SCHOOL OF BUILDING AND ENVIRONMENT

DEPARTMENT OF CIVIL ENGINEERING

UNIT – I – SEWERAGE SYSTEM – SCI 1306

INTRODUCTION

SANITARY ENGINEERING:

It is defined as the branch of public health engineering deals with the collection, conveyance, treatment and safe disposal of wastes for preventing the communicable diseases.

STAGES OF SANITARY ENGINEERING:

Conveyance of sewage
Collection of sewage
Treatment of sewage
Disposal of sewage

OBJECTIVES OF SANITARY ENGINEERING:

To maintain the environment and to prevent the effect of sewage to public health in general.

To prevent the effect of disposal of sewage on land or nearby water bodies from pollution.

To prevent the environment from mosquitoes, flies, bacteria etc.

To dispose the human excreta to a safe place before it starts decomposition.

SEWAGE:

It is a dilute mixture of the wastes of various types from the residential, public and industrial places.

It includes sullage water and foul discharge from the water closets, urinals, hospitals, stables etc.

STORM WATER:

It is the surface runoff obtained during and after the rainfall which enters sewers through inlet.

Storm water is not foul as sewage and hence it can be carried in the open drains and can be disposed off in the natural rivers without any difficulty.

SANITARY SEWAGE:

It is the sewage obtained from the residential buildings & industrial

effluents Establishments.

Being extremely foul it should be carried through underground conduits.

DOMESTIC SEWAGE:

It is the sewage obtained from the lavatory basins, urinals & water closets of houses, offices & institutions.

It is highly foul on account of night soil and urine contained in it.

Night soil starts putrefying & gives offensive smell.

It may contain large number of bacteria due to the excremental wastes of patients.

This sewage requires great handling &disposal.

INDUSTRIAL SEWAGE:

It consists of spent water from industries and commercial areas.

The degree of foulness depends on the nature of the industry concerned and processes involved.

SEWERAGE SYSTEM:

The entire system of collection of sewage and conveyance of sewage to treatment units by using sewers is called sewerage system.

The sewerage system carries two types of flow.

DRY WEATHER FLOW (DWF):

Domestic sewage and industrial sewage collectively, is called as DWF.

It does not contain storm water.

It indicates the normal flow during dry season.

WET WEATHER FLOW (WWF):

The flow of storm water is called WWF.

SULLAGE:

It is defined as the waste water from domestic buildings especially from bathrooms, kitchens etc.

It is merely waste water and does not create any bad smell or odour.

SLUDGE:

It is the organic matter deposited in the sedimentation tank during treatment.

SEWERAGE:

The entire system of collecting, carrying & disposal of sewage through sewers is known as sewerage.

SEWERS:

Sewers are underground pipes which carry the sewage to a point of disposal.

TRUNK SEWERS:

A trunk sewer is a one which collects the waste water or sewage from two or more main sewers.

MAIN SEWERS:

A main sewer is a one which collects the sewage from two or more sub main sewers.

SUB MAIN or BRANCH SEWERS:

A sub main or branch sewer is a one which collects the sewage from lateral sewers and discharges into main sewer.

LATERAL SEWER:

The sewer collecting the sewage directly from the building and discharging to the branch sewer is called lateral sewer.

COMBINED SEWER:

A sewer carries domestic sewage and storm water is called combined sewer.

SEWERAGE SYSTEMS

Separate system of sewage
Combined system of sewage
Partially combined or partially separate system

SEPARATE SYSTEM OF SEWERAGE:

In this system two sets of sewers are laid.

The sanitary sewage is carried through sanitary sewers while the storm sewage is carried through storm sewers.

The sewage is carried to the treatment plant and storm water is disposed of to the river.

ADVANTAGES:

Size of the sewers are small
Sewage load on treatment unit is less
Rivers are not polluted
Storm water can be discharged to rivers without treatment.

DISADVANTAGES:

Sewerage being small, difficulty in cleaning them.

Frequent choking problem.

System proves costly as it involves two sets of sewers.

The use of storm sewer is only partial because in dry season the will be converted in to dumping places and may get clogged.

COMBINED SYSTEM OF SEWAGE:

When only one set of sewers are used to carry both sanitary sewage and surface water.

This system is called combined system.

Sewage and storm water both are carried to the treatment plant through combined sewers.

ADVANTAGES:

Size of the sewers being large, chocking problems are less and easy to clean.

It proves economical as 1 set of sewers are laid.

Because of dilution of sanitary sewage with storm water nuisance potential is reduced.

DISADVANTAGES:

Size of the sewers being large, difficulty in handling and transportation.

Load on treatment plant is unnecessarily increased.

It is uneconomical if pumping is needed because of large amount of combined flow.

Unnecessarily storm water is polluted.

PARTIALLY COMBINED OR PARTIALLY SEPARATE SYSTEM:

A portion of storm water during rain is allowed to enter sanitary sewer to treatment plants while the remaining storm water is carried through open drains to the point of disposal.

ADVANTAGES:

The sizes of sewers are not very large as some portion of storm water is carried through open drains.

Combines the advantages of both the previous systems.

Silting problem is completely eliminated.

The problem of disposing storm water from houses is simplified.

DISADVANTAGES:

The quantity of storm water admitted in sewer may increase the load on pumping and treatment units.

The velocity of flow is low in dry weather.

SUITABLE CONDITIONS FOR SEPARATE SEWERAGE SYSTEMS: -

A separate system would be suitable for use under the following situations:

Where rainfall is uneven.

Where sanitary sewage is to be pumped.

The drainage area is steep, allowing to runoff quickly.

Sewers are to be constructed in rocky strata. The large combined sewers would be more expensive.

SUITABLE CONDITIONS FOR COMBINED SYSTEM: -

Rainfall in even throughout the year.

Both the sanitary sewage and the storm water have to be pumped.

The area to be sewered is heavily built up and space for laying two sets of pipes is not enough.

Effective or quicker flows have to be provided.

METHODS OF COLLECTION

The sanitation of a town or city is done by two methods:

Conservancy system

Water Carriage system

SEWERAGE SYSTEMS:

CONSERVENCY SYSTEM	WATER CARRIAGE SYSTEM
Very cheap in initial cost.	It involves high initial cost.
Due to foul smells from the latrines, they are to be constructed away from living room so building cannot be constructed as compact units.	As there is no foul smell latrines remain clean and neat and hence are constructed with rooms, therefore buildings may be compact.
The aesthetic appearance of the city cannot be improved	Good aesthetic appearance of city can be obtained.
For burial of excremental matter large area is required.	Less area is required as compared to conservancy system.
Excreta is not removed immediately hence its decomposition starts before removal,	Excreta are removed immediately with water, no problem of foul smell or hygienic trouble.
This system is fully depended on human agency .In case of strike by the sweepers; there is danger of insanitary conditions in	As no human agency is involved in this system ,there is no such problem as in case of conservancy system

SOURCES OF SEWAGE

SANITARY SEWAGE IS PRODUCED FROM THE FOLLOWING SOURCES:

When the water is supplied by water works authorities or provided from private sources, it is used for various purposes like bathing, utensil cleaning, for flushing water closets and urinals or washing clothes or any other domestic use.

The spent water for all the above needs forms the sewage.

Industries use the water for manufacturing various products and thus develop the sewage.

Water supplied to schools, cinemas, hotels, railway stations, etc., when gets used develops sewage.

Ground water infiltration into sewers through loose joints.

Unauthorized entrance of rain water in sewer lines.

QUANTITY OF SANITARY SEWAGE AND STORM WATER

The determination of sanitary sewage is necessary because of the following factors which depend on this:

To design the sewerage schemes as well as to dispose a treated sewage efficiently.

The size, shape and depth of sewers depend on quantity of sewage.

The size of pumping unit depends on the quantity of sewage.

FACTORS AFFECTING THE QUANTITY OF SANITARY SEWAGE FLOW: -

Rate of water supply

Population

Type of area served as residential, industrial or commercial

Infiltration and exfiltration

RATE OF WATER SUPPLY:

The rate of sewage may be 60 to 70 percent of water supply due to various reasons such as consumption, evaporation, use in industries etc.

This may be changes daily, seasonal and also standard of living of people.

POPULATION:

As the population increases the quantity of sewage also increases because the consumption of water is more.

TYPE OF AREA SERVED:

The quantity of sewage depends upon the type of area as residential, industrial or commercial.

The quantity is depending on population if it is residential, type of industry if it is industrial, Commercial and public places can be determined by studying the developing of other such places.

INFILTRATION AND EXFILTRATION:

Infiltration is the leakage of water from the ground surrounding the sewer.

Exfiltration is the leakage of sewage from the sewer into the ground surrounding the sewer.

The quantity of water increased through infiltration depends on the following factors:

- Length of sewer
- Size of sewer
- Sub soil water head

Nature and type of soil.

FACTORS AFFECTING THE QUANTITY OF STORM WATER FLOW: -

Intensity of rainfall

Catchment areas

Duration of rainfall

ESTIMATION OF QUANTITY OF STORM WATER: -

Rational method

Empirical Method

DESIGN OF SEWERS

Average daily flow = (70 – 80) % average water consumption

i.e. Average Daily Flow (ADF) of Sewage = 75%

Maximum Daily Flow = 1.5 x ADF

RATIONAL METHOD:

According to this method, the run off Q depends on the following factors,

Catchment area (A)

Intensity of rainfall (R)

Impermeability factor or Run-off co-efficient (I)

Quantity of storm water, $Q = \frac{C\ i\ A}{360}$

TIME OF CONCENTRATION:

It is defined as the total time required by the flow to reach to the maximum limit.

The addition of inlet time and flow time gives the time of concentration.

$$t_c = t_i + t_f$$

INLET TIME (t_i):

The time required by the storm water to reach the uppermost inlet of the sewer line known as the inlet time or time of entry.

FLOW TIME (t_f):

The time taken by the storm water to flow down the sewer upto a particular point of consideration is known as time of flow.

R or i = 25.4 a / t_c + b

Where, R or i = intensity of rainfall in mm/hr.

When t_c is 5 to 20 minutes, constant a = 30 and b = 10.

When t_c is 20 to 100 minutes, constant a = 40 and b = 20.

PROBLEMS

1.The catchment area of a city is 200 hectares. Assuming that the surface on which the rainfalls is classified as follows: Calculate the impervious factor. If the maximum intensity of rainfall is 40 mm/hour. Calculate the quantity of storm water which will reach the sewer lines.

TYPE OF SURFACE	% AREA	RUNOFF CO-EEFICIENT
Roofs	20	0.9
Pavement and Yards	15	0.8
Lawns and Gardens	30	0.15
Macadamised Roads	20	0.40
Vacant Plots	15	0.10

Solution:

$$\text{Impervious factor, } i = \frac{A_1 C_1 + A_2 C_2 + \ldots\ldots + A_n C_n}{A_1 + A_2 + \ldots\ldots\ldots + A_n}$$

$$= \frac{200\ (0.2X0.9 + 0.15X0.8 + 0.3X0.15 + 0.2X0.4 + 0.15X0.10)}{200\ (0.2 + 0.15 + 0.30 + 0.20 + 0.15)}$$

$$i = 0.44$$

$$\text{Quantity of storm water, } Q = \frac{C\ i\ A}{360} = \frac{0.44\ X\ 40\ X\ 200}{360}$$

$$Q = 9.778\ m^3/sec.$$

2. In the above example if the density of population is 300 persons/hectare and the rate of water supply is 250 litres/capita/day, Calculate the quantity of sanitary sewage for i) separate system and ii) for partially separate system.

Solution:

i) Quantity of sanitary sewage for separate system,

Quantity of water supplied = 200 X 300 X 250 = 15 X 10^6 litres/day

$$15 \times 10^6 / (24 \times 3600) = 173.6 \text{ litres/sec.}$$

But peak discharge for design purpose will be twice of this, 173.6 X 2 = 347 litres/sec.

Quantity of sanitary sewage for partially separate system,

= Quantity of sanitary sewage for separate system + Storm water drained from roof and pavement yards

$$\text{Quantity of storm water, } Q = \frac{C\,i\,A}{360} = \frac{200\,(0.2 \times 0.9 + 0.15 \times 0.8) \times 40}{360}$$

$$= 6.67 \text{ m}^3\text{/sec} = 6.67 \times 10^3 \text{ litres/sec.}$$

Quantity of sanitary sewage for partially separate system = $173.6 + 6.67 \times 10^3$

= 6843.5 litres/sec. or

= 6.843×10^3 litres/sec.

3.Estimate the storm water from 10 hectares of a surface having the following characteristics if the maximum rain intensity in the area is 5 cm/hr.

TYPE OF SURFACE	**% AREA**	**RUNOFF CO-EEFICIENT**
Roofs	30	0.9
Pavement	10	0.85
Paved Yards	5	0.80
Lawns and Gardens	25	0.10
Macadamised Roads	25	0.40
Thick vegetation	5	0.05

Solution:

$$\text{Impervious factor, } i = \frac{A_1 C_1 + A_2 C_2 + \ldots\ldots + A_n C_n}{A_1 + A_2 + \ldots\ldots\ldots + A_n}$$

$$= \frac{10\,(0.3\text{X}0.9 + 0.1\text{X}0.85 + 0.05\text{X}0.8 + 0.25\text{X}0.1 + 0.25\text{X}0.4 + 0.05\text{X}0.05)}{200\,(0.3 + 0.1 + 0.05 + 0.25 + 0.25 + 0.05)}$$

$i = 0.5225$

$$\text{Quantity of storm water, } Q = \frac{C\,i\,A}{360} = \frac{0.5225 \times 50 \times 10}{360}$$

$Q = 0.7257 \text{ m}^3\text{/sec.}$

4. A combined sewer of circular section is to be laid to serve a particular area. Design the sewer from the following:

Area to be served = 100 hectares

Population = 90000

Impermeability factor = 0.50

Time of entry = 3 min.

Time of flow = 17 min.

Rate of water supply = 240 lpcd. Assume any other data if necessary.

Solution:

Average Discharge $= \frac{90000 \times 240}{24 \times 60 \times 60} = 250$ litres/sec.

Maximum Discharge = 2 X Average Discharge

= 2 X 250 = 500 litres/sec = 0.5 m^3/sec.

$t_c = t_i + t_f = 3 + 17 = 20$ min.

$R = 25.4\ a / t_c + b = 25.4 \times 30 / 20 \times 10$

$R = 25.4$ mm/hr.

$Q = \frac{C\,i\,A}{360} = \frac{0.50 \times 25.4 \times 100}{360}$

$Q = 3.52\ m^3/sec.$

Total Sewage = Dry Weather Flow + Wet Weather Flow

=0.5 + 3.52

= 4.02 m^3/sec.

