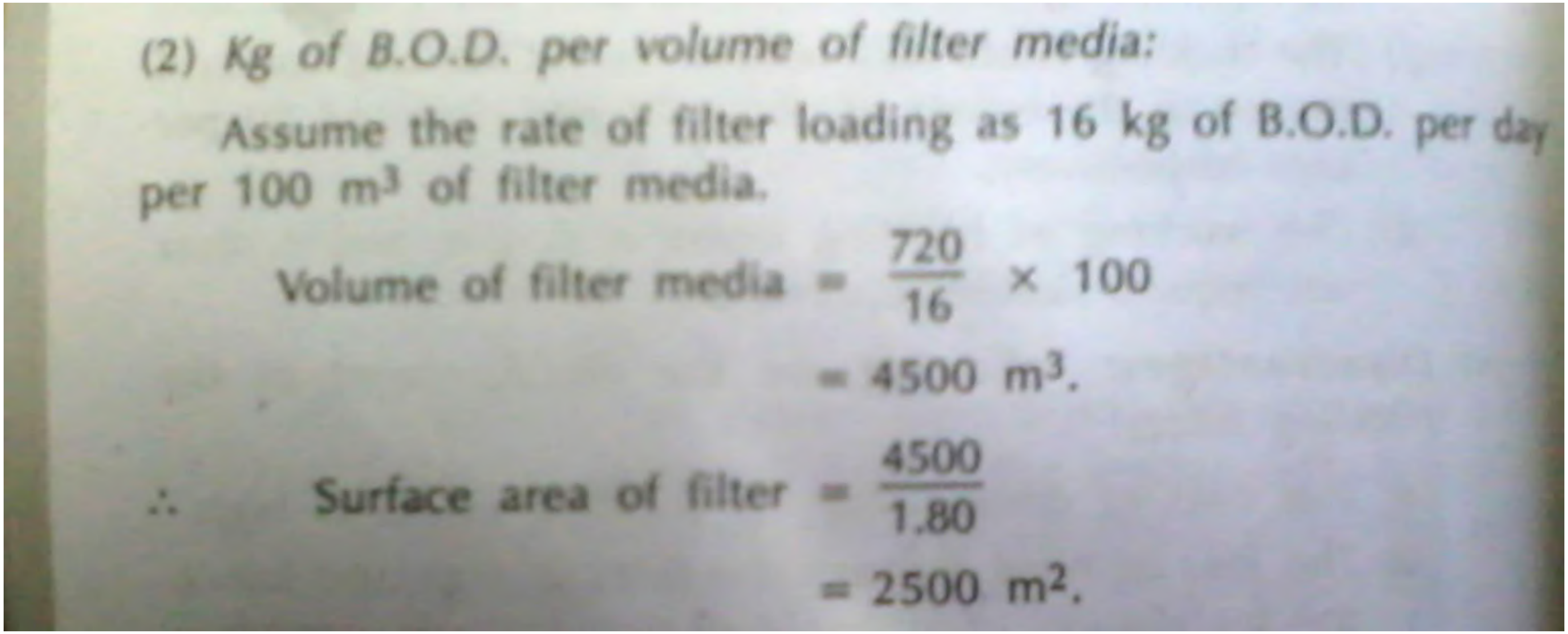
$$\text{Volume required} = \frac{720}{1440}$$

$$= 0.50 \text{ hectare-metre.}$$

Assume effective depth of filter as 1.8 m.

$$\text{Then, surface area of filter} = \frac{0.50 \times 10000}{1.80}$$

$$= 2778 \text{ m}^2.$$



(2) *Kg of B.O.D. per volume of filter media:*

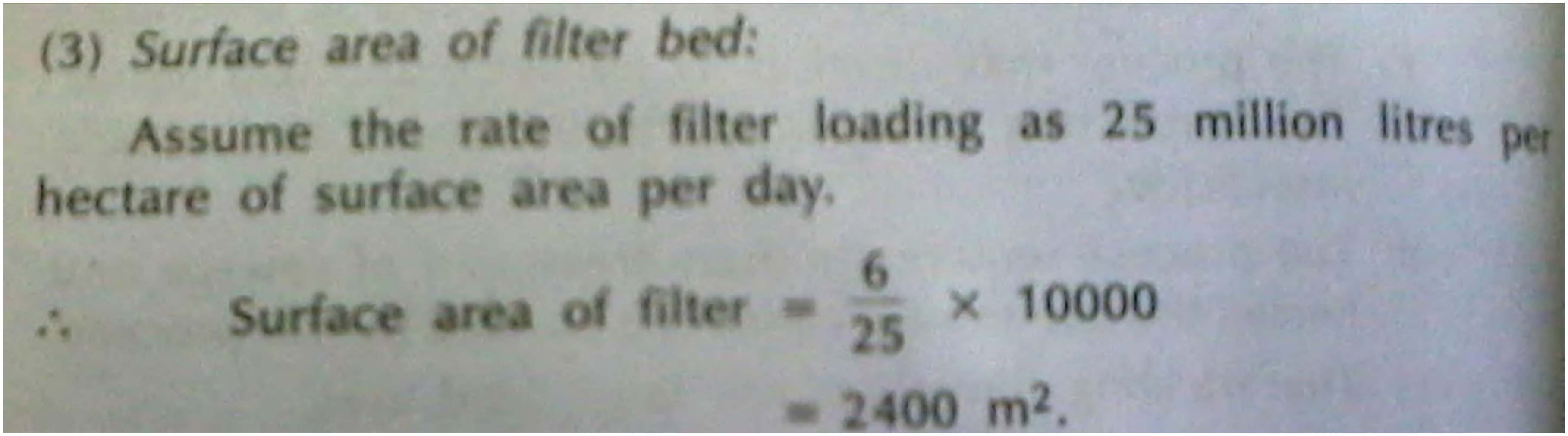
Assume the rate of filter loading as 16 kg of B.O.D. per day per 100 m^3 of filter media.

$$\text{Volume of filter media} = \frac{720}{16} \times 100$$

$$= 4500 \ m^3.$$

$$\therefore \quad \text{Surface area of filter} = \frac{4500}{1.80}$$

$$= 2500 \ m^2.$$



(3) *Surface area of filter bed:*

Assume the rate of filter loading as 25 million litres per hectare of surface area per day.

$$\therefore \quad \text{Surface area of filter} = \frac{6}{25} \times 10000$$

$$= 2400 \ m^2.$$

(4) *Volume of filter bed:*

Assume the rate of filter loading as 12 million litres per hectare-metre per day.

$$\text{Volume of filter bed} = \frac{6}{12}$$

$$= 0.50 \text{ hectare-metre.}$$

Then,

$$\text{surface area of filter} = \frac{0.50 \times 10000}{1.80}$$

$$= 2778 \text{ m}^2.$$

Adopt a circular trickling filter of diameter 45 m.

$$\text{Area of one filter} = \frac{\pi(45)^2}{4} = 1590 \text{ m}^2.$$

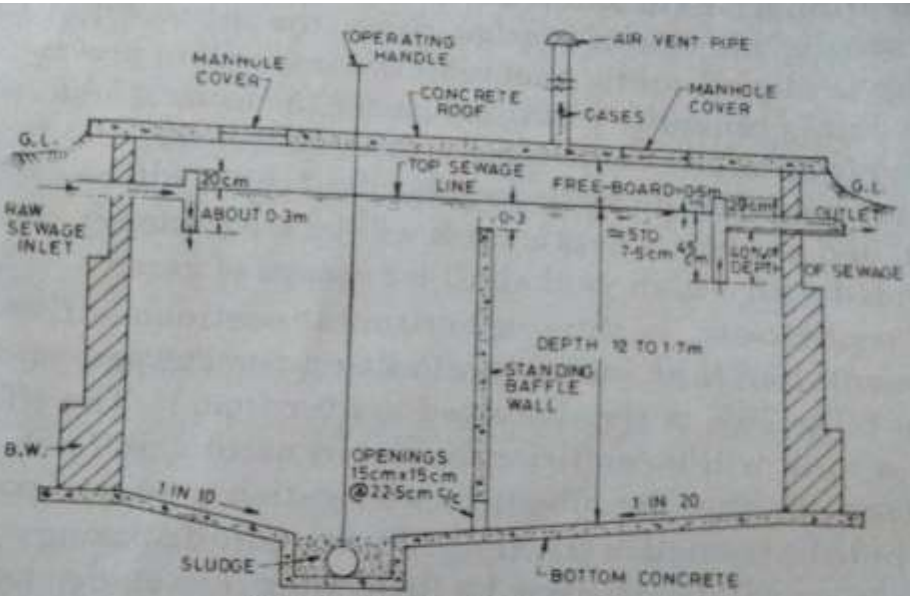
$$\text{Nos. of units required} = \frac{2778}{1590} \, \Omega \, 2.$$