$Q = A \times V$

$A = Q/V = 4.02/3$

$A = 1.34 m^2$

$A = \frac{\pi \times d^2}{4} = 1.34$

$d^2 = 1.34 \times 4 / \pi = 1.706 \quad d = 1.306$ m.

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.

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

Trunk or main sewers: 40 to 50 years

Treatment Units: 15 to 20 years

Pumping plant: 5 to 10 years

FLUCTUATIONS IN SEWERS

The sewage flow, like the water supply flow, is not constant in practice but varies.

The fluctuation may, in a similar way, be seasonal or monthly, daily and hourly.

Fluctuation in flow occurs from hour to hour and from season to season.

The seasonal variations are due to climatic effect, more water being used in summer than in winter.

The daily fluctuations are the outcome of certain local conditions, involving habits and customs of people.

Thus, in U.S.A. and other European countries, Monday is the washing day, as such, amount of sewage flow would be much greater than on any other day.

In India, however, Sundays or other holidays involve activities which permit greater use of water.

Hourly variations are because of varying rates of water consumption in different hours of the day.

The first peak flow generally occurs in the late morning it is usually about 200 percent of the average flow while the second peak flow generally occurs in the early evening between 6 and 9 p.m. and the minimum flow occurring during the night after twelve or early hours of the morning is generally about half of the average flow.

HYDRAULICS OF SEWERS

SELF CLEANSING VELOCITY:

The sewers should be laid at such a gradient that a minimum velocity, which will prevent the silting of particles in sewers are developed. Such a minimum velocity is known as self-cleansing velocity.

Self-cleansing velocity is generally,

0.6 m/s for sanitary sewer

1m/s for storm sewer.

NON-SCOURING VELOCITY:

The upper limit of velocity is set by scouring action of sewage.

If the velocity of flow exceeds a certain limit, the particles of solid matter start to damage the inside surface of sewers or in other words, a scouring action takes place.

The maximum permissible velocity at which no such scouring action will occur is known as non-scouring velocity and it mainly depends on the material of sewers.

Generally,

Sanitary sewer = 2.4 m/sec

Storm sewer = 3 m/sec

SHAPES OF SEWERS

Circular sewer section

Non circular sewer section

CIRCULAR SEWER SECTION:

Sewers are generally circular in shape.

The sewers are running at least half full.

If the depth in a circular sewer is less than one-half, there is considerable reduction in velocity and discharge and it results in poor performance.

ADVANTAGES OF CIRCULAR SEWERS:

The perimeter of circular sewer is the least with respect to the sewer of other shape.

The inner surface is smooth hence the flow of sewage is uniform and there is no chance of deposition of suspended particles.

From hydraulic point of view, circular section provides more hydraulic mean depth.

Construction cost and material requirement is less.

Non-circular shaped sewers are also adopted for the following reasons:

They can be construct in such a convenient shape and size so that a man can enter the sewer for cleaning, maintenance, etc.

The process of construction is easy.

The structural strength is more.

Cost of construction is low.

NON-CIRCULAR SEWER SECTIONS:

Standard Egg Shape

New Egg Shape

Horse Shoe Shape

Parabolic Shape

Semi Elliptical Shape

Rectangular Shape

U- Shaped

Semi Circular Shape

Basket Handle Shape

STANDARD EGG SHAPE

It is preferred for combined sewers.

Its advantage over circular shape is that it gives higher velocity during low flow of same capacity.

It is difficult to construct and less stable.

It requires additional bedding of brick masonry or concrete to make it stable.

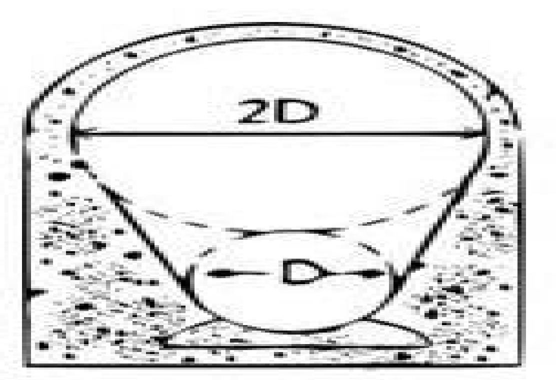

Figure No.1

HORSE SHOE SHAPED SEWER:

This may be used for large sewers with heavy discharges such as for trunk and outfall sewer.

Such sewer is suitable when headroom for the construction of sewer is limited.

The invert of this section may be flat, parabolic or circular.

Its height is more than its width.

Its wall most inclined with semicircular arch at top.

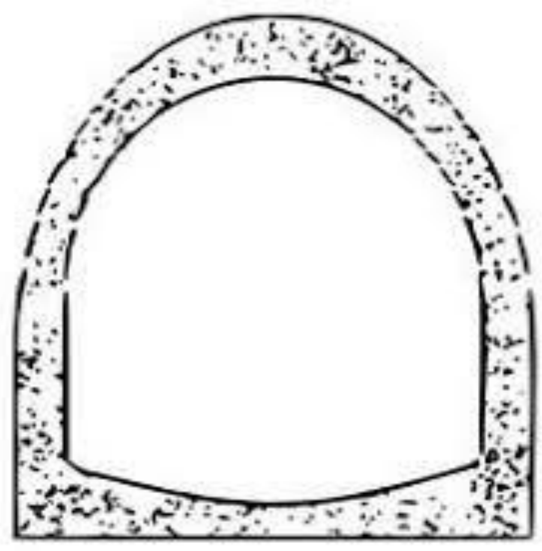

Figure No.2

PARABOLIC SHAPED SEWER:

The upper arch of the sewer forms the shape of parabola.

This may be used for carrying comparatively small quantities of sewage.

The invert may be elliptical or parabolic.

It is found to be economic in construction.

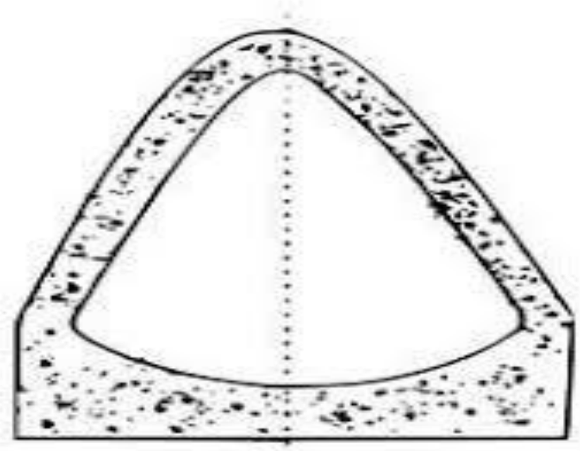

Figure No.3

SEMI ELLIPTICAL SHAPED SEWER:

It may be used for soil i.e. soft soil as it is more stable.

It is useful only for carrying large number or amounts of sewage.

It is adopted when sewers are greater than 1.8m in diameter.

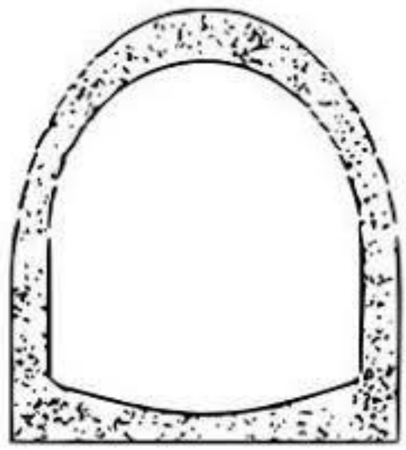

Figure No.4

RECTANGULAR SHAPED SEWER:

Generally, it is used for covered storm water drains.

It is stable and easy to construct.

Sometimes it is used to work as a storage tank.

Figure No.5

U SHAPED SEWER:

The section may have true shape of letter ‘U’, or a small trench of

U-Shape can be set up in the large section.

That trench is known as cunette.

Such type of sewer used for combined sewer having maximum flow of storm water.

It is used for longer sewers and especially in open cuts.

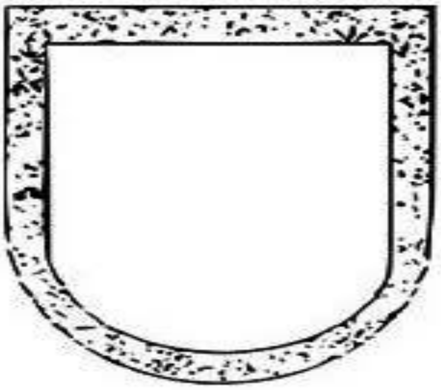

Figure No.6

SEMI CIRCULAR SHAPED SEWER:

This section gives a wider base at bottom and hence it becomes suitable for constructing large sewers with less available headroom.
It is out dated.

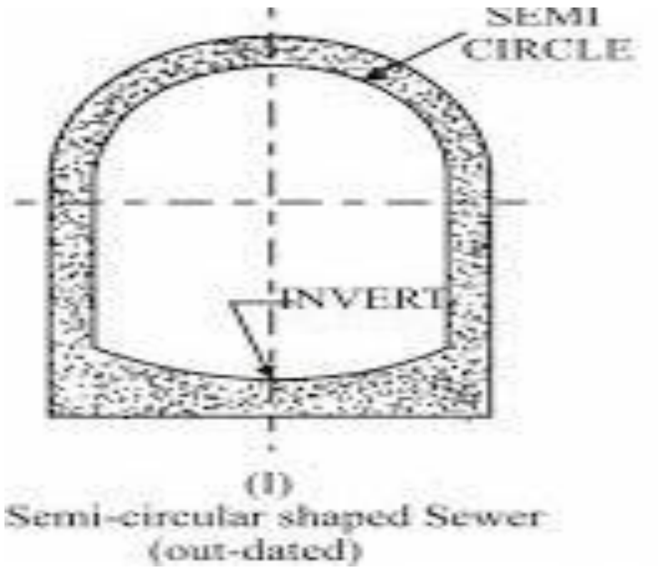

Figure No.7

BASKET HANDLE SHAPED SEWER:

In this type of sewer, the upper portion of sewer has got the shape of a basket- handle.
The bottom portion is narrower in width than the upper portion.
It carries small discharge through the bottom narrow portion and during monsoon it runs full.
It is also out dated.

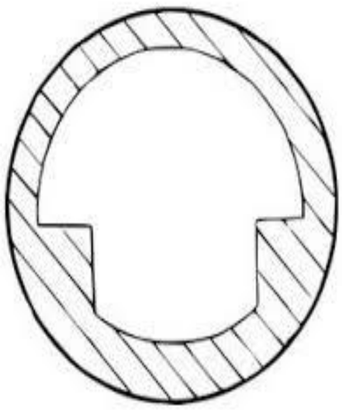

Figure No.8

FACTORS CONSIDERED WHILE SELECTING MATERIAL FOR SEWER

Resistance to corrosion
Resistance to abrasion
Strength and durability
Weight of the material

Imperviousness
Economy and cost
Hydraulically efficient

RESISTANCE TO CORROSION:

Sewer carries wastewater that releases gases such as H_2S.
This gas in contact with moisture can be converted in to 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.

RESISTANCE TO ABRASION:

Sewage contain considerable number 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 material.
This abrasion can reduce thickness of pipe and reduces hydraulic efficiency of the sewer by making the interior surface rough.

STRENGTH AND DURABILITY:

The sewer pipe should have sufficient strength to withstand all the forces that are likely to come on them.
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.

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.

IMPERVIOUSNESS:

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

ECONOMY AND COST:

Sewer should be less costly to make the sewerage scheme economical.

HYDRAULICALLY EFFICIENT:

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

SEWER MATERIALS

Asbestos Cement (AC) Sewer
Brick Sewer
Cement Sewer
Cast iron (C.I) Sewer
Steel Sewers
Plastic Sewers
Vitrified Clay or Stoneware Sewers
Lead Sewers

ASBESTOS CEMENT SEWERS:

Asbestos Cement (AC) Sewers are manufactured from a mixture of cement and asbestos fiber.
Asbestos Cement (AC) Sewers are suitable for carrying domestic sanitary sewage.
Asbestos fibers are thoroughly mixed with cement to act as reinforcement.
These pipes are available in 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.
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.

ADVANTAGES OF ASBESTOS CEMENT (AC) SEWER

Smooth.
Light in weight.
Can easily be cut, fitted and drilled.
Durable against soil corrosion.

DISADVANTAGES OF ASBESTOS CEMENT (AC) SEWER

Brittle cannot withstand heavy loads.
They are easily broken in handling and transport.

BRICK SEWERS:

Brick Sewers are made at site and used for construction large size sewer.
Brick Sewers are very useful for construction of storm sewer or combined sewer.
Nowadays brick sewers are replaced by concrete sewer.
Brick sewers my get deformed and leakage may take place.
A lot of labour work is required.
To avoid leakage the brick sewer should be plastered.
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 ground water through brick joints.
These are lined from inside with stone ware or ceramic block to make them smooth and hydraulically efficient.
Lining also make the pipe resistant to corrosion.

CEMENT CONCRETE SEWERS:

PCC - for dia up to 60 cm
Suitable for small storm drains.
Not durable.
RCC - for dia > 60 cm
They may be cast in situ or precast, resistant to heavy loads, corrosion and high pressure.
These are very heavy and difficult to transport.
These pipes can be cast in situ or precast pipes.
Precast pipes are better in quality than the cast in situ pipes.

ADVANTAGES OF CONCRETE PIPES:

Strong in tension as well as compression.
Resistant to erosion and abrasion.
They can be made of any desired strength.
Easily moulded, 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.

DISADVANTAGES OF CONCRETE PIPES:

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.

CAST IRON (C.I) SEWERS:

These types of sewer are High strength and durability water tight.
Cast Iron sewers can withstand high internal pressure and can bear external load.
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.
They form 100% leak proof sewer line to avoid ground water 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.
Cast Iron sewers are suitable for the following conditions:
When the sewage is conveyed under high pressure.
When there is considerable difference in temperature.

STEEL SEWERS:

Steel sewers are Impervious, light, resistant to high pressure, flexible.
They are generally used for outfall and trunk sewers.
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.
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.

PLASTIC SEWERS:

Nowadays PVC sewers are used for carrying sewage.
Plastic sewers are resistant to corrosion.
Such types of sewer are light in weight, smooth and can be bent easily.
But Plastic sewers are having high co-efficient of thermal expansion and cannot be used in very hot areas.
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.
High Density Polyethylene (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.
These are commonly used for conveyance of industrial wastewater. They offer all the advantages offered by PVC pipes. Glass Fiber Reinforced Plastic Pipes This martial is widely used where corrosion resistant pipes are required.

GRP or FRP 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.

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.

ADVANTAGES OF STONEWARE SEWERS:

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.

DISADVANTAGES OF STONEWARE SEWERS:

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.

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.

DESIGN CRITERIA FOR SEWER SYSTEM

For the design of sewer, the following factors are to be considered.

Rate of water supply
Intensity of rainfall
Type of sewer material
Velocity of flow
Slope of the ground
Shape of the sewer.

VELOCITY OF FLOW

The velocity of flow in a sewer line is determined by the following formulae:

Chezy's Formula
Kutter's Formula
Basin's Formula
Manning's Formula
Crimp and Burge's Formula
Hazen's Williams Formula

CHEZY'S FORMULA:

$V = C\sqrt{mi}$ m/sec.
Where, V – Velocity of flow in m/sec.
C – Chezy's Constant
m – hydraulic mean depth (A/P) in m.
i - hydraulic gradient or hydraulic slope

KUTTER'S FORMULA:

According to this formula, value of Chezy's constant (C) is given by,

$$C = \frac{23 + \frac{0.00155}{i} + \frac{1}{N}}{1 + \left(23 + \frac{0.00155}{i}\right)\frac{N}{\sqrt{m}}}$$

BASIN'S FORMULA:

$$C = \frac{157.6}{[1.81 + (K/R^{1/2})]}$$

MANNING'S FORMULA:

$$V = \frac{1}{n} m^{2/3} i^{1/2}$$

Where, n – manning's constant.

m – hydraulic mean depth (A/P) in m.

i - hydraulic gradient or hydraulic slope

CRIMP AND BURGE'S FORMULA

$V = 83.50\ m^{2/3}\ i^{1/2}$

Where,

m – hydraulic mean depth (A/P) in m.

i - hydraulic gradient or hydraulic slope.

HAZEN'S WILLIAMS FORMULA:

$V = 0.85\ C_H \times m^{0.63}\ i^{0.54}$

Where,

C_H - Hazen's Williams constant.

m – hydraulic mean depth (A/P) in m.

i - hydraulic gradient or hydraulic slope

1. Calculate the velocity of flow in a sewer of diameter 1.36 m. The gradient of sewer line is 1 in 420. If n = 0.012 in Manning's formula, what is the discharge when running one-half full.

Solution:

Velocity of flow,

$$V = \frac{1}{n}\ m^{2/3}\ i^{1/2}$$

$$m = A/P = \frac{\pi d^2/4}{\pi d} = d/4 = 1.36 / 4 = 0.34 \text{ m.}$$

$$= \frac{1 \times 0.34^{2/3} \times (1/420)^{1/2}}{0.012}$$

V = 1.981 m/sec.

Discharge,

$Q = A \times V = ½ \times \pi d^2/4 \times 1.981$

$Q = 1.438\ m^3/sec.$

2.Calculate the discharge for a stoneware sewer, running full. The diameter of the sewer is 200 mm and it is laid at a slope of 1 in 72. Take n = 0.013 in Manning's formula.

Solution:

Discharge,

$V = \frac{1}{n} m^{2/3} i^{1/2}$ $m = A/P = \frac{\pi d^2/4}{\pi d} = d/4 = 0.2/4$

$= \frac{1 X 0.05^{2/3} X (1/72)^{1/2}}{0.013}$ $m = 0.05$ m.

V = 1.23 m/sec.

$Q = A X V = \pi d^2/4 X 1.23$

$Q = 0.038 m^3/sec.$

3.Calculate the discharge of a sewer, running full having a diameter of 200 mm and laid at a slope of 1 in 240 by using crimp and Burge's formula.

Solution:

Discharge,

$V = 83.50 m^{2/3} i^{1/2}$ $m = A/P = \frac{\pi d^2/4}{\pi d} = d/4 = 0.2/4$

$= 83.50 X 0.05^{2/3} (1/240)^{1/2}$

V = 0.55 m/sec. $m = 0.05$ m.

$Q = A X V = \pi d^2/4 X 0.55$

$Q = 0.017 m^3/sec.$

VENTILATION OF SEWERS

Sewage flowing in sewer has got lot of organic and inorganic matters present in it.

Some of the matters decompose and produce gases. These gases are foul smelling, corrosive and explosive in nature.

If these gases are not disposed of properly, they may create a number of difficulties.

They may cause air locks in sewers and affect the flow of sewage.

They may prove to be dangerous for the maintenance squad working in sewers.

They may also cause explosions and put the sewer line out of commission.

For the disposal of these gases, ventilation of sewer line is a must.

Various gases are produced in sewers due to the purification of organic materials of sewage.

These gases are very foul in nature, cause harm to human health and corrode the sewers.

The gases so produced are highly explosive and may cause accidents.

Due to the above difficulties, the sewers must be properly ventilated.

METHODS OF VENTILATION

Proper construction of sewers

Proper design of sewers

Running the sewer at half full or 2/3 depth.

Providing manholes with gratings.

Providing manholes with chemicals.

Proper house drainage system

Providing the ventilating columns or shafts.

PROPER CONSTRUCTION OF SEWERS:

The sewer should be laid at such a gradient that self-cleansing velocity is developed and hence the swage will have no chance of staying at one point for longer period.

PROPER DESIGN OF SEWERS:

The sewers are designed to run two-third or even one-half full and the remaining top space is reserved for the accumulation of sewer gases.

The proper design of sewers also ensures enough ventilation.

PROVIDING MANHOLES WITH GRATINGS:

The manhole covers are sometimes provided with perforations, through which the sewer gets exposed to the atmosphere.

This will help in achieving some ventilation, but it will cause air pollution, hence adopted in isolated places.

The other disadvantage of this method is that it permits road dust, storm water etc. to enter the sewer.

PROVIDING MANHOLES WITH CHEMICALS:

In this method, chemicals are placed in the manhole covers.

These chemicals react with the sewer gases and make them harmless.

As this method is costly, it is rarely adopted.

PROPER HOUSE DRAINAGE SYSTEM:

The lateral sewers are ventilated independently by suitable provision of ventilating shafts or columns.

The sewer gases are carried in these columns and they are relieved in the atmosphere above the height of the building.

PROVIDING THE VENTILATING COLUMNS OR SHAFTS:

The ventilating shaft is provided along the sewer line at an interval of 150 m to 300 m.

They are also provided at the upper end of every branch sewer and at every point where sewer diameter changes.

Ventilating shaft helps to remove the foul and explosive gases produced in the sewer.

They provide fresh air to the workers working in the manholes.

They also help to prevent the formation of air locks in the sewage and thereby ensure the continuous flow of sewage inside the sewer.

CLEANING AND MAINTENANCE OF SEWERS

The sewers should be properly cleaned and maintained in good working condition.

It should be noted that sewers which are once laid and buried into the ground should not be forgotten as they are also liable to corrosion, deterioration, erosion etc.

CAUSES

Breakage of sewers
Clogging
Odours

BREAKAGE OF SEWERS:

The sewers are sometimes broken after being laid under the ground.
Several factors may contribute to the breakage of sewers, being poor foundation, excessive superimposed loads, impact due to vibrations etc.
The presence of corrosive matter in sewage will slowly eat away the material of sewer and it will ultimately result in the breakage of sewer.

CLOGGING:

Clogging mainly occurs in sewers of small size as it is possible for a man to enter such sewers and clean them.
The clogging may be due to waste building materials, ashes, deposition of sand and grit.
It may also be caused by the contribution of greasy matter from garages, hotels, soap industries.
It may be noted that clogging is predominant in sewers lay at flat slopes such that the self-cleansing velocities are not developed.

ODOURS:

The organic matter present in sewer decomposes and gives out unpleasant odours.
It is essential to clean the sewers to bring down the intensity of such unpleasant odours to the minimum possible extent.

METHODS OF CLEANING OF SEWERS

Cleaning and Flushing
Cleaning of catch pits
Inspection
Periodical Repairs
Proper Connections

CLEANING AND FLUSHING:

The cleaning of large sewers is done manually.

The man enters the sewers through manholes and scraps the dies of sewer by hand.

The scraped material is removed through manholes.

The cleaning of small sewers is affected by flushing.

For this purpose, the automatic flushing tanks are sometimes installed on the sewer line.

CLEANING OF CATCH PITS:

The catch pits used to collect storm water are cleaned after every storm.

The catch pits contain debris, silt, sand etc. and even the water contained in catch pits is likely to give rise to the growth of mosquitoes.

A slight trace of organic matter in silt will give unpleasant odour.

The oil and grease traps are also periodically cleaned to avoid the nuisance due to unpleasant odours.

INSPECTION:

The sewer and its appurtenances should be inspected at regular intervals to ascertain their proper working.
The inspection includes examination of structures, measuring rate of flow, determining the amount of clogging.
In case of small sewers, inspection may be also carried out through lamp holes.
In case of large sewers, inspection is carried out by entering and examining the condition of sewer.
Extreme care should be taken before entering the sewer and absence of poisonous and explosive gases in sewer should be confirmed before entering the sewer.
A fire-hose with nozzle may be also inserted in the sewer and the water under pressure may be discharged through the nozzle to clean the sewer.

When flushing is inadequate to remove obstructions in the sewer, the following methods are employed to make the sewer clean.

Flexible rod.

Mechanical tools.

Use of pills.

The precautions to be taken during inspection, only experienced workers should be allowed to enter the sewer for inspection.

The explosion proof electric lighting equipment should only be used for inspection inside the manhole.

The workers should be provided with proper protective measures such as gas masks, rubber gloves, gum boots, non-sparkling tools, safety belt etc.

The workers should be trained to guard against the water borne diseases through sewage. They should also be advised to keep excellent personal hygiene.

The warning signs for traffic should be placed on the road on which manholes are opened out for inspection.

PERIODICAL REPAIRS:

The damaged portions of sewers should be immediately repaired.

The brick sewers require frequent repairs.

The broken bricks should be replacing and pointing to the brickwork should be done at regular intervals.

The manholes also should be periodically examined and repaired, if necessary.

The damaged or broken covers of street inlet or catch basin should be replaced.

The manhole covers which have loose by traffic should be tightened.

The defective connections between the house sewers and the street sewers should be immediately repaired.

The ventilating columns or shafts should be checked at regular intervals and it should be ensured that they are functioning properly.

PROPER CONNECTIONS:

The connection of lateral sewers with branch sewers should be carried out by authorized licensed plumbers only.

The plumbing work of house drainage should be carefully done and the joints should be made water tight.

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SCHOOL OF BUILDING AND ENVIRONMENT

DEPARTMENT OF CIVIL ENGINEERING

UNIT – II – LAYOUT OF SEWERAGE SYSTEM – SCI 1306

LAYING OF SEWERS

- It is common practice to lay sewer line between two manholes at a time.
- The trench is excavated between two manholes and the bedding layer of concrete is provided for soft soil while in case of rocky or hard soil, no bedding.
- The sewers are laid down between two manholes.
- The various steps involved in the laying and testing of sewers are:
- ✓ Setting out Sewer Centre Line
- ✓ Alignment and Gradient of Sewers
- ✓ Excavation of Trenches, Timbering and Dewatering
- ✓ Laying and Jointing of Pipe Sewers
- ✓ Testing of Pipe Sewers
- ✓ Backfilling of Trenches.
- **SETTING OUT SEWER CENTRE LINE:**
- ✓ This is the first step in the laying of sewers.
- ✓ The laying of sewers is generally carried out by starting from the tail end or the outfall end, and proceeding upwards.
- ✓ The advantage of starting the laying of sewers from the tail end is that the tail sewers may be utilized even during the initial period of construction.
- ✓ On the other hand, if the laying of sewers is started from the head end the functioning of the sewerage scheme has to wait till the completion of the entire scheme.
- ✓ From the longitudinal section of the sewer line, the positions of manholes are located on the ground because it is the general practice to lay sewer line between two manholes at a time.
- ✓ The sewer centre line is marked on the ground by driving the pegs at an interval of 7.5 m or 15 m as per convenience.
- ✓ The sewer centre line should be properly maintained during the construction.
- **ALIGNMENT AND GRADIENT OF SEWERS:**
- ✓ The sewers should be laid to the correct alignment and gradient by setting the positions and levels of sewers so as to ensure a smooth gravity flow.
- ✓ This is done with the help of suitable boning rods and sight rails, and a dumpy level.
- ✓ Modified levels of invert are first obtained by adding a suitable vertical length to the invert levels mentioned on the longitudinal section.
- ✓ These modified levels of invert are marked on the sight rail.

- ✓ These levels are marked either by fixing nails on sight rails or by adjusting the top of sight rails to the modified invert levels of sewer line.
- ✓ Thus, an imaginary line parallel to the proposed sewer line is obtained on the ground.
- ✓ In order to check the invert level of sewer boning rod is used. The boning rod is a vertical wooden post fitted with a cross-head or tee at top and an iron shoe at bottom. The boning rod is moved to and fro in the trench so as to obtain the invert-line of the sewer on the prepared bed of the trench.

- ➢ **EXCAVATION OF TRENCHES:**

- ✓ The work of excavation is usually carried out in the form of open cut trenches but in certain situations as indicated later tunneling is also adopted.
- ✓ The excavation is made so as to have trenches of such lengths, widths and depths which would enable the sewers to be properly constructed.
- ✓ In busy streets and localities, the length of the trench to be excavated in advance of the end of the constructed sewer and left open at any time is usually not more than 18 m.

- ➢ **TIMBERING OF TRENCHES:**

- ✓ It may be necessary to restrict the top width of the trench and hence the excavation has to be made with vertical sides.
- ✓ When the depth of the trench exceeds 1.5 to 2 m, and when the excavation has to be made with vertical sides which cannot be sustained, it becomes necessary to support the sides of the trench by sheeting and bracing.
- ✓ This operation is known as timbering of trench.
- ✓ There are various methods adopted for timbering of trenches out of which box sheeting is most commonly used.
- ✓ Sometimes in place of timbering steel sheeting is adopted in the case of badly water-logged areas or in other situations where timber is not easily available.
- ✓ Steel sheeting is more water-tight, stronger and durable, and though costlier than timber, it can be used many times without disintegration and hence more economical in works of larger scale.

- ➢ **DEWATERING OF TRENCHES:**

- ✓ Where the sub-soil water level is very near the ground surface, the trench becomes wet and muddy because of water oozing in the trench from the sides and bottom.
- ✓ In such cases the construction of sewer becomes difficult.
- ✓ As such trenches for sewer construction needs to be dewatered to facilitate the placement of concrete and laying of pipe sewer or construction of concrete or brick sewer and kept dewatered until the concrete foundations, pipe joints or brick work or concrete have cured.