UNIT 5

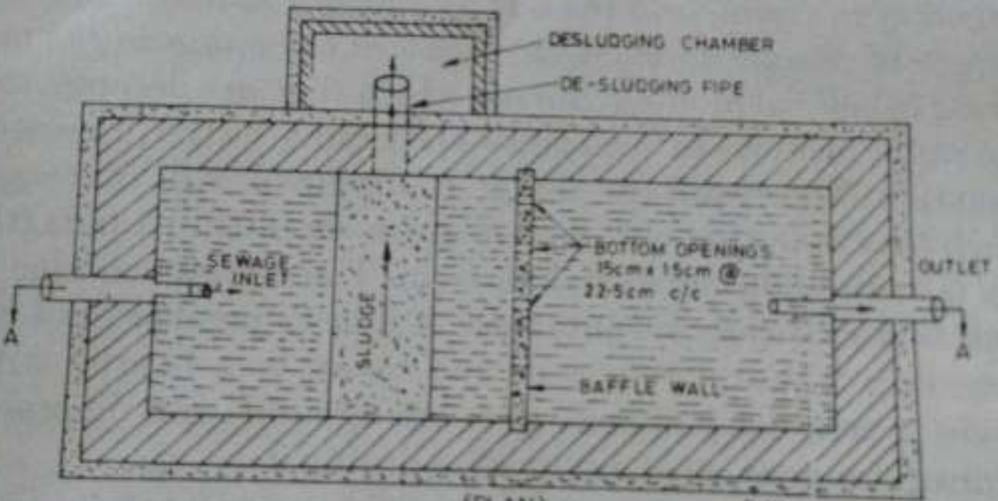
SEPTIC TANKS

- Primary Sedimentation with longer detention period of the order of 12-36 hours with extra provisions for digestion of settled sludge.
- A septic tank is thus a horizontal continuous flow type of sedimentation tank directly admitting raw sewage and removes around 60-70% of dissolved matter.
- Sludge digestion is carried out under anaerobic conditions which leads to formation of foul gases which are let out in to atmosphere through high vent shafts(2m above the top of building)
- The sludge settled at the bottom of the tank, and the oils and greasy matter rising to the top surface of sewage as cum are allowed to remain in the tank for a period of several months .
- The digested sludge is periodically removed at an interval of 6 – 12 months and in no case exceeding 3 years.

- Septic tank effluent should be disposed of properly in a sanitary manner preferably after drying it.
- Septic tanks are generally provided in area where sewers have not been laid.
- Mostly used for isolated communities ,schools, hospitals and other public institutions.
- Generally not recommended for communities having more than 300 population.
- Waste water containing excessive detergents and disinfectants are not suitable for treatment in septic tanks as they adversely affect the biological activity.
- Continuous water supply is prerequisite for effective working of septic tank.



(SECTIONAL ELEVATION A-A)



(PLAN)

Fig. 9.50. Septic Tank.

Design considerations of septic tank

1) **Capacity of septic tanks**: should be capable of storing the sewage flow during detention period and an additional volume of sludge for 6months to 3 years depending upon periodicity of cleaning.

- If only water closets are connected to septic tank , sewage flow is about 40-70 lpcd
- If sullage is also discharged into septic tank, sewage flow is around 90 – 150lpcd
- Accumulation of sludge and scum depends on characteristics of raw sewage at varying rates and efficiency of digestion.
- Rate of accumulation of sludge has been recommended as 30 litres/person/year.
- Minimum capacity of septic tank for about 8-10 people may be kept as 2250 litres when all liquid wastes are discharged in to it and 1400 litres when only water closets wastes are discharged.
- Free board of 0.3m may be provided for accommodating scum in the tank.

Inlet and Outlet baffles:

- The baffles/tees should extend up to the top level of scum(about 22cm above the top sewage line) but stop a little below the bottom of the covering slab(by at least 7.5cm in order to allow free movement of gases.)
- Inlet should penetrate by about 30cm below top sewage line and outlet should penetrate to about 40% of sewage depth
- The outlet invert level should be kept 5 – 7.5cm below the inlet invert level.

Detention time

Varies between 12 – 36 hours but generally adopted as 24 hours.

Length to width ratio : 2 – 3

Depth: 1.2 – 1.8m.

Disposal of Effluent from Septic Tanks

- Effluent contains large amount of putrescible organic matter of the order of 200 – 250 mg/l
- Effluent has BOD of the order 100 – 200mg/l
- This has to be disposed carefully so as to reduce nuisance or risk to health of people.

Following three methods are generally adopted for disposing in addition to its usage for gardening, farms etc.

- Soil absorption system
- Biological filters
- Up flow Anaerobic filters

Soil absorption system

- Involves disposal of effluent on land
- Can be adopted when sufficient porous land is available(percolation rate not to exceed 60minutes)

Soak Pit/Seepage Pit

- Circular covered pit through which the effluent is allowed to be soaked in to surrounding soil.
- Soak pit can be either filled with aggregate or kept empty
- When empty, the pit is lined with brick/stone/concrete blocks with dry open joints. Lining below the inlet level is supported by 7.5cm thick coarse aggregate backing and above inlet level is plastered with cement mortor
- Inlet pipe may be taken to a depth of 0.9m from top as an anti-mosquito
- measure.
- Soil should be highly porous with percolation rate not exceeding 30 minutes.(**Percolation rate of soil is defined as the time in minutes required for seepage of water through that ground by 1cm)**

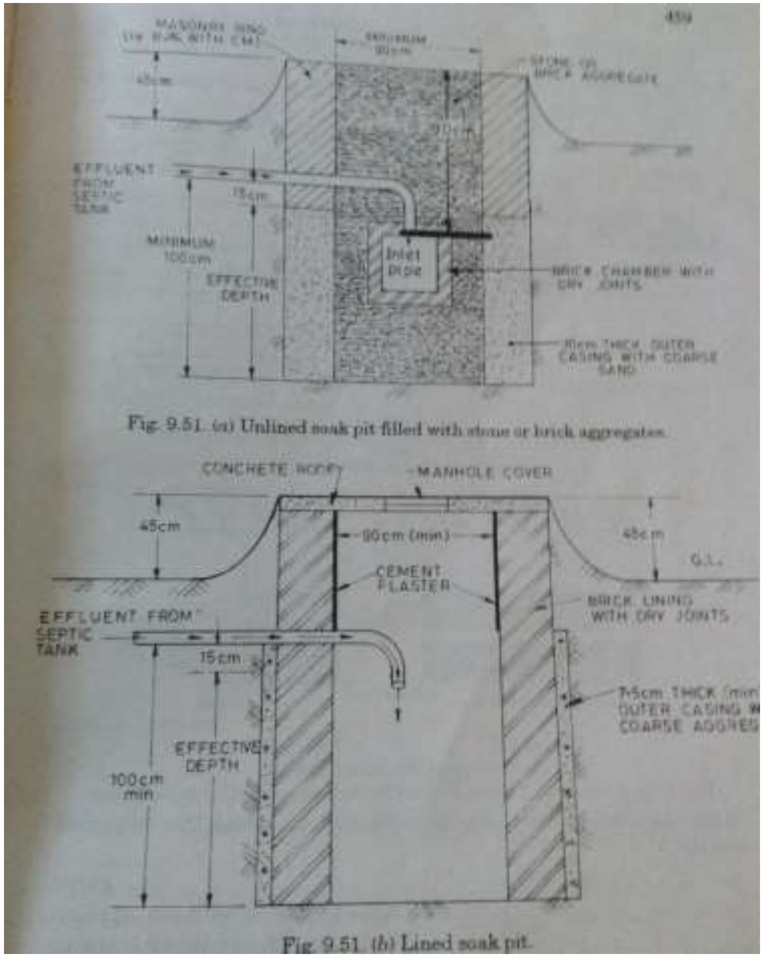
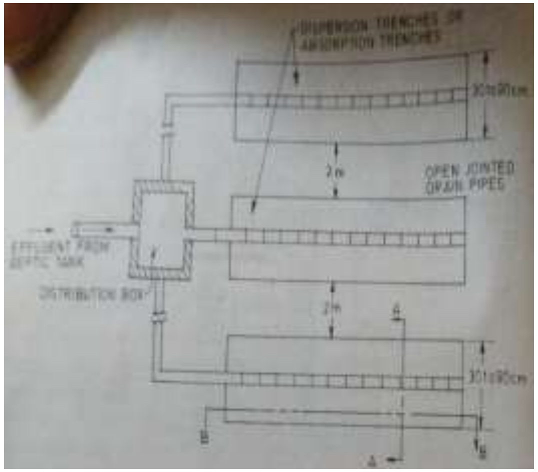
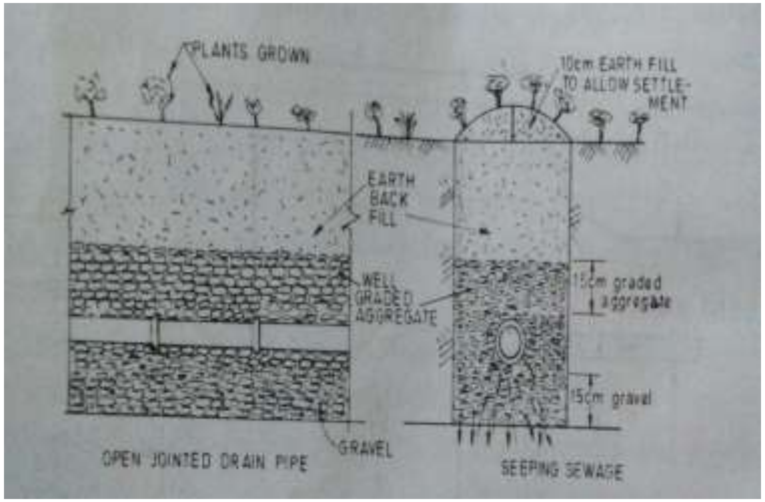


Fig. 9.51. (a) Unlined soak pit filled with stone or brick aggregates.