- **LAYING AND JOINTING OF PIPE SEWERS:**
- ✓ Before laying the pipe sewer it should be ensured that the trench has been excavated up to the level of the bottom of the bed of concrete or the bed of compacted granular material if such a bed is to be provided, or up to the invert level of the pipe sewer if no such bed is to be provided.
- **TESTING OF PIPE SEWERS:**
- ✓ Sewers are normally subjected to the following tests before they are put into service:
- ✓ Tests for straightness and obstruction
- ✓ Water test
- ✓ Air test
- ✓ Smoke test.
- **BACKFILLING OF TRENCHES:**
- ✓ Backfilling of the sewer trench is an important consideration in laying of sewers.
- ✓ However, the trench should be backfilled only after the laid sewer has been tested and approved for water tightness of joints.
- ✓ Further when class A bedding is used the backfilling should be carried out only after the concrete has set.
- ✓ The work of backfilling should be carried out with due care, particularly the selection of the soil used for backfilling around the sewer, so as to ensure the future safety of the sewer.
- ✓ The method of backfilling to be used varies with the width of the trench, the character of the material excavated, the method of excavation and degree of compaction required.
- **TESTS FOR STRAIGHTNESS AND OBSTRUCTION:**
- ✓ As soon as a section of sewer is laid it is tested for straightness and obstruction.
- These tests are carried out in the following two ways:
- ✓ At the high end of the sewer a smooth ball of diameter 13 mm less than the pipe bore is inserted.
- ✓ If there is no obstruction such as yarn or mortar projecting through the joints, the ball will roll down the invert of the pipe and emerge at the lower end.
- ✓ A mirror is placed at one end of the sewer line and a lamp is placed at the other end.
- ✓ If the sewer line is straight, the full circle of light will be observed. If the sewer line is not straight, this would be apparent.
- ✓ The mirror will also indicate any obstruction in the sewer line.

➢ **WATER TEST:**

✓ Water test is carried out to find out the water tightness of the joints.

✓ This test is carried out after giving sufficient time for the joints to set.

✓ In the case of concrete and stoneware pipes with cement mortar joints, pipes are tested three days after the cement mortar joints have been made.

✓ It is necessary that the pipelines are filled with water for about a week before commencing the application of pressure to allow for the absorption by the pipe wall.

JOINTS IN SEWERS

➢ Joints are used to john various lengths of pipes to develop a sewer line.

➢ The type of joint to be adopted depends on the pipe material, internal pressure and external loads, and many other factors.

REQUIREMENTS OF GOOD SEWER JOINTS:

➢ The following are the requirements of good sewer joints

1. It should be economical and easy in construction
2. It should be water tight and highly resistant to infiltration of ground water and exfiltration of the sewage
3. It should be resistant to sewage gases and acids
4. It should be non-absorbent and should not absorb anything
5. It should be durable and have long life
6. It should be easily available in required quantity
7. It should not be easily broken or cracked by traffic

TYPES OF JOINTS:

➢ Following are the 5 common types of sewer joints:

✓ Bell and Spigot Joints.

✓ Collar Joints.

✓ Expansion Joint.

✓ Flanged Joint.

✓ Flexible Joint.

✓ Mechanical Joint.

✓ Cement Mortar Joint.

BELL AND SPIGOT JOINTS:

This joint is also known as socket and spigot joint.

This type of joint is mainly used for cast iron pipes of all sizes and concrete pipes below 60 cm in diameter.

The pipes which are to be joined by this joint are made in such a way so that one end is enlarged arid the other end is normal.

The enlarged end is called socket or bell and the normal end is called spigot.

The spigot end is inserted into the bell end and the gap of the joint is filled up with molten lead or bitumen or cement mortar.

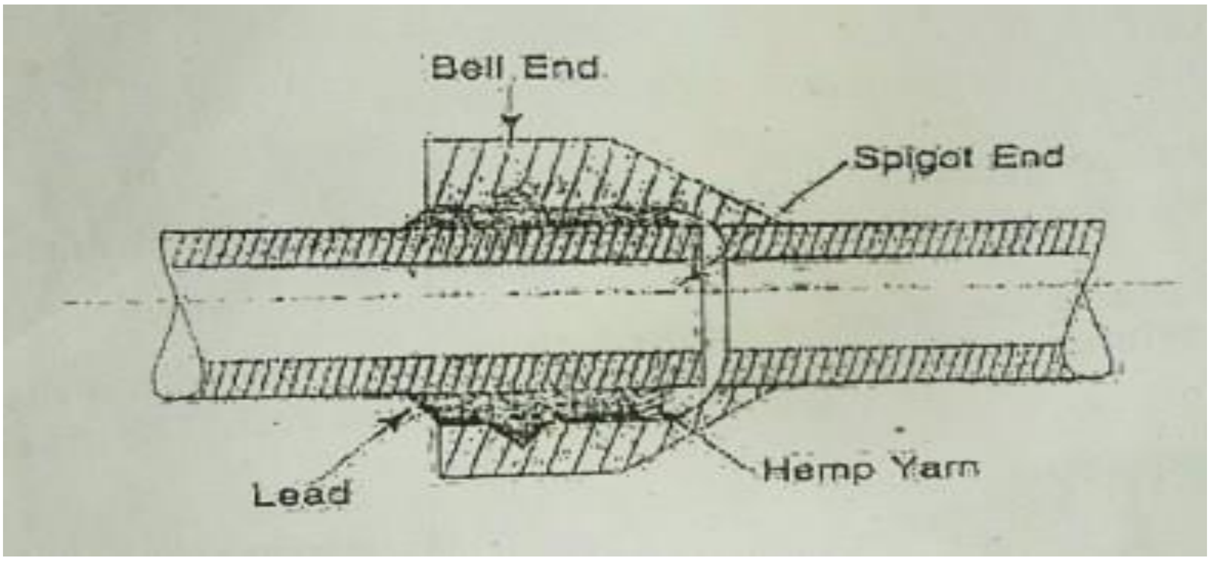


Figure No.1

COLLAR JOINTS:

- ✓ For such a joint in sewers, the plain ends of the consecutive lengths of pipe are kept near each other.
- ✓ A collar of slightly bigger diameter is placed around.
- ✓ The annular space between the collar and the ends of the pipe then filled with cement mortar of 1:1 proportion.
- ✓ Such joints used for concrete pipes of larger diameters.

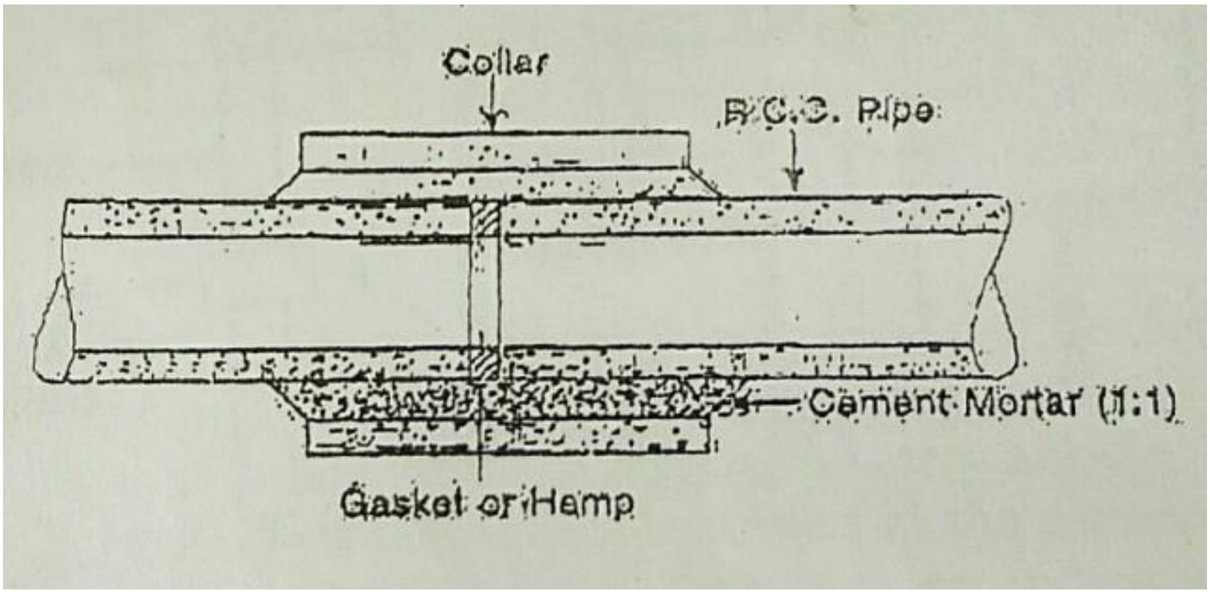


Figure No.2

EXPANSION JOINT:

This joint is adopted at places where pipes expand or contracts due to variation in atmospheric temperature.

Here the socket end is cast flanged and the spigot end is plain.

A flanged ring and a rubber gasket are placed in position on the spigot end.

Then the spigot end is inserted into the socket end nut and bolts are tightened.

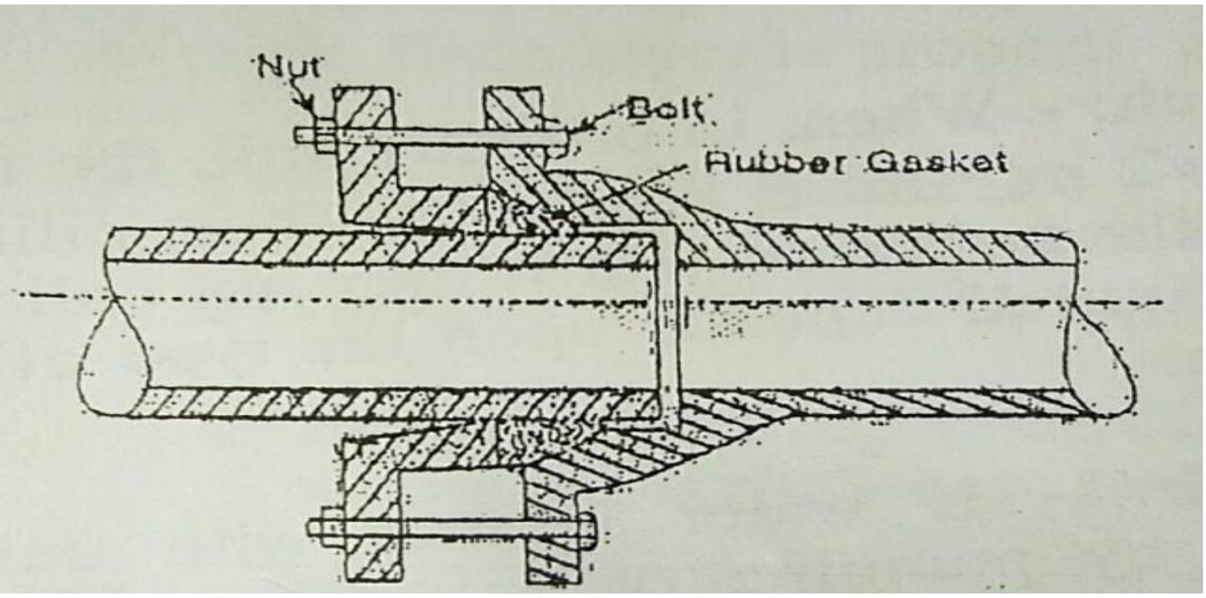


Figure No.3

FLANGED JOINT:

This joint is mostly used for temporary work.
The pipe used in this type of joint has flanges on both ends.
While joining the pipes, a rubber gasket is inserted between the flanges and nut bolts are tightened.

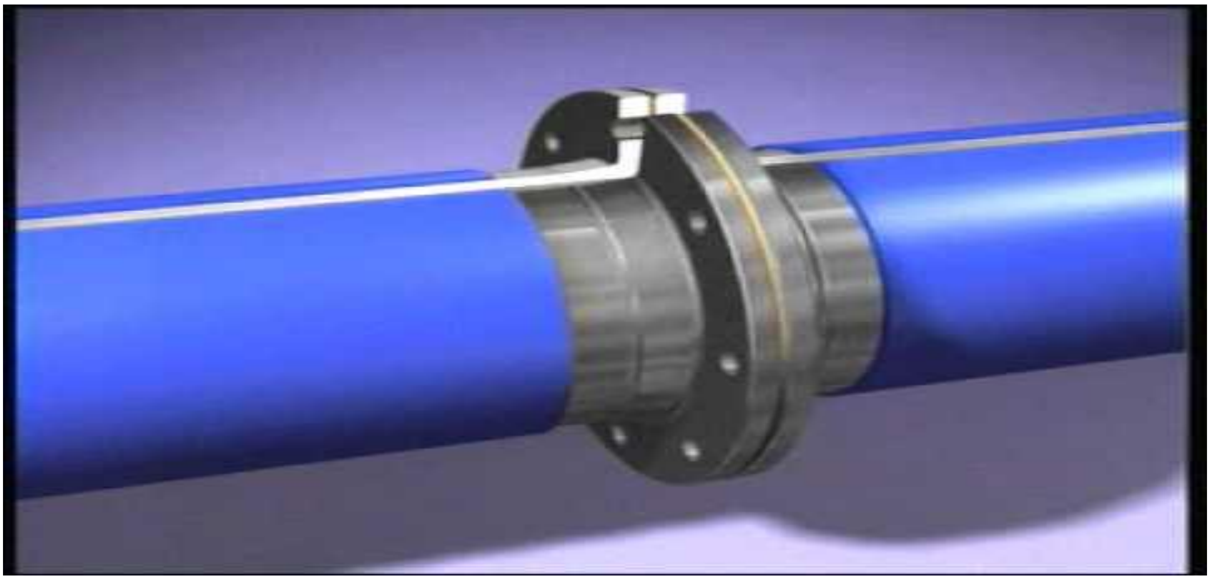


Figure No.4

FLEXIBLE JOINT:

This joint is used at such places where settlement is likely to occur after laying of the pipe.
For this joint, one pipe has spigot end and another pipe has socket end.
The spigot is fitted into the socket and bitumen is filled in the annular space formed between socket and spigot.

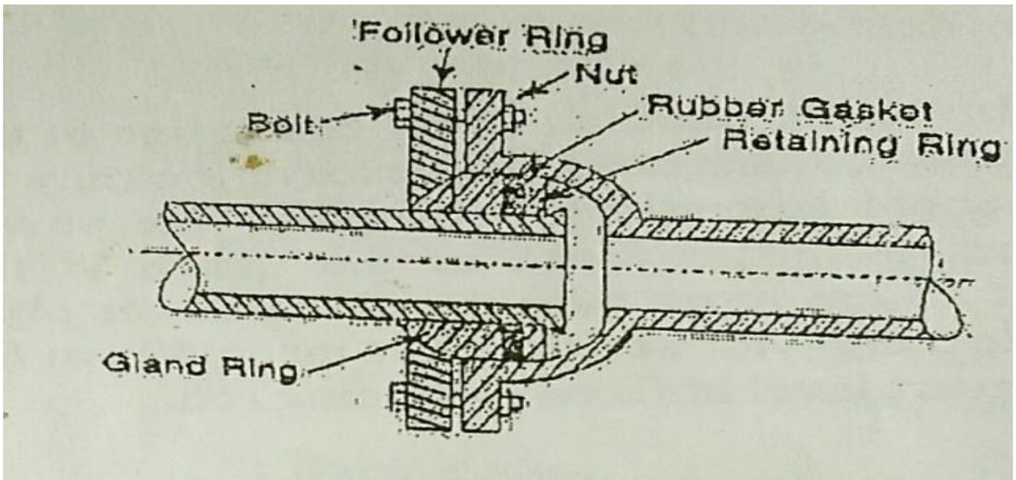


Figure No.5

MECHANICAL JOINTS:

- ✓ Such joints use mechanical devices like flange rings, bolts, screwed ends etc. so that to keep the two ends together.
- ✓ Therefore it, used for metallic sewers made of cast iron, steel etc.

Figure No.6

CEMENT MORTAR JOINT:

- ✓ A rich cement mortar of 1:1:5 or 1:2 is applied between the space of bell and spigot end.
- ✓ For maintaining the alignment of sewers, a special arrangement of gasket or packing pieces may be placed.
- ✓ The mortar is placed in the annular space formed between bell and spigot ends and the joints is finished by applying cement mortar at an angle of 45° on the outer face.

- ➢ **ADVANTAGES:**

- ✓ Easy availability of joint materials
- ✓ Strength of the joint is satisfactory.

- ➢ **DISADVANTAGES:**

- ✓ In this joint, cement is the main material which has been heavily affected by acids, alkaline materials etc.
- ✓ The problem of cement mortar joint is, it requires skilled labours of construction.
- ✓ If the construction is poor, the joint becomes poor and does not water-tight.

- ✓ Generally, cement mortar joints are more rigid in nature.
- ✓ If any repair work or replacement of joint is to be made, it leads to the breakage of sewer or joint.

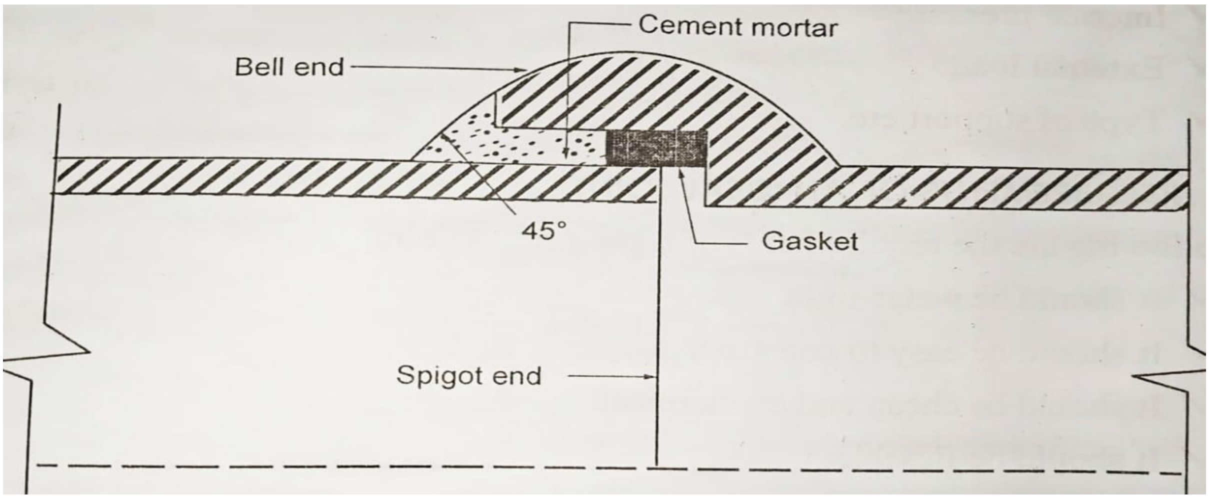


Figure No.7

SEWER APPURTENANCES

Sewage flowing in the sewer line contains a large number of impurities in the form of silt, fats, oils, rags etc.

Under normal flows they are not likely to settle and choke the sewers, but during small flows self-cleansing velocity is not likely to develop and the chances of choking of the sewers are increased.

Chokings have to be removed time to time, and facilities should be provided on the sewer lines for this purpose.

Therefore, for proper functioning and to facilitate maintenance of the sewage system, various additional structures have to be constructed on the sewer lines.

These structures are known as sewer appurtenances.

Following are the important appurtenances:

- Manholes
- Drop manholes
- Lamp holes
- Street Inlets
- Catch basins

- Flushing Tanks
- Grease and oil traps
- Regulators
- Inverted siphons

MANHOLES:

- ✓ The manholes are R.C.C or masonry chambers constructed on the sewer line to facilitate a man to enter the sewer line and make the necessary inspection and repairs.
- ✓ These are fitted with suitable cast iron covers.
- ✓ The manholes should be installed at every point where there is a change in direction, change in pipe size, or considerable change in gradient.
- ✓ As far as possible sewer line between two subsequent man holes should be straight.
- ✓ The centre distance between manholes is less for sewers of smaller size while it may behave such a size that man can easily enter in the working chamber.
- ✓ The minimum size is 50cm diameter.

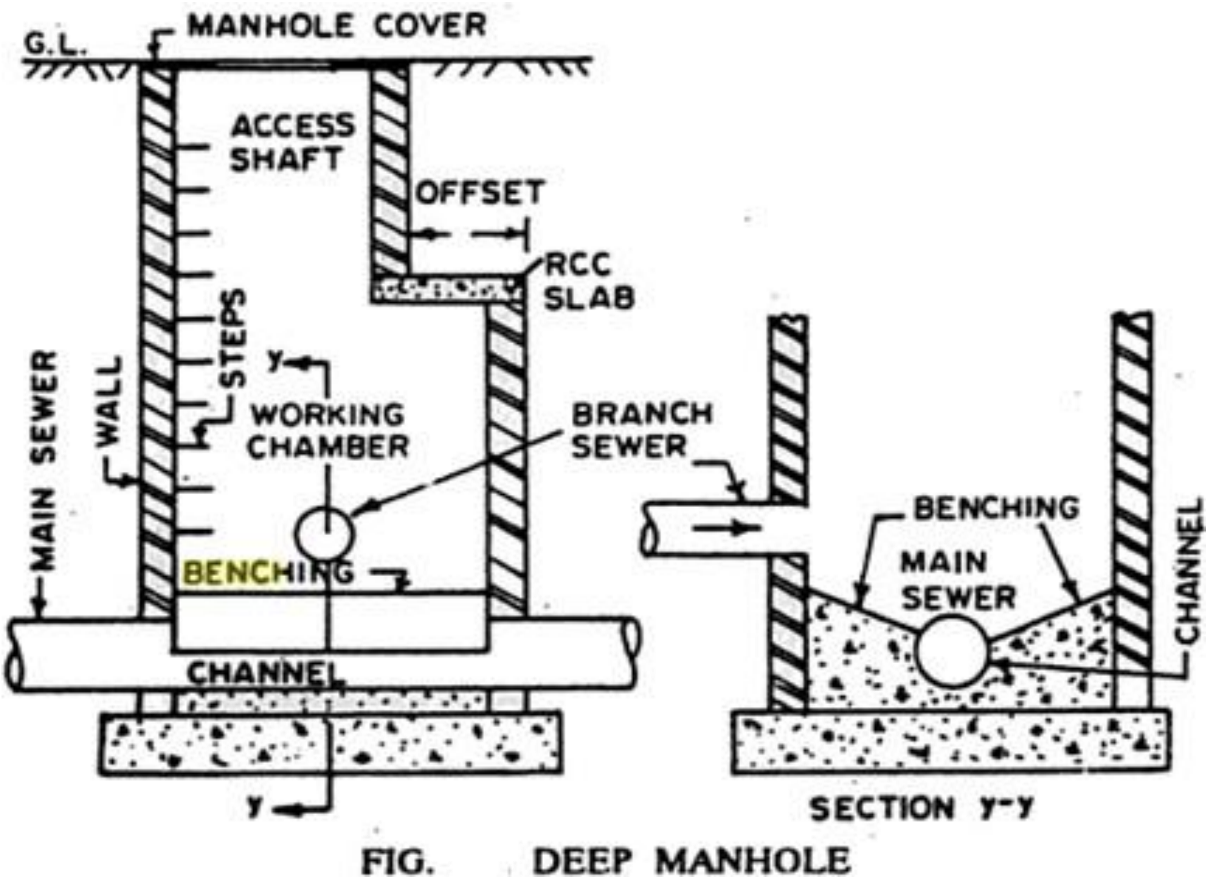


Figure No.8

DROP MANHOLE:

- ✓ A manhole in which a lateral service line or the main line enters a manhole above the manhole's channel or above the flow line so that the flow drops to a lower level is called a drop manhole.
- ✓ The drop manhole is a type of manhole in which a vertical pipe is provided.
- ✓ It is a measure of connecting high level branch sewer to low level main sewer. They are connected through a vertical pipe.
- ✓ The installation of a drop manhole becomes necessary when there is difference in levels is more than 60cm between branch sewer and the main sewer, which can be avoided by increasing the sewer grade.

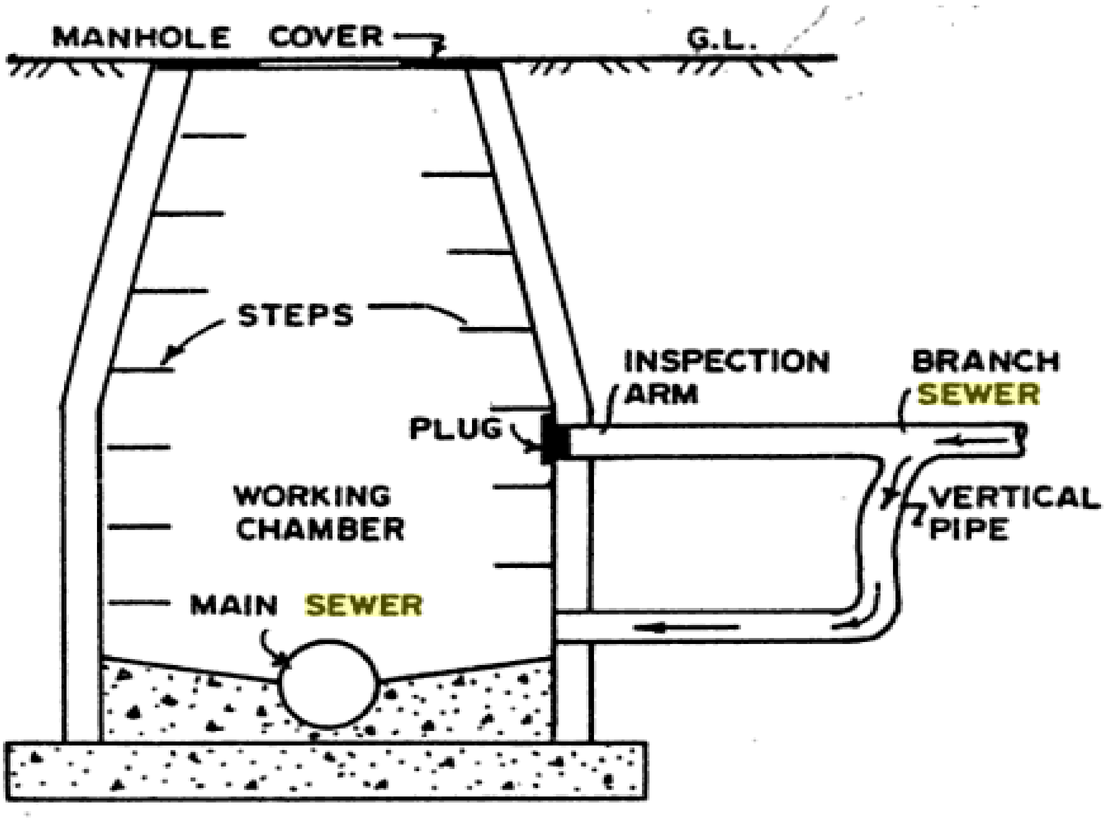


Figure No.9

LAMP HOLES:

- ✓ In narrow lanes, change of gradient and slight curves where space is insufficient for the construction of manholes, a vertical shaft of 20-30 cm diameter is connected to the sewer by a T – bend.
- ✓ These small size openings are covered by a cast iron or R.C.C cover flush with the road level at the top.

- ✓ A small, vertical pipe or shaft extending from the surface of the ground to a sewer.
- ✓ A light (or lamp) may be lowered down the pipe for the purpose of inspecting the sewer.

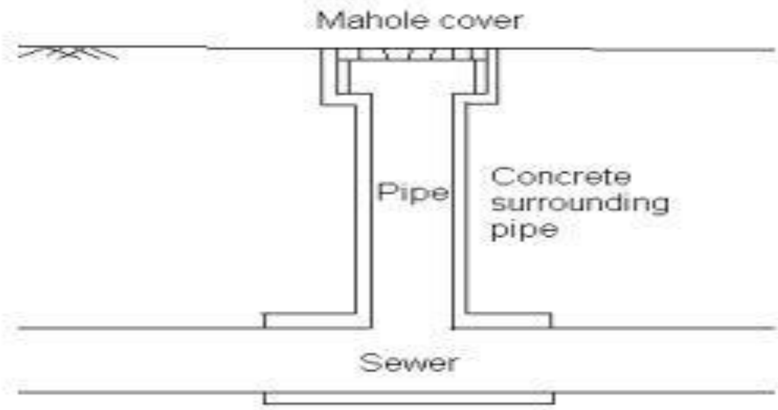


Figure 8.12 Lamp hole

Figure No.10

STREET INLETS:

- ✓ These are meant to admit the surface runoff to the sewers and form a very important part of the system.
- ✓ Their location and design should therefore be given careful consideration.
- ✓ Storm water inlets may be categorized under three major groups viz, curb inlets, gutter inlets, and combination inlets, each being either depressed or flush depending upon their elevation with reference to the pavement surface.
- ✓ The actual structure of an inlet is usually made of brick work.
- ✓ The clear opening shall not be more than 25mm.
- ✓ The connecting pipe from the street inlet to the main street sewer should not be less than 200mm dia. and should have sufficient slope.
- ✓ Maximum spacing of inlets would depend upon various conditions of road surface, size and type of inlet and rainfall. A maximum spacing of 30m is recommended.
- ✓ Inlets are of three types:
- ✓ Curb inlet, Gutter inlet, Combined Curb and Gutter inlet

CURB INLETS:

- ✓ Curb inlets are vertical openings in the road curbs through which the storm water flows and are preferred where heavy traffic is anticipated.
- ✓ These inlets are more suitable than gutter inlets, because less quantity of floating solids enter in the catch pits.