Fig. 9.51. (b) Lined soak pit.





Soak Pits

Absorption Trenches

Absorption trenches

- Septic tank effluent is allowed to enter a masonry chamber(distribution box) from where it is uniformly distributed through an underground network of open jointed pipes into absorption trenches called dispersion trenches.
- The suspended organic matter present in the effluent will be absorbed in the absorption trenches which consists of gravel and well graded aggregate and water will seep down to the water table.
- Plants are usually grown on the top of trenches which get their irrigation water from seeping water .

Biological filters

- Used where soil is relatively impervious(percolation rate>60min) or water logged areas or where limited land is available.
- Effluent is brought in contact with a suitable medium , the surfaces of which become coated with organic film which oxidizes much of the organic matter through agency of micro organisms.

Up flow anaerobic filters(reverse filters)

- Septic tank effluent is introduced from bottom and microbial growth is retained on the stone media leading to efficient digestion
- BOD removal is around 70% and effluent is clear from odour and nuisance.

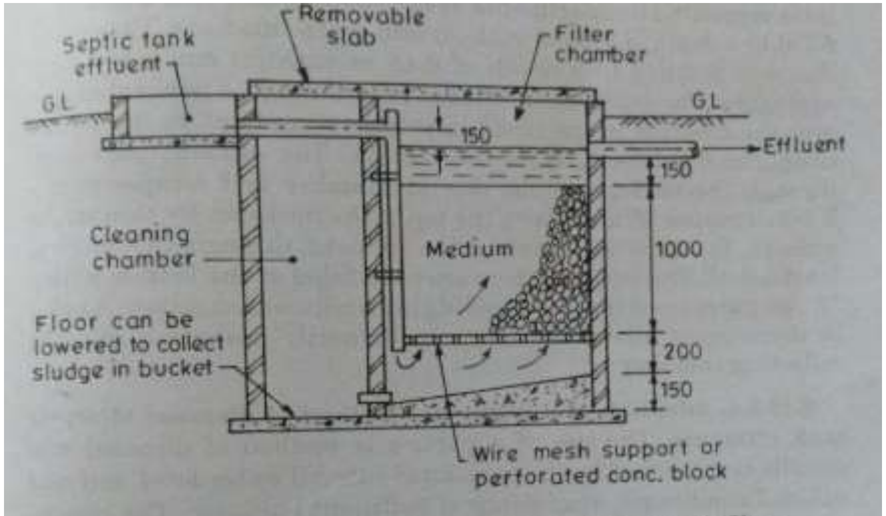


Fig. 9.54. (a) Single chambered rectangular upflow anaerobic filter.

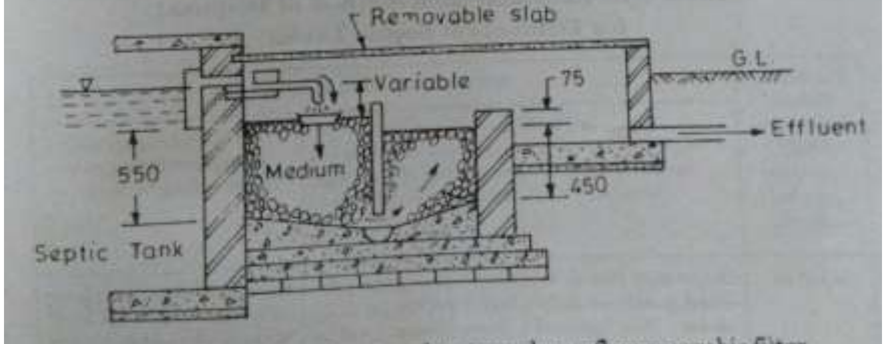


Fig. 9.54. (b) Double chambered rectangular upflow anaerobic filter.

Table 9.13. Recommended Method of Disposal for Effluents of Septic Tanks

Position of Subsoil water level (SSWL) below the ground level	*Soil and Subsoil Condition*		
	Porous soil with percolation rate		*Dense and clayey soils with percolation rate exceeding 60 min.*
	not exceeding 30 min.	*exceeding 30 min. but not exceeding 60 min.*	
≤ 1.8 m	*Dispersion trench* located partly or fully above the ground level in a mound.	*Dispersion trench* located partly or fully above ground level in a mound.	*Biological filter* partly or fully above ground level with under drains ; or *Upflow anaerobic filter*. The final effluent is discharged in to a city sewer or a drain, or used for gardening purposes.
> 1.8 m	*Soak pit* or *Dispersion trench*	Dispersion trench	*Sub-surface biological filter* with under-drains or *Upflow anaerobic filter*. The final effluent is discharged into a city sewer or used for gardening purposes.

Design the dimensions of a septic tank for a small colony of 150 persons provided with an assured water supply from the municipal head works at a rate of 120 lpcd. Assume any data you may need.

- Quantity of water supplied = per capita * population

  = 120 * 150 litres/day

  = 18000 litres/day

Assuming 80% of water supplied becomes sewage, we have quantity of sewage produced = 80 * 18000/100 = 14400 litres/day

Assuming the detention period as 24 hours,

Capacity of the tank = 14400 * 24/24

=14400 litres.

Assuming the rate of deposited sludge as 30 litres/capita/year and also assuming period of cleaning as 1 year, we have

Volume of sludge deposited = 30 * 150 * 1 = 4500 litres.

Total required capacity of the tank = Capacity of sewage + Capacity of sludge

= 14400 + 4500

=18900 litres or 18.9 cu.m

Assuming 1.5m as the depth of the tank, we have

Surface area of the tank = 18.9/1.5

= 12.6m2

If the ratio of the length to width is kept as 3:1, we have

3B * B = 12.6

B = √(12.6)/3

= 2.05m = 2.1m(say)

Provide length of the tank as 6m so that area of cross section provided will be 12.6m2(6*2.1 same as required)

Therefore the dimensions of the septic tank will be

6m * 2.1m * 1.8m (assuming free board of 0.3m)

- Design a septic tank for the following data
  No of people = 100
  Sewage Capacity/day = 120 litres
  Desludging period = 1 year
  Length: width = 4:1
- What would be the size of its soak well if the effluent from this tank is to be discharged in to it. Assume percolation rate through the soak well to be 1250l/m3/d

Solution for second part

Percolation rate = 1250l/m3/day

Sewage outflow = 12000 litres/day

Volume of filtering media required for soak well = 12000 / 1250

= 9.6m3

If depth of the soak well is taken as 2m, then area of the soak well required = 9.6/2 = 4.8m2

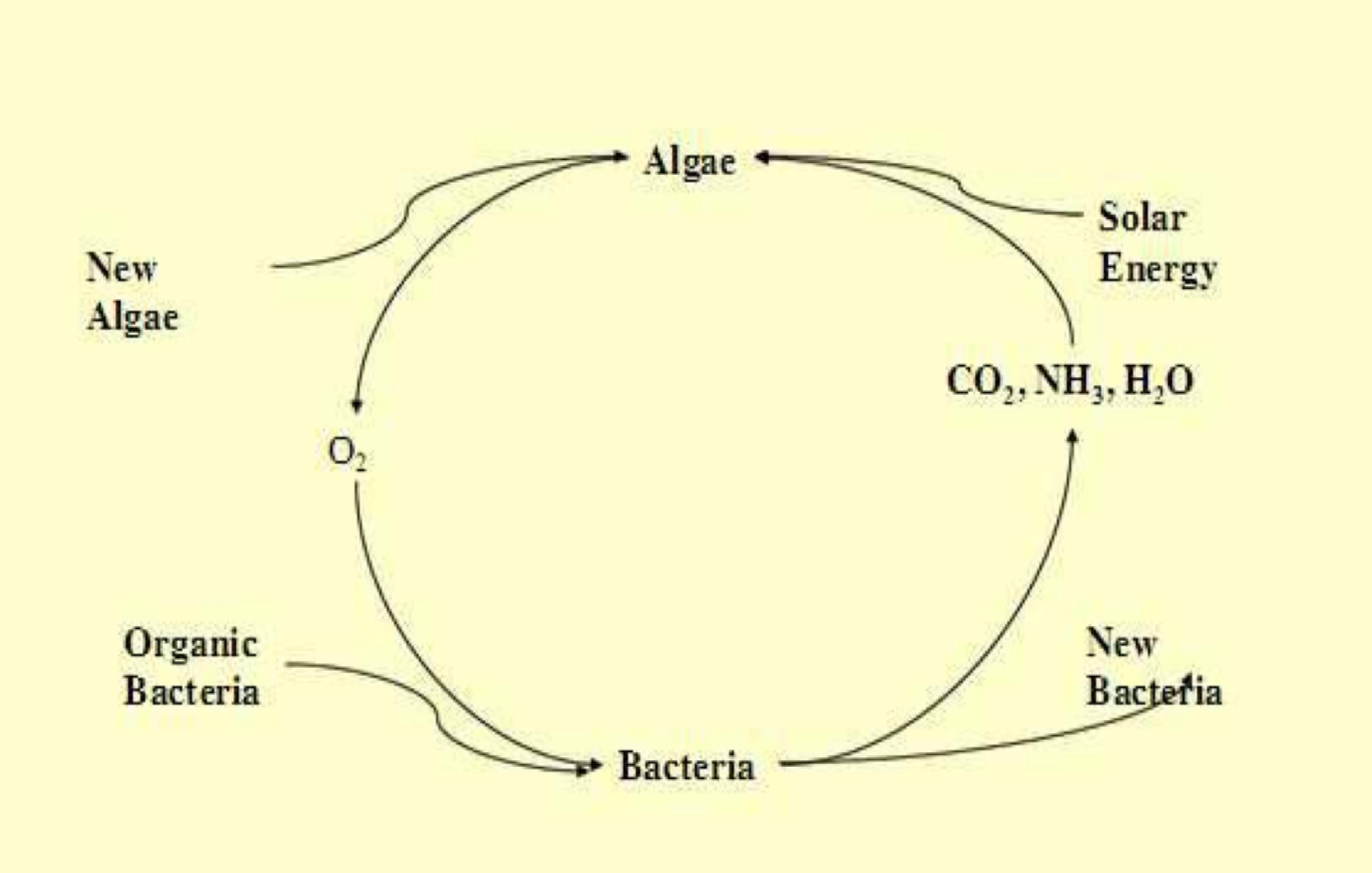
Therefore diameter of soak well required = $\pi d^2/4 = 4.8$

=> d = 2.47m = 2.5m(say)

OXIDATION POND

- It is an artificial pond of shallow depth in which sewage can be retained for sufficient time to satisfy BOD. It may be used to treat raw or partially treated sewage. Usually settled sewage is preferred.
- THEORY:
  - It purify sewage by dual action of aerobic bacteria and algae.
  - Sewage is stored under favorable climatic conditions(sunlight and warmth) for growth of algae.
  - Aerobic bacteria obtain oxygen from atmosphere and use it in decomposition of organic matter of sewage.
  - CO_2 produced during decomposition, carbohydrates of sewage is broken up by algae (photosynthesis) into carbon and oxygen.
  - The carbon is used in producing more carbohydrates and released oxygen keeps DO content of water at high level
  - Combined action may be called as BACTERIAL ALGAE SYMBIOSIS. Where aerobic bacteria and algae live and works together for their mutual benefit.

AEROBIC BACTERIA-ALGAE SYMBIOSIS



- DESIGN ASPECTS:

LOADING:

- Loading of sewage is expressed in terms of BOD applied.
- In India loading of sewage may be between 150-320 kg/day/hectare with good algae (chlorella) seeding at 5 day BOD.
- In cold countries like Europe BOD loading is 40-80 kg/day/ hectare (almost one forth of India).

Hence efficiency of pond depends upon temprature(which directly affects biological activity rate) and sunlight intensity(affects photosynthesis).

DETENTION TIME:

- In India DT of 10 - 15 days are sufficient for proper development of algae but in cold country DT is upto 45 days

- DESIGN ASPECTS:

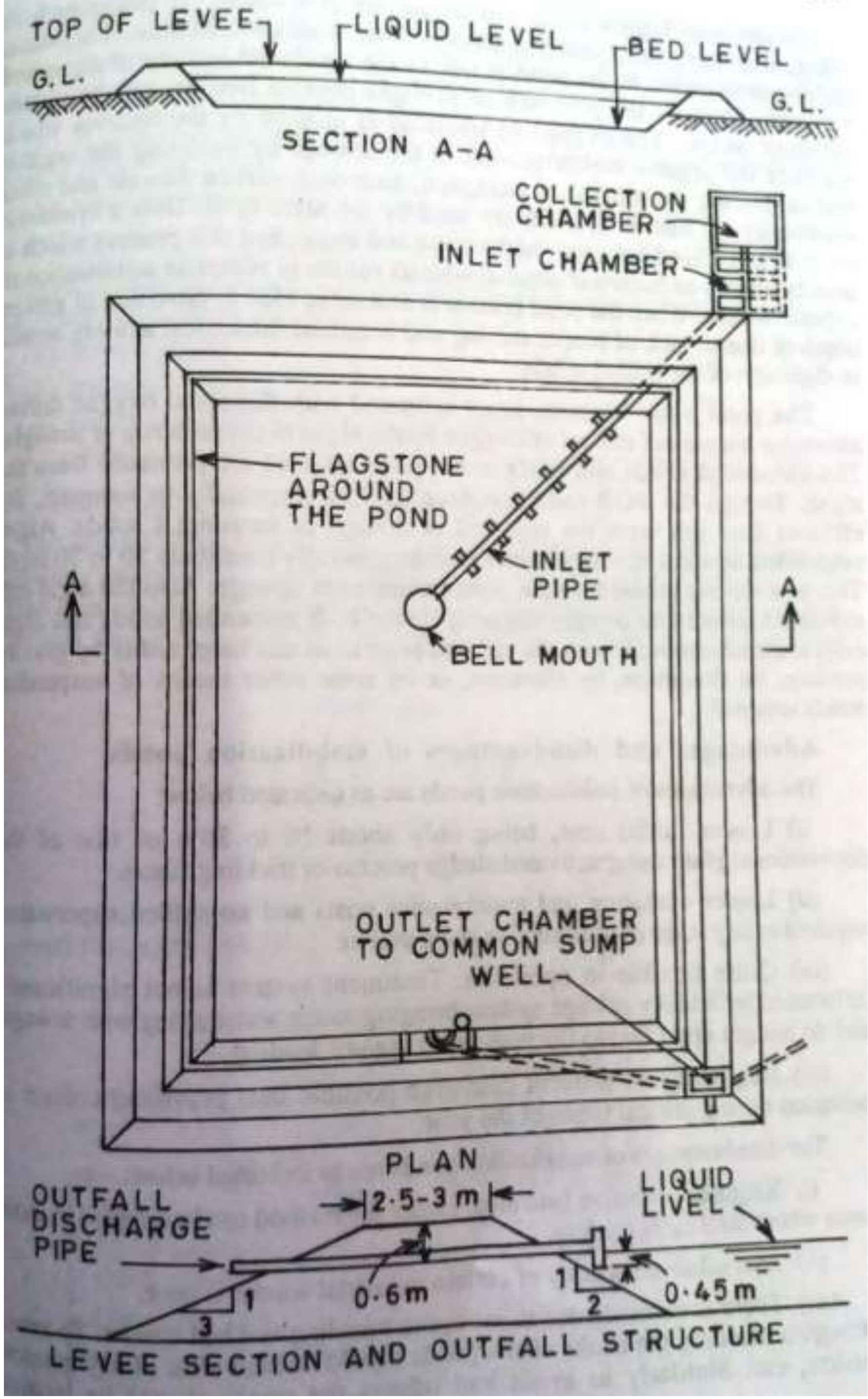
DEPTH AND SURFACE AREA :

- Depth doesn't play any vital role therefore pond should be kept shallow so that sunlight and oxygen may reach the sewerage. Generally depth of 80 -150 cm is kept. Free board of 50 -120 cm is provided.
- Surface area of pond kept as large as possible depending upon the loading. The pond is constructed into compartment of suitable sizes and sewage is allow to flow in zig-zag manner through these compartments

Construction

- It should be constructed with respect to wind direction with veward side so that even in burst situation the town public many not be caused any nuisance
- Usually it is located 300 m away from colony or town
- For economy purpose it is better to chose site having natural pond so that less earth work is to be done
- It can be constructed in any shape and size depending upon an area and plan
- Bed level of pond depend upon invert level of sewage carrying the sewage to the oxidation pond .
- If ground soil is highly coarse, layer of fine clay and ashes should be sprinkle on the surface to prevent seepage in under ground.
- Inlet and outlet pipe should be of CI or stone ware. Stop wall should be provided to control of sewage in the pond.

OXIDATION POND



Operation and Maintenance

- To prevent mosquitoes nuisance, water mimmows, fish is used which eat up the larvae of mosquitoes and prevent its breeding. Chemicals are not used because it may effect algae growth.
- Quantity of sludge collected is small, for 120 cm deep pond sludge removal is required once in 6 years.