Figure No.11

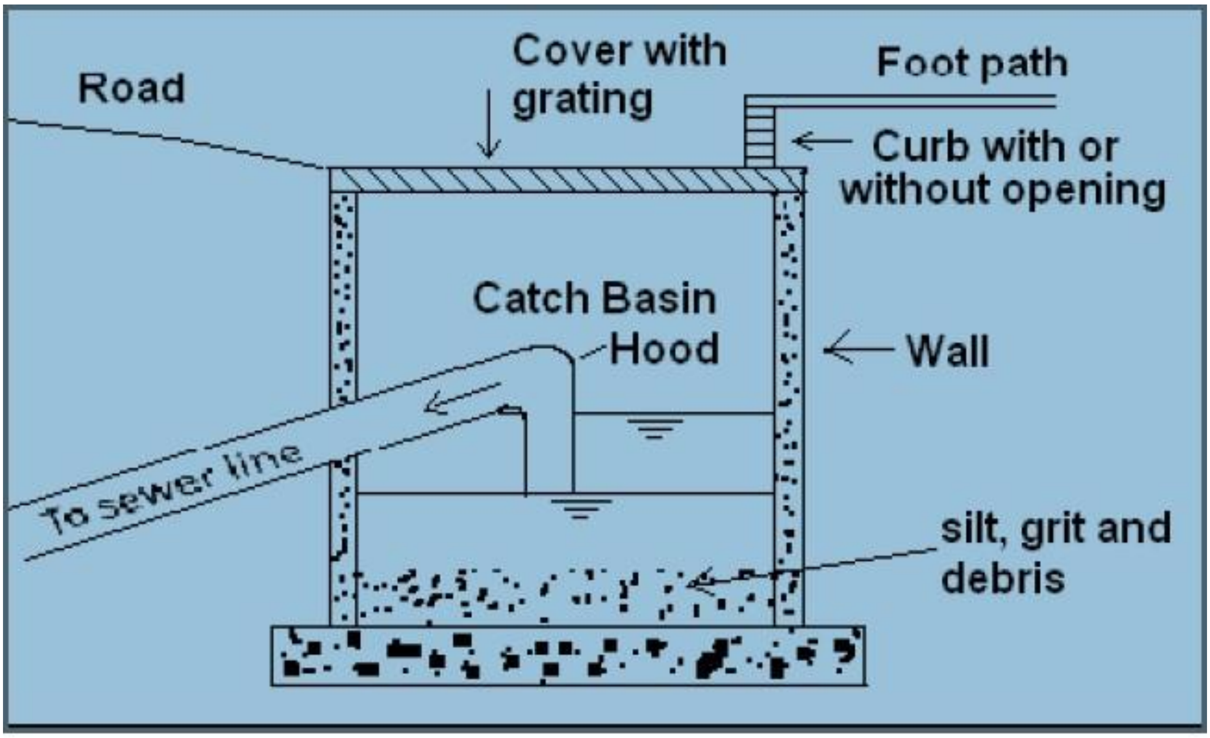
GUTTER INLETS:

- ✓ Gutter inlet is sometimes called horizontal inlet also.
- ✓ This inlet is constructed in road gutter and storm water enters directly into it through horizontal grating provided at the top of the inlet.
- ✓ Such inlets are suitable for roads having steep slope, because its capacity to handle storm water is quite large.

Figure No.12

CATCH BASINS:

- ✓ Catch basins are the structures of pucca chamber and a stout cover.
- ✓ They are meant for the retention of suspended grit, sludge and other heavy debris and floating rubbish from rainwater which otherwise might have entered and cause choking problems.
- ✓ The outlet pipe from the catch basin may be submerged in order to prevent the escape of odours from the sewer and provision that also causes retention of floating matter.
- ✓ Their use is not recommended since they are more of a nuisance and a source of mosquito breeding apart from posing substantial maintenance problems.



Catch Basins

Figure No.13

FLUSHING TANKS:

- ✓ Flushing tanks are provided to flush the sewers.
- ✓ They are seldom used.
- ✓ At such places where self-cleansing velocity is not developed or when the ground is flat and it is not possible to lay the sewer lines at designed gradients, flushing tanks required to flush the sewer line.

- ✓ They are installed at suitable intervals to clean the sewers of choking and obstructions.
- ✓ It resembles a manhole but it is equipped with a siphon at the bottom.
- ✓ This is called the automatic flushing tank in which the water is automatically released from the tank at suitable intervals which may be water supply pipe tap.

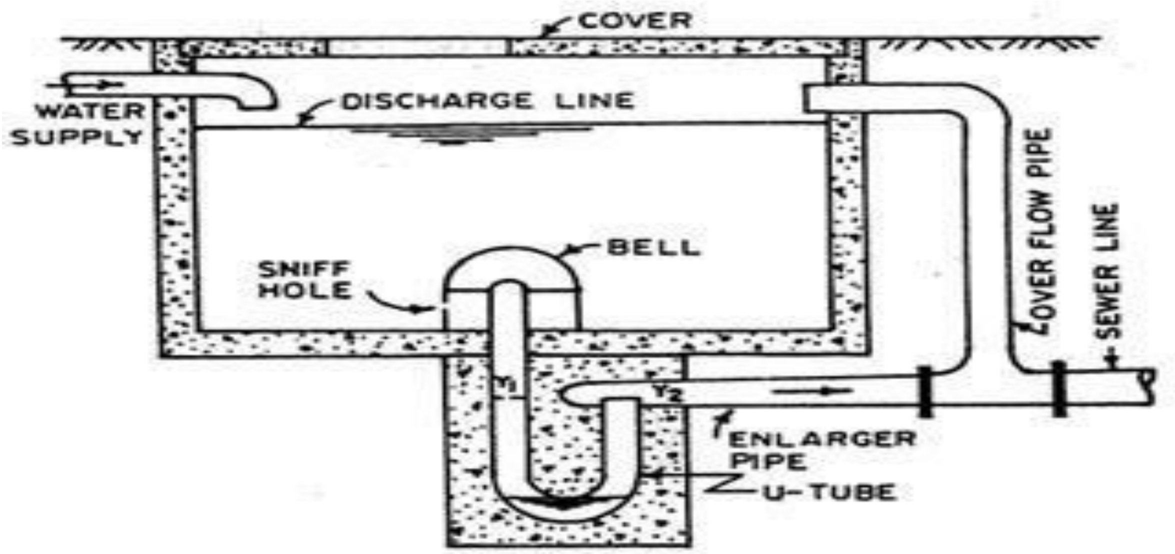


FIG. AUTOMATIC FLUSHING TANK.

Figure No.14

GREASE AND OIL TRAPS:

- ✓ The sewage from kitchens of hotels and restaurants and industries contains oil and grease and fats
- ✓ If these oils and greases are not removed from the sewage they will stick to the interior of the sewer and clogging.
- ✓ Sewage from garages, particularly from floor drains and wash racks, contains oil, mud and sand.
- ✓ The principle, on which oil and grease trap work, is since oil and grease being lighter than water float on the surface of sewage, and the outlet is provided well below the surface so the water is excluded from oil and grease.
- ✓ If silt also has to be excluded, it is done by providing outlet at top.
- ✓ The silt settles at bottom and silt free water can be drained through outlet.

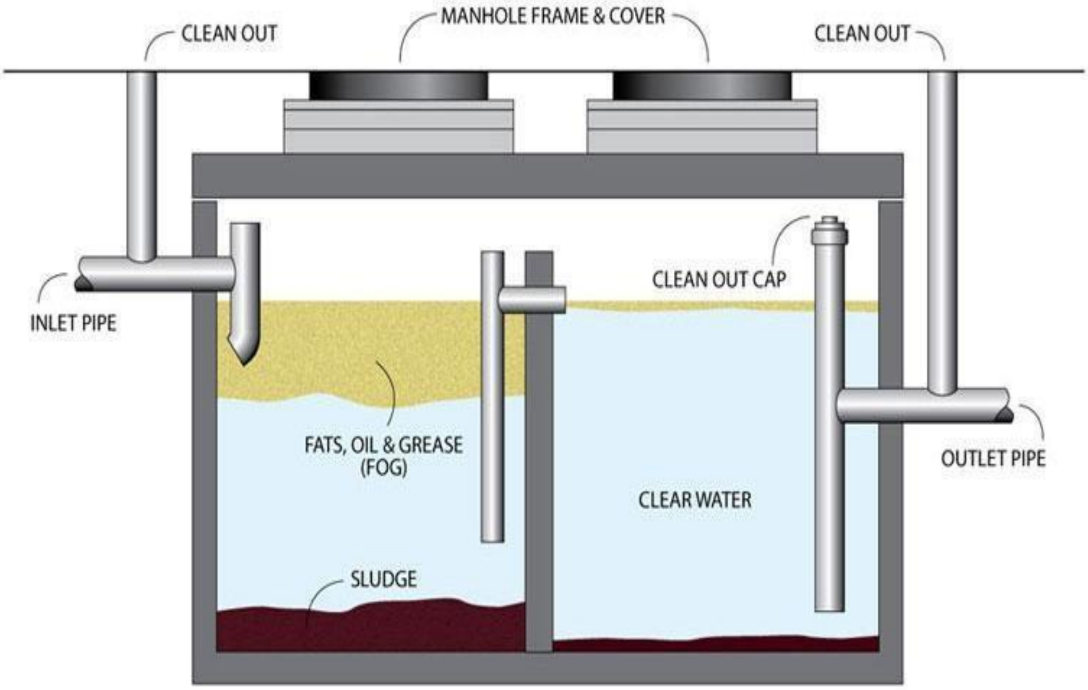


Figure No.15

REGULATORS:

- ✓ A Regulator is a device that diverts sewage flow from one sewer into another.
- ✓ The regulator usually goes into action when the sewage flow reaches a predetermined amount.
- ✓ It may then divert all the sewage or only that part above the predetermined flow at which it begins to function.
- ✓ Regulators are mostly used where combined sewers discharge into interceptors.
- ✓ The interceptor takes the dry-weather flow, but the storm water is diverted into a sewer which flows to the nearest water course.

INVERTED SIPHONS:

- ✓ Inverted siphons are used to carry sewage or stormwater under streams, highway cuts, or other depressions in the ground.
- ✓ Inverted siphons (also called depressed sewers) allow stormwater or wastewater sewers to pass under obstructions such as rivers.

Figure 8.5 Inverted siphon

Figure No.16

PRINCIPLES GOVERNING THE DESIGN FOR DRAINAGE IN BUILDINGS

- House Drainage should be **preferable laid by side of the building** to facilitate easy repair and better maintenance.
- House sewer joints should be **leek proof** because leekage if any shall create an odour problem and leaked wastewater shall infilterate in the ground and shall reduce **bearing capacity of soil** below foundation, which is not desirable.
- The sewage or sullage should **flow under the force of gravity**.
- The house sewer should **always be straight**.
- The entire system should be **well ventilated** from start to the end.
- The house sewer should be connected to the manhole such that the invert level is sufficiently higher to avoid back flow of sewage in house sewer.
- Where ever there is change in direction of sewer line in the premises, provide **inspection chamber at the junction**.
- **Rain water** from roofs or open courtyards **should not be** allowed to flow through the **house sewers**.
- **Siponage action** can never be permitted and therefore adequate **ventilation systems** should be installed.

PLUMBING SYSTEMS FOR DRAINAGE:

Following are the four systems of plumbing for the building drainage:

- ✓ One pipe system
- ✓ Two pipe system
- ✓ Single stack system
- ✓ Single stack partially ventilated system

ONE PIPE SYSTEM:

- ✓ In this system only one main pipe is provided which collects both the foul soil waste as well as unfoul waste from the buildings.

- ✓ The main pipe is directly connected to the drainage system.
- ✓ If this system is provided in multistoried buildings the lavatory blocks of various floors are so placed one over the other, so that the waste water discharged from the different units can be carried through short branch drains.
- ✓ All the traps of the W.C., basins sink, etc. are fully ventilated and connected to the ventilation pipe.
- ✓ But all gully traps and waste pipes are completely dispensed with.

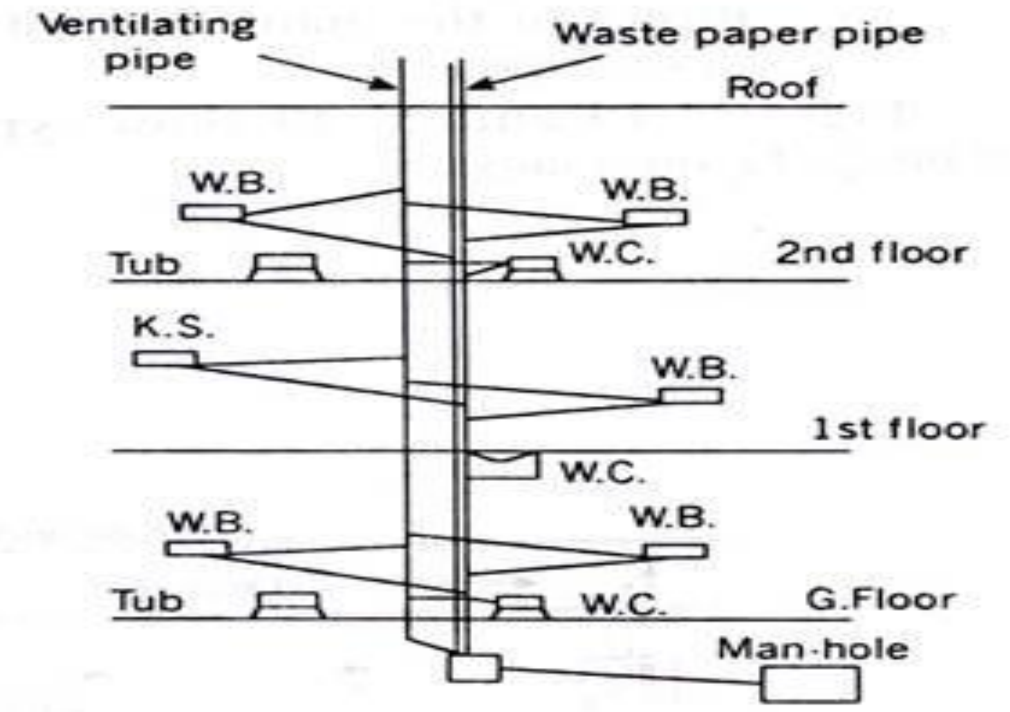


Fig. 24.22. One-pipe system.

Figure No.17

TWO PIPE SYSTEM:

- ✓ This is the most common system used in India.
- ✓ In this system, two pipes are provided.
- ✓ One pipe collects the foul soil and lavatory wastes, whereas the second pipe collects the unfoul water from kitchen, bathrooms, house washings, rain water etc.

- ✓ The soil pipes (pipes carrying the soil waste) are directly connected to the drain, whereas the waste pipes (pipes carrying unfoul water) are connected through the trapped gully.
- ✓ All the traps used in this system are fully ventilated.

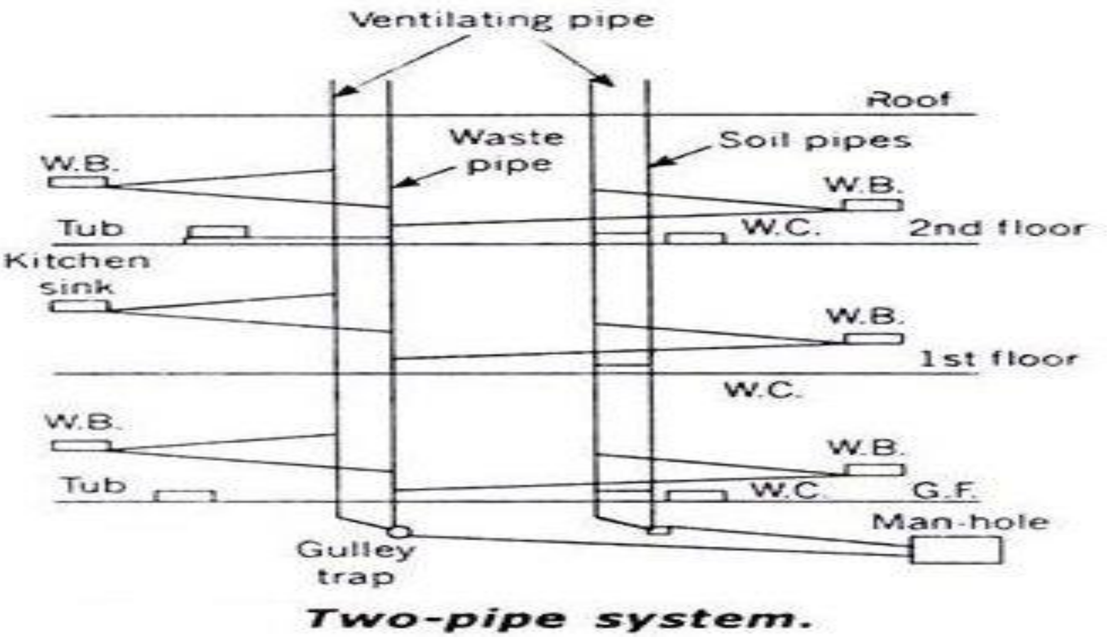


Figure No.18

SINGLE STACK SYSTEM:

- ✓ This is similar to single pipe system, the only difference being that no ventilation is provided even in the traps too.
- ✓ Hence it uses only one pipe which carries the sewage as well as the sullage and is not provided with any separate vent pipe.

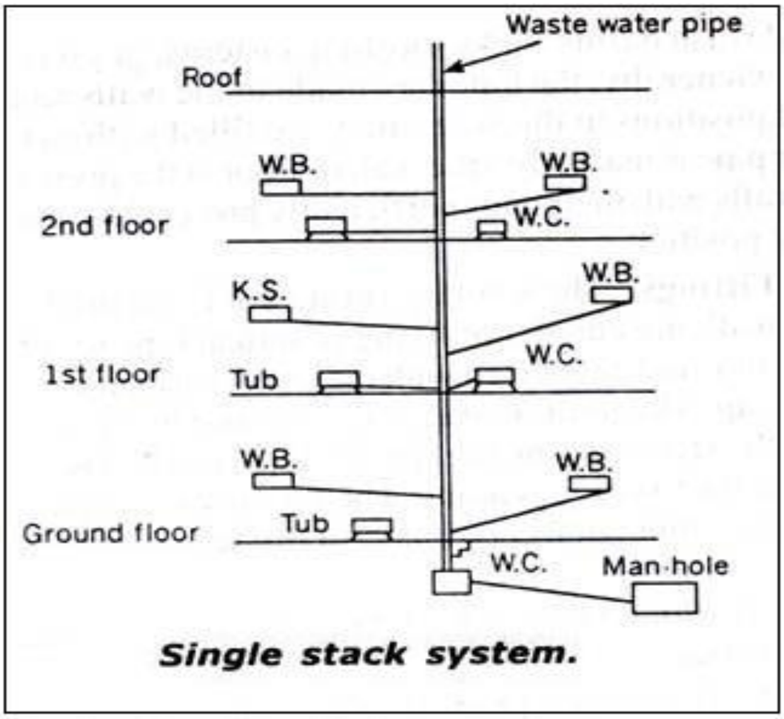


Figure No.19

SINGLE STACK PARTIALLY VENTILATED SYSTEM:

- ✓ This is an improved form of single stack system in the sense that in this system, the traps of the water closets are separately ventilated by a separate vent pipe called relief vent pipe.
- ✓ This system is in between the one pipe and single-stack system.
- ✓ In this system only one pipe is provided to collect all types of waste water foul as well as unfoul.

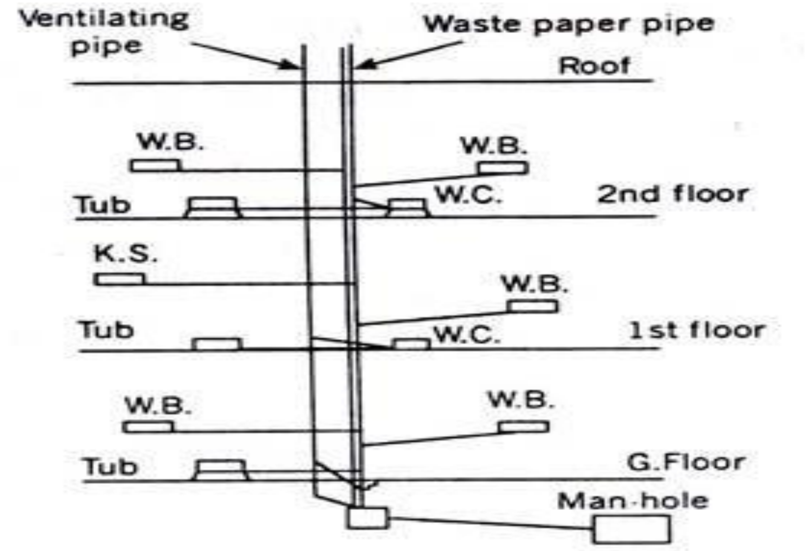
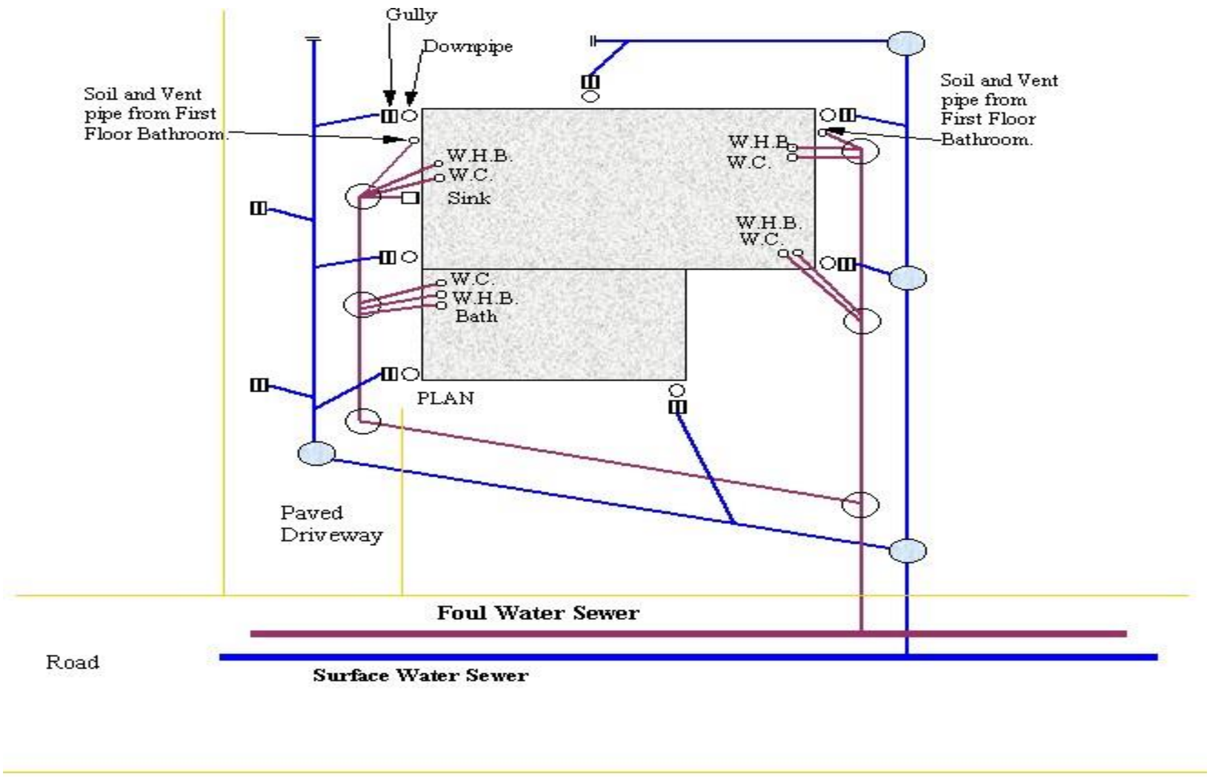


Fig. 24.24. Single-stack partially ventilated system.

Figure No.20

TYPICAL LAYOUT PLAN SHOWING HOUSE DRAINAGE CONNECTIONS



DRAINAGF LAYOUT

Figure No.21

IMPORTANT TERMS:

Pipes:

In house drainage system pipes may be designated depending upon the function as shown below.

Soil Pipe: A pipe carrying human Sewage from W.C.

Waste Pipe: A pipe carrying sullage.

Vent Pipe: It is a pipe installed to provide flow of air to or from the drainage system or to provide circulation of air in the drainage system to protect the water seal of traps against Siphonage and backflow.

Antisiphonage Pipe: It is the pipe which is installed to preserve the water seal in the trap through proper ventilation

Rain water Pipe: A pipe carrying only rain water.

Pipe Sizes:

Soil pipe:	100mm
Waste pipe: horizontal:	30-50mm
Waste pipe: vertical :	75mm
Rainwater pipe :	75mm
Vent pipe:	50mm

Traps:

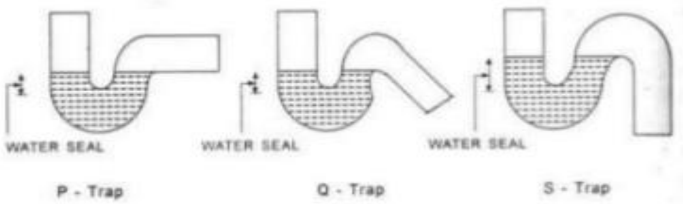
Traps are U shaped fixtures that have Water seal in it. This water in the **trap** creates a seal that prevents sewer gas from passing from the **drain** pipes back into the occupied space of the building. Essentially all plumbing fixtures including sinks, bathtubs, and toilets must be equipped with either an internal or external **trap.**

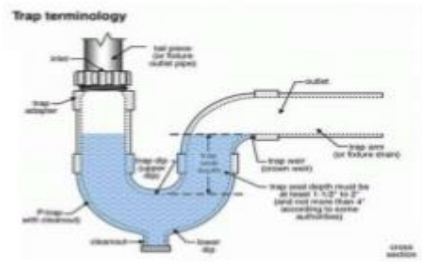
Depending upon the shapes the traps are classified as:

P-Trap: P-traps exit into the wall behind the sink.

Q-Trap: This trap is used in toilet under water closet.

S-Trap: This trap is usually used with Siphonage pipe.





TRAPS:

- ✓ A trap is a device which is used to prevent sewer gases from entering the buildings.
- ✓ The traps are located below or within a plumbing fixture and retains small amount of water.
- ✓ The retaining water creates a water seal which stops foul gases going back to the building from drain pipes.
- ✓ Therefore, all plumbing fixtures such as sinks, washbasins, bathtubs and toilets etc. are equipped with traps.

- ✓ This article tells you the features of traps, various types of traps and water seal.

- ➢ A trap has following features:

- ✓ It may be manufactured as an integral trap with the appliance as in some models of European WC, or it may be a separate fitting called an attached trap, which is connected to waste or foul water outlet of appliances.

- ✓ The traps should be of a self-cleansing pattern.

- ✓ Traps for use in domestic waste should be convenient for cleaning.

- ✓ A good trap should maintain an efficient water seal under all conditions of flow.

Traps:

Based on the Use, the traps are classified as:

Floor Traps (Nahni Trap): This trap is generally used to admit sullage from the floors of rooms, bathrooms, kitchen etc. in to the sullage pipe. This is provided with cast iron or stainless steel or galvanized gratings (Jallis) at its top so that the entry of larger matter is prevented thereby chances of blockage are reduced.

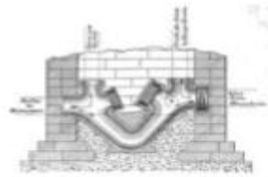
Gully Traps: A Gully trap or gully is provided at a junction of a roof drain and other drain coming from kitchen or bathroom.

Intercepting Traps: Intercepting Traps: Intercepting traps is provided at junction of a house sewer and municipal sewer for preventing entry of foul gases of municipal sewer in to the house drainage system.


Nahni Trap


Gully Trap


Intercepting Trap


Section through Intercepting trap

Sanitary Fittings:

Following sanitary fittings are used in the house drainage system.

Wash Basin: These are plumbing fixtures mainly used for handwashing.

Sinks: Sinks are the plumbing fixtures provided in kitchens for cleaning utensils.

Bath tubs: A circular waste hole at the bottom of bath tub is provided for drainage purpose. Bath Tub is the plumbing fixtures provided in the bathroom for taking bath.

Water Closets: A water closets is a pan like water flushed plumbing fixture designed to remove human excreta directly and dispose the same in to the soil pipe through trap.

Urinals: a bowl or other receptacle, typically attached to a wall in a toilet, into which men may urinate.