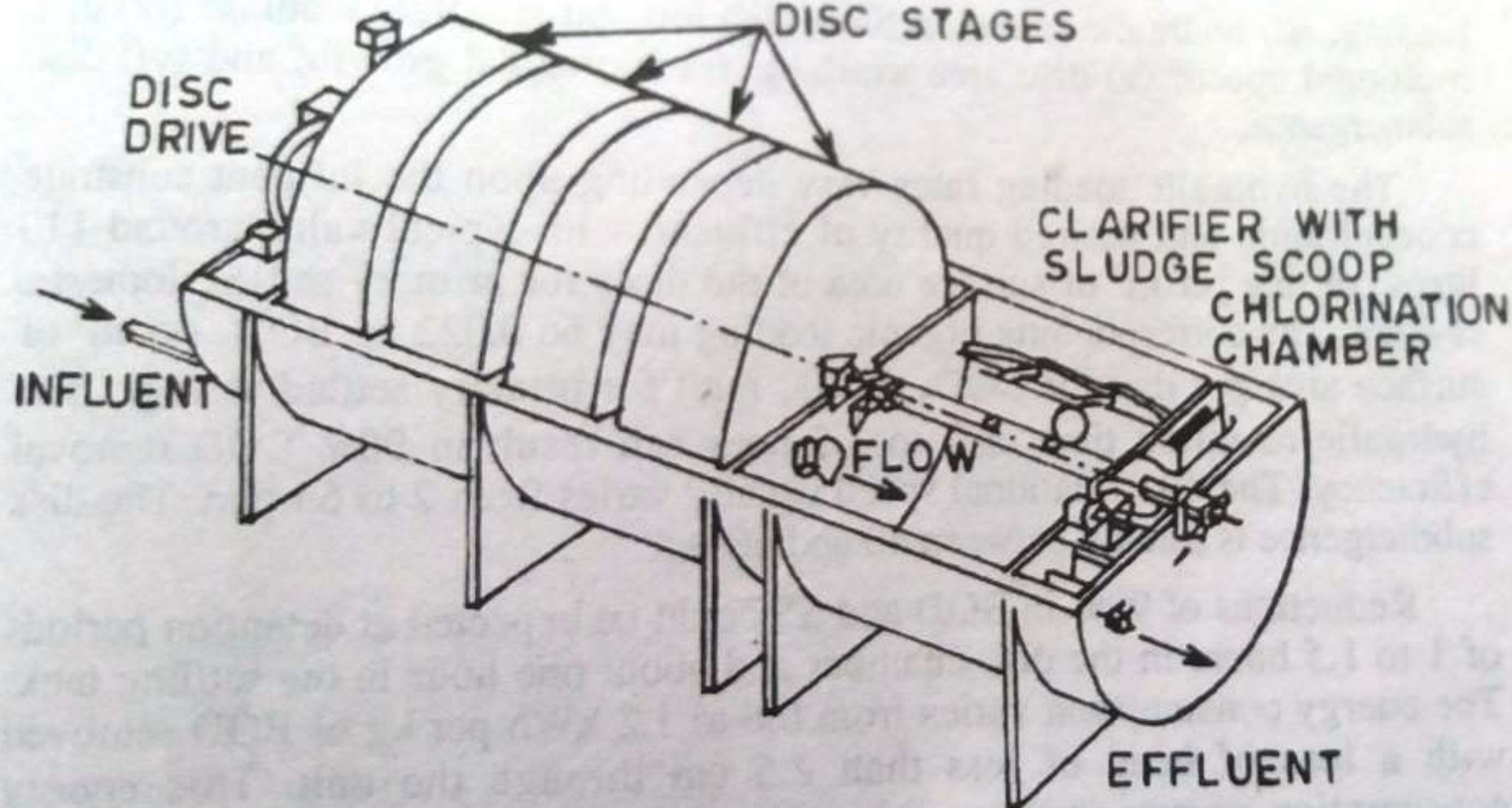
Advantages and Disadvantages

- Advantages
  - No skill workers are required
  - BOD removal is very high (75-95 %)
  - Low initial cost about Rs 10 -20 per capita per day
  - Since natural action are involved in operation of oxidation pond considerable cost is reduced as compared to artificial sewage treatment
- Disadvantages
  - Ponds may some tine become septic due to overloading or unfavorable cloudy season
  - It may give out objectionable odor and cause mosquitoes nuisance
- Uses
  - It is suitable for small town in tropical regions with dry climate and warm temperature.

Rotating Biological Contactors (RBC)

- It is aerobic attach growth treatment process
- Constructional Features
  - It consists of cylindrical horizontal flow tank usually divided into number of stages which are hydraulically connected. Tank may be of steel fiberglass, concrete and masonry
  - A series of closely spaced circular disc of PVC, asbestos cement mounted on horizontal shaft.
  - The disc are about 3 m in diameter, 10 mm thick and placed 30-40 mm on center along the shaft of variable length
  - The disc are submerged in sewage flowing to the tank. The shaft is rotated at slow speed, normally less than 10 rpm
  - A driving mechanism comprising of motor and reduction gear
  - Each reactor module consists of tank with circular disc mounted on a shaft driven by motor through reduction gear. Several modules may be arranged in parallel or in series to meet flow and effluent quality requirement.

RBC



DISC STAGES
DISC DRIVE
CLARIFIER WITH SLUDGE SCOOP
CHLORINATION CHAMBER
INFLUENT
FLOW
EFFLUENT

Process Description

- When discs called bio-disc come in contact with sewage biological growths become attached to the surface of disc and form a slime layer over entire wetted surface of disc.
- Disc film adsorbed the organic pollutant during submerge period of rotation cycle and major amount of oxygen transfer occurs when bio film is exposed to atmosphere during other half of rotating cycle. However, substrate utilization within microbial film is continuous processes. Disc rotation affects oxygen transfer and maintained bio mass in aerobic condition.
- Further excess bio mass growing on the disc surfaces is sheared off and sloughed bio mass is kept in suspension by mixing action by rotating disc and carried out of the tank along with the effluents
- Both substrate utilization within microbial film and slogging of excess bio mass are continuous process which helps in maintaining constant thickness of microbial film on disc

- Basic process flow sheet consists of primary sedimentation following screening and grid removal, aerobic biological treatment in RBC unit and SST for solid liquid separation of sloughed film from treated sewage.
- The settled slugged from PST and SST has to be suitable treated and dispose

Design and Operation Parameters

- Hydraulic loading rate varies from 0.04-0.06 m^3/day/m^2 and organic loading rate varies from 0.05-0.06 KgBOD_5/m^2/day
- Hydraulic detention time of 1-1.5 hrs can result in 90 % BOD removal efficiency
- Disc rotational speed varies from 2-6 rpm
- Energy consumption varies from 0.6-1.2 kW/hr/person/year
- Due to operational limitation of number of discs on one shaft, the process may consists of number of stages in series.

Advantages

- Low F/M ratio resulting in higher efficiency of organic matters removal
- Low HRT minimizing tank volume and capital cost
- Low head loss and low power requirement
- Ability to resist shock load

Aerated Lagoons

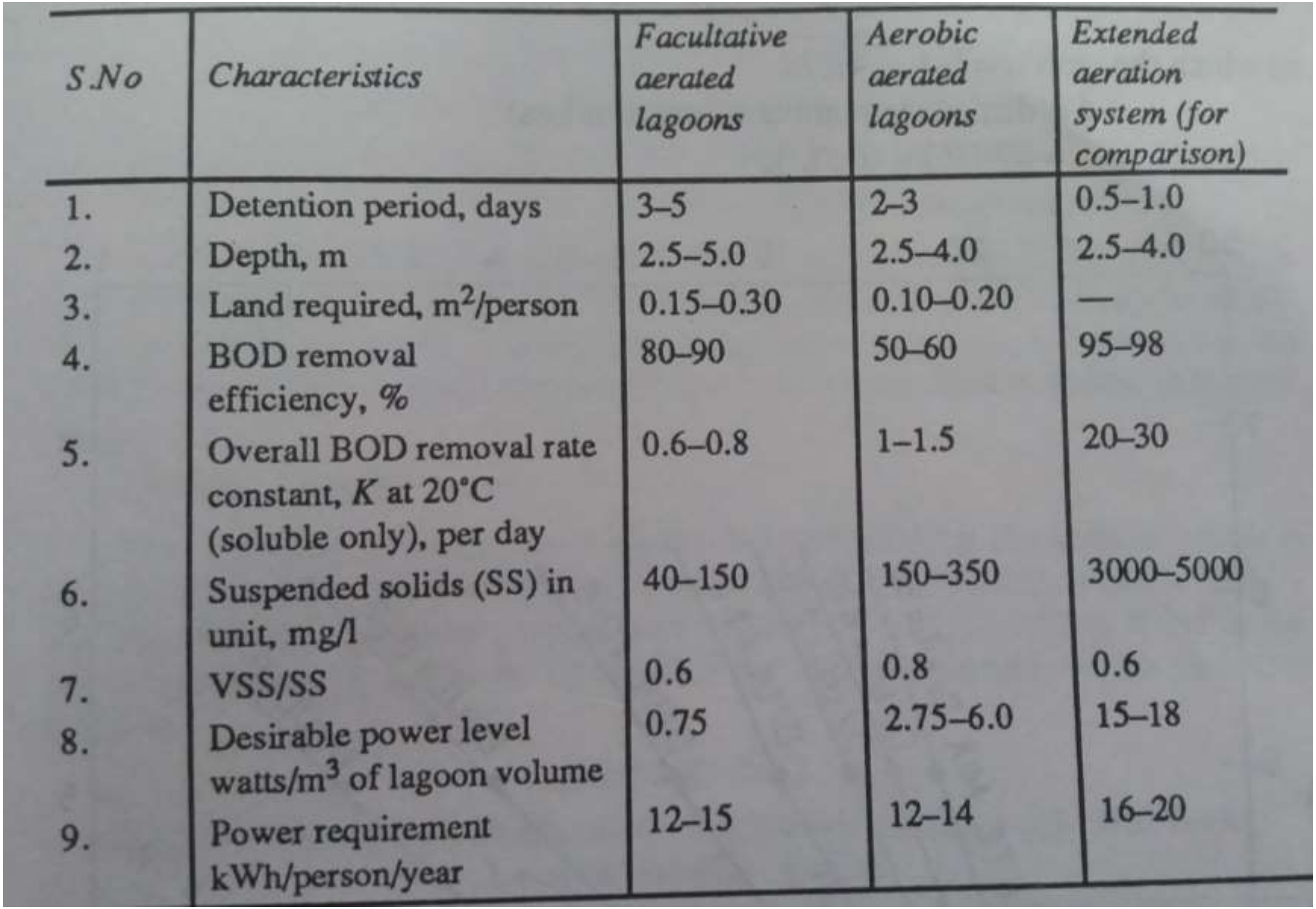
- It is deep waste stabilization pond in which sewage is aerated by mechanical aerators to stabilize organic matter rather than relying on photosynthetic oxygen produced by algae.
- This system of treatment is intermediate between oxidation pond and ASP
- Depending on how microbial mass of solid is handled it is classified as:

FACULTATIVE AERATED LAGOONS/PARTIALLY MIXED

AEROBIC AERATED LAGOONS/COMPLETE MIX

- Facultative aerated lagoons/partially mixed type
  - Rate of aeration is not adequate to keep all the solid and suspension but enough to keep top layer aerobic
  - The sewage solid tend to settle down hence lower part of such lagoons established anaerobic bottom
  - As both aerobic and anaerobic conditions are developed therefore it is called facultative aerated lagoons
- Aerobic aerated lagoons/complete mix
  - Greater amount of aeration is provided to keep all the solid in suspension due to which entire pond is aerobic
  - It consists of two units first is mechanical surface aerator are so designed that solid do not settle to the bottom of tank while second unit is used as settling tank for removal of suspended solids
  - As such process is similar to ASP without recirculation

Characteristics of Aerated Lagoons



S.No	*Characteristics*	*Facultative aerated lagoons*	*Aerobic aerated lagoons*	*Extended aeration system (for comparison)*
1.	Detention period, days	3–5	2–3	0.5–1.0
2.	Depth, m	2.5–5.0	2.5–4.0	2.5–4.0
3.	Land required, m^2/person	0.15–0.30	0.10–0.20	—
4.	BOD removal efficiency, %	80–90	50–60	95–98
5.	Overall BOD removal rate constant, K at 20°C (soluble only), per day	0.6–0.8	1–1.5	20–30
6.	Suspended solids (SS) in unit, mg/l	40–150	150–350	3000–5000
7.	VSS/SS	0.6	0.8	0.6
8.	Desirable power level watts/m^3 of lagoon volume	0.75	2.75–6.0	15–18
9.	Power requirement kWh/person/year	12–15	12–14	16–20

Comparison of Aerated lagoons and oxidation pond

- Aerated lagoons are basically up gradation of oxidation pond overloaded due to industrial waste without adding to the land requirement.
- As aerated lagoons are deeper than oxidation pond and as they are artificially aerated less land and less detention period are required for aerated lagoon as compared to oxidation pond

SOLID WASTE

Solid Wastes are all the wastes arising from human and animal activities that are normally solid and that are discarded as useless or unwanted.

Solid-waste management - *the collecting, treating, and disposing of solid material that is discarded because it has served its purpose or is no longer useful. Improper disposal of municipal solid waste can create unsanitary conditions, and these conditions in turn can lead to pollution of the environment and to outbreaks of vector-borne disease—that is, diseases spread by rodents and insects.*

Types and Sources of Solid Wastes

Municipal Solid Waste: Solid Wastes from residences, Institutions, Commercial establishments, markets and slaughter houses, construction and demolition wastes from buildings.

Solid waste from Industry – Chemical precipitates, fly ash from thermal plants.

Solid wastes from Hospital and health care units(Bio medical wastes)

Solid wastes from wastewater treatment plants – Chemical Precipitates and biological solids.

Solids waste can also be classified as House refuse, Street refuse and trade refuse.

Municipal Solid Waste

- Resulting from municipal activities and services such as street wastes, dead animals, market and slaughter wastes
- **Domestic/residences** – wastes generated as a consequence of house hold activities like cooking, cleaning, repairs, hobbies, package waste, news papers, decoration and old furnishings
- Includes non hazardous industrial waste and treated bio-medical wastes.

Garbage: The term applied to vegetable and animal wastes resulting from the handling, storage , preparation, cooking and serving of food. Contains putrecible organic matter – smell and odour problem, attracts flies, rats – requires immediate attention.

Rubbish: General terminology used to solid wastes generating from residences, institutions, commercial establishments excluding garbage and ash.

Ash: Residue from burning of wood, coal, charcoal and coke and any other combustible material – very fine powder, cinders and clinker.

Bulk waste – Bulk house hold waste which cannot be accommodated in the normal storage containers of household like household appliances, cookers, refrigerators, washing machine, furniture, wood, vehicle spares and packaging material.

Street Sweeping: Waste collected from streets, walkways, parks etc. which includes paper, plastics, soil/sand, leaves and vegetable residues.

Waste from dead animals:
Term applied to dead animals that die naturally or accidentally
Highly decomposable – results in health problems – intense odour and smell problem.
Construction and demolition wastes:
Waste materials generated during demolition and construction of houses, commercial establishments, institutions, stones, concrete, bricks, roofing materials , sand , soil, steel, wires, wood etc. These waste need to be handled by recycling.

- The quantity of solid wastes (refuse) produced by a society depends upon the living standards of its residents.
- Industrialization has resulted in vast increase in the amount of refuse generated per person.
- Each citizen produces about 0.3 to 0.8 kg of solid domestic waste per day.(Directly proportional to industrialization)
- For example: Delhi produces about 4000 tonnes of solid wastes where as New York produces 25000 tonnes/day of solid wastes.
- Average Refuse is about 25% higher than yearly average during summer season.

Item/Constituent	**App Avg Consumption(% age by weight at disposal site)**	
	For a typical Indian City	For a typical city of USA
Garbage	50%	20%
Rubbish(paper, glass)	10%	50%
Ashes	15%	15%
Fine dust, silt and sand	25%	15%
Density	400 – 600 kg/m^3	100 – 250 kg/m^3
Calorific Value in Kilocal/kg	1200 – 1600	3500

- Quantity of rubbish in Indian refuse is very small when compared with developed countries.
- Large quantities of papers, card boards, plastics, synthetic polymers etc are picked up and removed enroute by the rag pickers before the refuse reaches the disposal site.(Reduces the calorific value of Indian refuse).
- Quantity of garbage is small in developed countries is very small because of garbage grinders and use of tinned and ready made packed foodstuffs.
- Density of Indian refuse is generally higher than that of developed countries and hence can be carried efficiently and economically by mechanical transport for land fillings.
- As the calorific value of Indian refuse is much smaller and its moisture content is high it cannot be easily burnt or incinerated and hence the method of incinerated disposal is not suitable for India.

Collection, Removal and Carriage of Refuse

- Refuse is generally collected in small containers in individual houses and from their collected by sweepers in small hand driven lorries/carts and then dumped into the masonry chambers constructed along roadsides by municipalities or refuse chambers.
- This method is highly unsatisfactory and need tremendous improvements and changes.

Disposal of Refuse

The refuse can be disposed of by various methods such as

1) Sanitary land filling
2) Burning or Incineration
3) Bargeing it out into the sea
4) Pulverization
5) Composting (by digestion by bacterial agency)

Disposal of refuse by Sanitary Land Filling:

- Refuse is carried and dumped in to low lying area under an engineered operation, designed and operated according to the acceptable standards, as not to cause any nuisance or hazards to public health or safety.
- Refuse is filled up in layers of 1.5m and each such layer is covered by good earth of at least 20cm thickness so that the refuse is not exposed directly.
- Each layer has to be left out for at least seven days and compacted by bull dozers, trucks for settlement before filling the second layer of refuse.
- Insecticides like DDT, Creosote etc should be sprayed on the layers to prevent breeding of mosquitoes and flies.
- Final cover of 1m of earth is laid and compacted at top of the filled up land to prevent rodents from burrowing in to the surface.

- Filled up refuse will get stabilized due to decomposition of organic matter and subsequent conversion in to stable compounds(Biological method)
- Refuse stabilization can be divided in to five phases
  - First phase : aerobic bacteria and fungi which are dominant will deplete the available oxygen to effect oxidation of organic matter.(Temp increases due to aerobic respiration)
  - Second Phase: Anaerobic and Facultative bacteria develop to decompose the organic matter and H_2 and CO_2 are evolved.
  - Third Phase: Methanogenic bacteria develop to cause evolution methane gas
  - Fourth Phase: Methanogenic activity gets stabilized
  - Fifth Phase: Methanogenic activity subsides representing depletion of the organic matter and ultimately the system returns to aerobic conditions with in the land fill.
  - The moisture content of dumped material should be around 60%
  - Refuse gets stabilized with in a period of 2 – 12 months and settles down by 20-40% of its original height.
  - Filled up land can be used for developing green lands, parks recreational spots.
  - Unequal settlements and odour troubles can be there.

Advantages of Sanitary land filling

- This method is simple and economical. No costly equipment is required.
- Separation of different kinds of refuse as required in incineration method is also not required.
- There are no residues or byproducts left out/evolved in this method and hence no further disposal is required.
- Low lying and water logged areas and old quarry pits can be easily reclaimed and put to better use
- Mosquito breeding places are also eliminated.

Disadvantages of sanitary land filling

- Low lying areas may not always be available. Though they are available today they may become scarce in future as solid waste generation is a continuous process.
- Continuous evolution of foul gases near the site leading to environmental pollution
- Use of insecticides is required to prevent fly nuisance
- Dumped garbage may contain harmful substances such as plastic, unused medicines, sanitary napkins, insecticides which releases a colored liquid during rainy seasons called as Leachate which is highly poisonous which leads to contamination of soil/ground water and also lead to diseases like cholera, typhoid.

Disposal of refuse by Incineration and Thermal Pyrolysis

- It’s a sanitary method of refuse disposal.
- Refuse should have high calorific value to ensure suitable to burning process.(Heat which garbage can generate is called calorific value)
- Segregation of garbage/rubbish/dead animals to be done from broken glass/metals and other incombustible matter.
- Left out ashes and clinkers from the incinerators along with non-combustible matter measure up to 10-25% of original waste
- Resulting waste can be disposed of by land filling or used as recycled material.
- Heat produced during burning of refuse is used for running turbines to generate electricity.
- Can also be used for burning hazardous solid wastes of the hospitals.
- **Thermal Pyrolysis is burning of refuse in the presence of very sparse air or oxygen, so that wastes do not completely burn, but only smoulder to produce charcoal like product**.

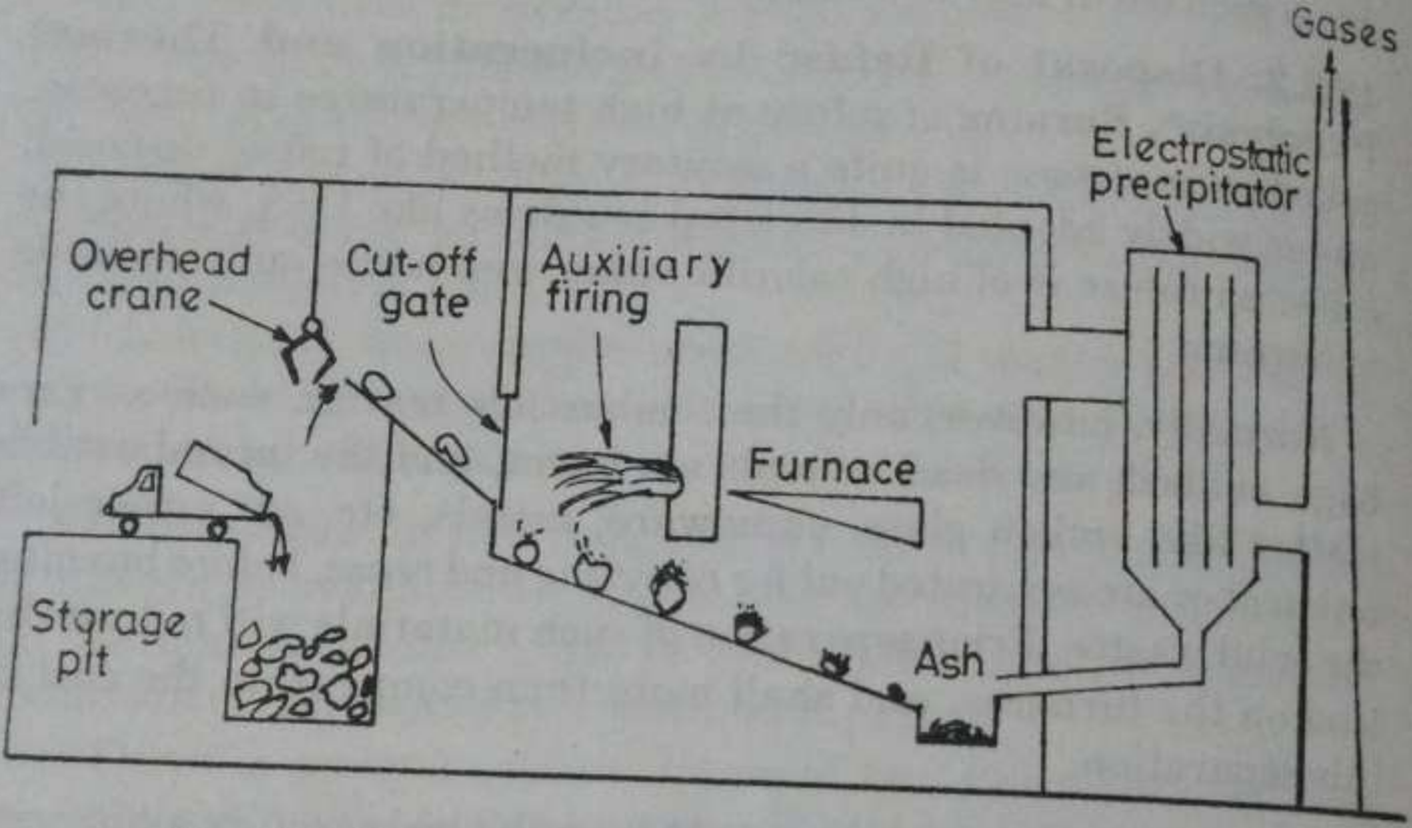


Fig. 12.1. Schematic sketch of a conventional incinerator (travelling grate type).

- Need to dry the wastes before burning.
- Fuel is used for initial drying of these wastes
- Electrostatic precipitators are used to reduce air pollution
- Emissions of dioxins is a serious problem with incinerators.
- Emissions are highly contaminated with lead and hence to be treated again before disposing in land fills.
- Large size incinerators are called destructors and they can burn 100 – 150 tonnes of refuse per hour
- A destructor consists of furnace chamber, combustion chamber, expansion chamber and tall chimney around 25m height.
- Ancillary works consist of ash-pit, charging apparatus, forced draft apparatus, preheating arrangements and steam generating apparatus etc.

- Refuse containing 80% garbage and 20% rubbish will burn with out any auxiliary fuel, if air supplied for combustion is pre-heated to about 150^0C
- Refuse containing 50 – 60% garbage and 40 – 50% rubbish will burn satisfactorily without any preheated air
- When moisture contents are very high such as during rainy seasons, auxiliary fuels such as coal, wood, oil etc will be required.
- The minimum temperature in the combustion chamber should be larger than 670^0C so as to incinerate all organic matter and oxidize foul smelling gases.
- For steam generation, around 1000^0C is required to be produced in combustion chamber.

Incinerators in India

- First Incinerator is Installed in Delhi to dispose 300 tonnes of daily refuse by BHEL near timarpur in 1986.(With Danish assistance)

- Plant is designed to produce 3.75MW of electricity out of which 3MW is utilized by Wazirabad Water works and rest is consumed by plant itself .

Advantages of Incineration method

- Sanitary method of refuse disposal
- Ensures complete destruction of pathogenic bacteria and Insects
- No odour trouble
- Cost can be recovered by selling steam power and clinkers
- Disposal site can be located with in city outskirts
- Transportation problems can be reduced
- Requires less space for refuse disposal

Disadvantages of Incineration method

- Very Costly method and requires lot of technical know-how
- Solid wastes to be burnt should have high calorific value
- Smoke, odour can generate due to improper and incompetent operation of plant.

Pyrolysis/thermal Pyrolysis

Most of the organic substances can be split through a combination of thermal cracking and condensation reactions in to gaseous, liquid and solid fractions when heated in an oxygen free atmosphere – this process is known as Pyrolysis.

Since the Pyrolysis process is highly endothermic(Consuming heat) it is also known as DESTRUCTIVE DISTILLATION.

When an organic waste is Pyrolysed, we get the following types of products at different stages /temperatures

A) A gas stream which primarily contains hydrogen, methane, CO,CO_2 depending upon the organic character of the solid waste

B) A Liquid fraction consisting of tar/oil stream and contains acetic acid, acetone and methanol

C) A solid fraction consisting of charcoal like product of pure carbon or any other inert material which have entered the process.

Pyrolysis may be used for reducing the quantities of sludge produce in a Water and waste water treatment plants before their ultimate disposal in to Land fills/water bodies.

Disposal of refuse in sea

- Disposed in the sea after carrying it to a distance of 15-20km from coast.
- Method is quite cheap but has following disadvantages
- The bulky and lighter parts of the refuse do not settle down, remain floating and tend to return to the shores especially during high tides.
- This method requires ships for taking the refuse in to interior of the sea- movement may be difficult during monsoons.

Disposal of refuse by pulverization

- Refuse is pulverized using grinding machines so that the physical characters are changed and also volume is reduced.
- Grinded material becomes practically odorless and unattractive to the insects.
- Disposed by filling in trenches or digested in digesters.

Disposal of refuse by composting

- Composting of refuse is a biological method of decomposing solid wastes.
- Decomposition can be done either aerobically or anaerobically
- The final product is a manure called Compost or humus which is in great demand as fertilizer.
- *Composting is considered to be aerobic process, because it involves piling up of refuse and its regular turning, either manually or by mechanical devices so as to ensure sufficient supply or air and oxygen during its decomposition by bacteria, fungi and other microorganisms like antinomycetes*.
- The process starts with mesophilic bacteria, which oxidizes the organic matter to carbon dioxide and liberate heat and temperature increases to 45^0C at this point, thermophillic bacteria takes over and continues decomposition and temp rises to 60^0C
- After 3 weeks, the compost is stabilized which is indicated by sharp decline in temperature of compost mass.
- Final compost will have an earthy smell and dark brown colour.
- Moisture content to be around 55% to ensure optimum rate of aerobic biological activity.

In India composting is practiced in rural areas on the mixture of **night soil and refuse** by means of **Indore method and Bangalore method**.

Indore Method

- Manual turning of piled up mass(Refuse + night soil) under aerobic conditions.
- Layers of vegetable wastes and night soil are alternatively piled in depths of 7.5 – 10 cm each to a total depth of about 1.5m in a trench or on ground to form a **windrow.**

- **The mixture is kept aerobic by turning regularly for 2 – 3 months and the compost is undisturbed for another 1- 1.5 months with out turning.**
- **Entire process takes around 4 months.**

Bangalore Method

- Anaerobic method where there is no turning of matter is involved and hence the method is clean when compared to Indore method.
- Refuse + night soil are piled up in layers in an underground trench(10m * 1.5m *1.5m) and top layer is covered with earth of about 15cm depth.
- With in 2 -3 days of burial intensive biological action starts and organic matter begins to be destroyed
- Temperature increases to 75^{o}C which prevents breeding of flies
- Refuse gets stabilized after 4 – 5 months depending on the season
- Refuse gets converted into brown colored odorless innocuous powdery mass called HUMUS.
- Humus is sieved on 12.5mm sieve to remove stones, broken glass etc
- Carbon-nitrogen ratio and moisture content are to be controlled properly for success of this method

Fully mechanized composting plants involve receipt, segregation, pulverization of refuse before its digestion in closed digestors.

- **Receipt of refuse**: received at the plant @ 2-6 tonnes/vehicle.
- **Segregation** – Dry refuse is allowed to move along a belt conveyor, where in ferrous matter is removed by magnetic separators and other materials such as papers, card boards etc are removed for recycling.
- Separation can be done either manually or using shaker screens/rotarys.
- **Grinding or pulverizing** : refuse is grinded by means of hammer mills, Dano grinders,Rusping machine.

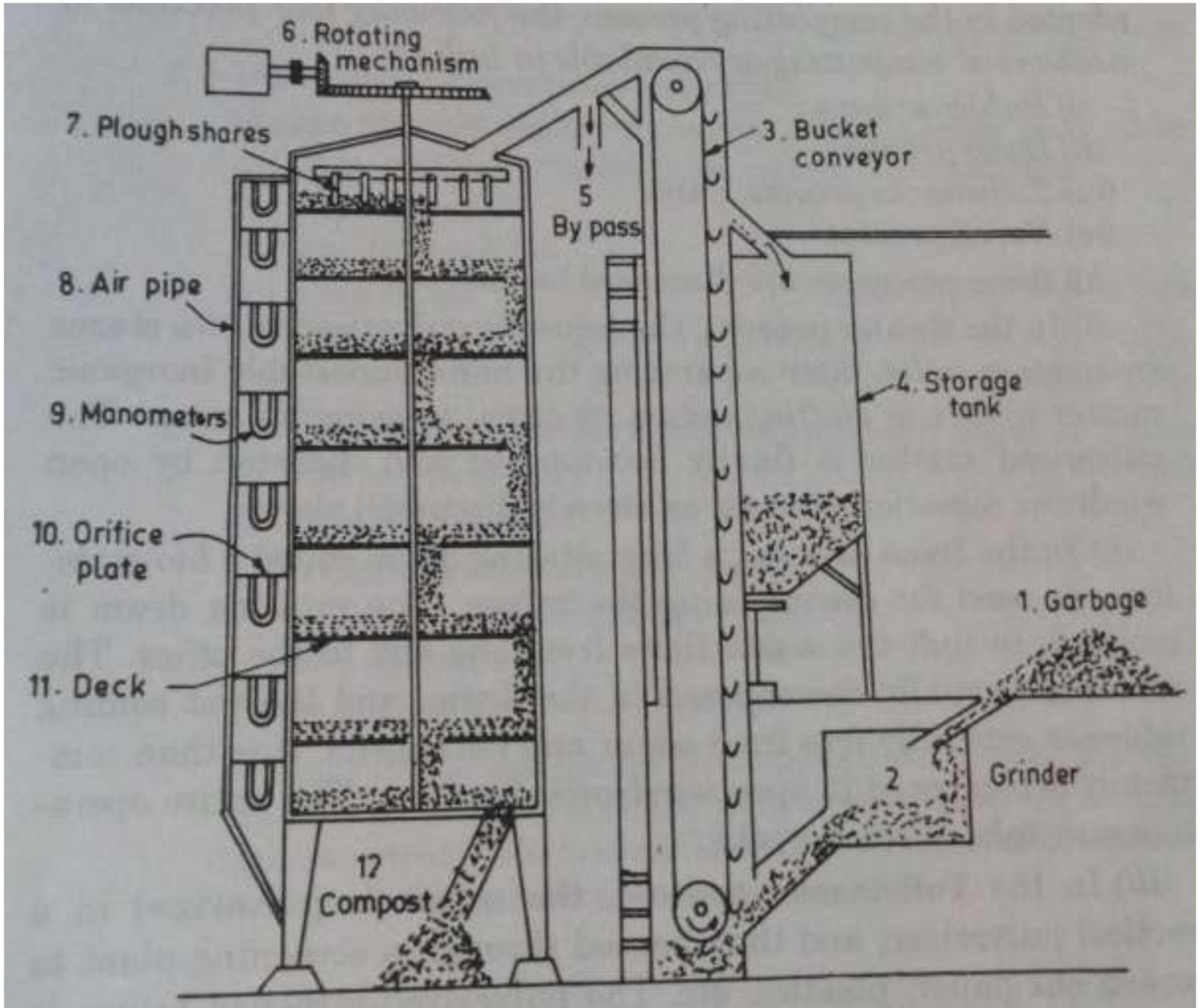


Fig. 12.2. Diagram of a large scale modern Refuse Digestor Plant

Digestion or Fermentation of refuse

- Refuse is digested under controlled conditions of temperature and moisture content using Vertical/horizontal cylinders or Silo type digestors.
- Closed digestors are most hygienic and require less space and but are costly.
- Digestion period normally varies between 2-5 days for low C-N ration refuse and 7-9 days for high C-N ratio.(Carbon-Nitrogen)
- In India refuse is digested by open windrows digestion process which consist of piling up of refuse in stacks(windrows) of about 1.5m height to 2.5m width and moisture content of 60%.
- Piled up refuse is turned by mechanical devices like self propelled over cab loaders, rotary ploughs once/twice/thrice a day.
- Bulldozers and pocklain machines are used for reshaping the stacks and for forming new ones.
- The moisture content and aeration of the refuse is properly monitored so that drying of refuse and loss of heat doesn't happen.(air should not exceed $2m^3$ per kg of volatile solids per day)
- The final stabilized humus can finally (20 - 60% of refuse volume) be collected, sieved and enriched by addition of chemical nutrients such as nitrogen,phophorous etc and sold in market.

Mechanical composting methods

Buhler Process:
Refuse is pulverised in two stages in hammer mills after separating the non-compostable inorganic matter by strong shifting action on circular swinging sieves. The pulverized matter is finally decomposed and digested by open windrows digestion process.

Dano Process:
A long inclined rotating drum called bio-stabilizer is used for decomposing of refuse. The refuse is partially decomposed in the drum and output is free from odour and pathogens. Output refuse is again decomposed in open windrows system which takes about 4 weeks time.

Tollemache Process

- Refuse is pulverized in a vertical pulverizer and then passed through a screening plant to screen out paper, plastics etc.
- The pulverized –screened refuse is allowed to decompose in open windrows for 3 weeks with 3-4 turnings. The compost is then cured for 4 – 5 weeks

Nusoil Process

- Non-compostable inorganic matter is separated from the refuse and then remaining refuse is pulverized in hammer mill. Decomposition takes place in a circular digestors having 7 sections and the refuse moves downward through each section one by one.
- It is kept for one day in each section and air flow rate and water addition rate are continuously monitored

THE END

ALL THE BEST