Wash Basin


Water Closet


Sink


Bath Tub


Urinal

SEWAGE PUMPING STATION

A pumping station is made up of a large tank, known as a wet well, that acts as the receiver for sewage from a building or a group of buildings.

Sewage from individual houses flows into the wet well.

The sewage will then sit in the well until it reaches a predetermined level.

Once it reaches this level, a pump will kick in to pressurize the sewage so that it will travel out of the wet well, uphill, to a point where it enters the main sewer, or that it can then travel into the main sewer using gravity.

ADVANTAGES OF A SEWAGE PUMP STATION

- ✓ A pump station offers convenience when installing a sewage system, and has a potential of cutting construction cost.
- ✓ Pump stations are fitted with remote monitoring systems, which keep operators updated.
- ✓ Sewage is pumped automatically without any human contact, which eliminates the risk of health problems.
- ✓ Different sizes of pumps are available for domestic applications and commercial applications.
- ✓ The intake of the pumps is often wide to prevent blocking.
- ✓ Sewage pumping systems are fitted with alarms to alert you to problems with the system.
- ✓ This minimizes the risk of sewage overflowing as you are alerted quickly.

DISADVANTAGES OF A SEWAGE PUMP STATION:

- ✓ Design and installation need to be done expertly to ensure that the system is reliable and fit for purpose.
- ✓ This requirement for expertise means that it can be costly.
- ✓ Although the pump systems generally don’t use much power, there is still a cost to the electricity over using a gravity system.
- ✓ It can be difficult to source parts for your pump.
- ✓ This can be avoided by taking up a maintenance contract with Pumping Solutions.

- ✓ Fat and grease build-ups can impact reliability.
- ✓ Although pumps are selected to minimize the risk of blockages, there is still potential for blockages to occur.

PUMPS FOR SEWAGE PUMPING:

- ✓ Centrifugal pump
- ✓ Reciprocating pump
- ✓ Air pressure pump or ejectors

CENTRIFUGAL PUMPS:

- ✓ Centrifugal pumps are most commonly used for pumping sewage, because these pumps can be easily installed in pits and sumps, and can easily transport the suspended matter present in the sewage.

RECIPROCATING PUMPS:

- ✓ Reciprocating pumps are much less employed these days for sewage pumping, because of their high initial cost, difficulty in maintenance and greater wear and tear of valves.
- ✓ However, in cases where it is required to deal with difficult sludges and where large quantity of sewage is to be pumped against low heads, reciprocating pumps may be used after passing the sewage through screen with 20 mm spacing.

AIR PRESSURE PUMPS OR PNEUMATIC EJECTORS:

- ✓ Pneumatic ejectors are used for pumping or lifting small quantities of sewage.
- ✓ The conditions favouring installation of pneumatic ejectors are:
- ▪ Where small quantity of sewage is to be lifted from basement of a building to a high-level sewer.
- ▪ Where the quantity of sewage from a low-lying area does not justify the construction of a pumping station.
- ▪ Where a centrifugal pump of small capacity is likely to clog.

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SCHOOL OF BUILDING AND ENVIRONMENT

DEPARTMENT OF CIVIL ENGINEERING

UNIT – III – CHARACTERISTICS OF SEWAGE – SCI 1306

WASTE WATER CHARACTERSTICS

- Wastewater is simply that part of the water supply to the community or to the industry which has been used for different purposes and has been mixed with solids either suspended or dissolved.
- Wastewater is 99.9% water and 0.1% solids.
- The main task in treating the wastewater is simply to remove most or all of this 0.1% of solids.
- Sewage is dilute mixture of the various types of wastes from the residential, public and industrial places.
- The characteristics and composition of sewage mainly depend on this source.
- Sewage contains organic and inorganic matters which may be in dissolved, suspension and colloidal state.
- Sewage also contains various types of bacteria's, virus, protozoa, algae, fungi etc. Some of these are pathogens and are harmful to the human and animal life.
- **STRENGTH OF SEWAGE: -**

✓ Sewage is a water-carried waste, in solution or suspension, which is intended to be removed from a community.

✓ Also known as wastewater, it is more than 99% water and is characterized by volume or rate of flow, physical condition, chemical constituents and the bacteriological organisms that it contains.

TYPES OF WASTEWATER FROM HOUSEHOLD

TYPE OF WASTE WATER	SOURCE OF WATER
GREY WATER	Washing water from the kitchen, bathroom and laundry.
BLACK WATER	Water from flush toilet.
YELLOW WATER	Urine from separated toilets and urinals.
BROWN WATER	Black water without urine.

Table No.1

RAW SEWAGE:

This indicates that sewage that is not treated.

FRESH SEWAGE:

This indicates that sewage which has been recently originated or produced.

ANALYSIS OF SEWAGE:

- ✓ Before the designing of treatment and disposal of sewage, it is necessary to have the information regarding various constituents of sewage.
- ✓ It is necessary for the following purposes:
- ▪ To know the strength, character, constituents and condition of sewage to be treated for laying down the line of treatment and types of disposal works to be adopted.
- ▪ To control and regulate the performance of sewage treatment works from day 2 day suiting the sewage.
- ▪ To determine the final effluent obtained after treatment is within the limit of self-purification or not.
- ▪ To control and regulate the performance of sewage treatment works from day 2 day suiting the sewage.
- ▪ To determine the final effluent obtained after treatment is within the limit of self-purification or not.

SAMPLING OF SEWAGE

- ➢ The constituents of sewage continuously change with time and position in tanks.
- ➢ The quantity of sewage reaching disposal works in morning differs from that of reaching in noon or night.
- ➢ Therefore, it is difficult to collect the true sample of sewage.
- ➢ To avoid this difficulty, sewage samples are collected over a period of 24 hours after 1-hour interval.
- ➢ All the samples collected are kept in cool place so that biological character may not change before analysis.
- ➢ Each sample bears the date and its time of collection.
- ➢ Sometimes preservative such as chloroform, sulphuric acid, formaldehyde are added in the samples to prevent change in the quantity of sewage.
- ➢ For conducting BOD test, no preservative should be added in the sewage.

➢ Each sample should carry a label as under Source, Date, Time, Preservative added and Collectors identity.

CHARACTERISTICS OF SEWAGE

➢ Physical characteristics of sewage

➢ Chemical characteristics of sewage

➢ Biological characteristics of sewage

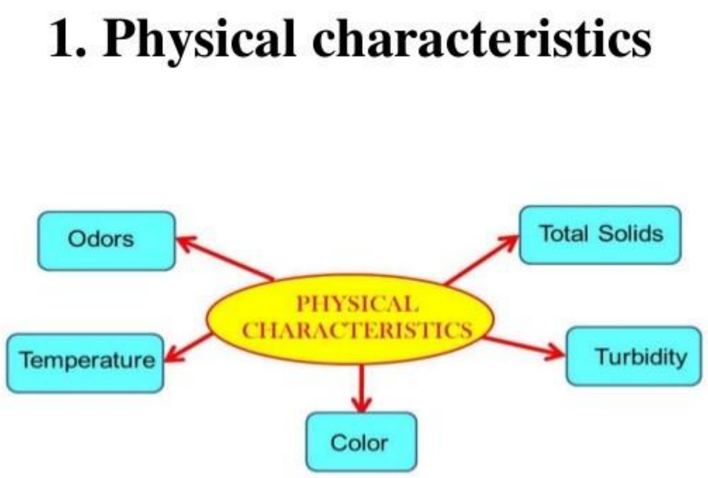


Figure No.1

➢ **COLOUR:**

✓ Color of sewage indicates its strength and age.

✓ Fresh sewage is yellow in colour. Sometimes grey or light brown also indicates the fresh sewage.

✓ If the sewage colour is black or dark, it indicates decomposed or stale sewage.

✓ When industrial effluent is mixed it give characteristic color to sewage.

✓ At a temperature of above 20 °C, sewage will change from fresh to old in 2 - 6 hours.

✓ The old sewage is converted to dark grey and black color due to anaerobic activities, known as stale or septic color.

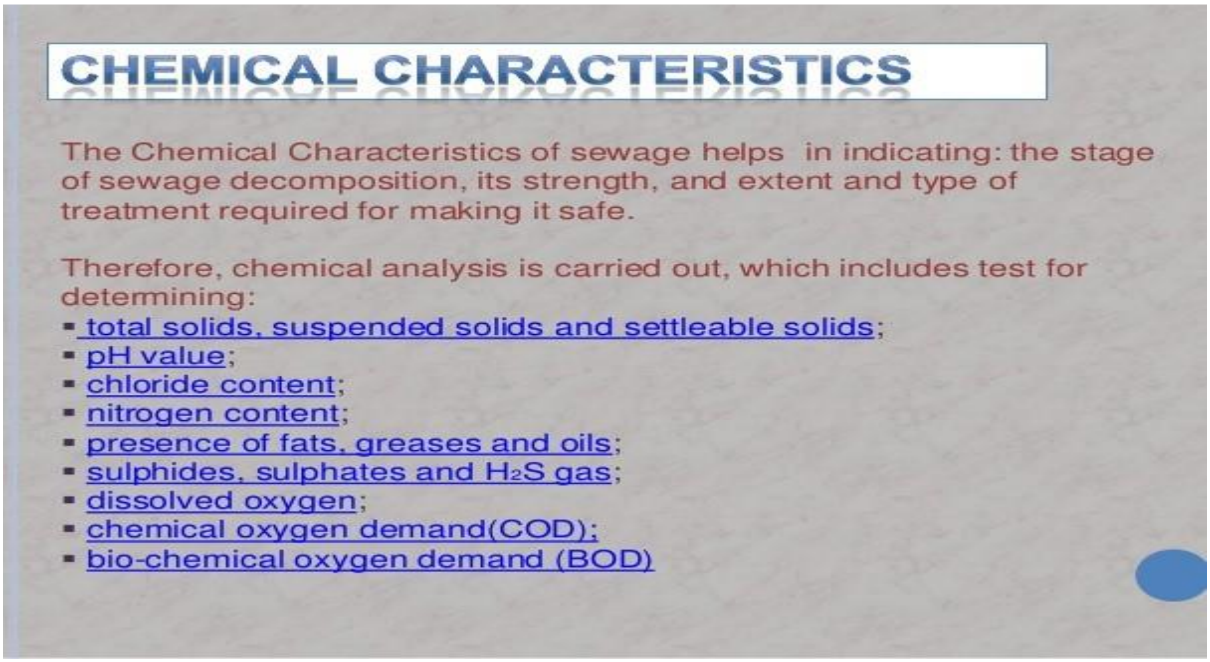
✓ Some industrial sewage also add color to domestic wastewater.

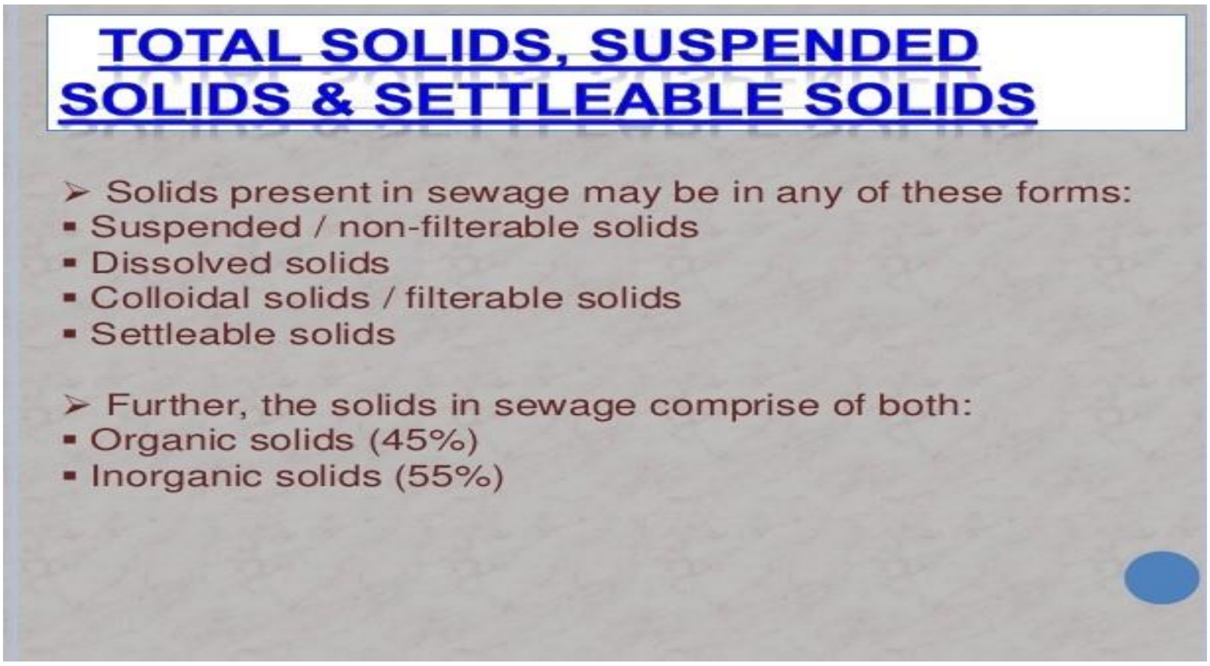
✓ The grey, dark grey and black color is due to formation of sulfide produced under anaerobic conditions reacts with the metals present in wastewater.

- ✓ Colour should be less than 15 TCU (True Colour Units) as per the standards.

- **ODOUR:**
- ✓ Fresh domestic sewage is almost odourless.
- ✓ Septic or stale sewage is putrid in odor which is due to generation of H_2S during anaerobic decomposition of organic matters.
- ✓ When industrial effluent is mixed, it gives characteristics odor to sewage.
- ✓ Fresh domestic sewage has a slightly soapy or oil odour.
- ✓ Stale sewage has a pronounced odour of Hydrogen Sulphide (H_2S).
- **TEMPERATURE:**
- ✓ Temperature of sewage depends upon season. However, temperature is slightly higher than that of ground water.
- ✓ High temperature of sewage is due to evolution of heat during decomposition of organic matter in sewage.
- ✓ If temperature increases, the viscosity of sewage decreases.
- ✓ The reduction in viscosity causes increase in efficiency of treatment units.
- ✓ Temperature of sewage the sewage is slightly more than that of water, because of the presence of industrial sewage.
- ✓ The temperature changes when sewage becomes septic because of chemical process.
- ✓ The lower temperature indicates the entrance of ground water into the sewage.
- **TURBIDITY:**
- ✓ Sewage is highly turbid.
- ✓ Turbidity of sewage is due to dissolved substances, colloidal matters, suspended solids and microbial cells.
- ✓ Measure of light-transmitting properties of water, used to indicate quality of waste discharges and natural waters with respect to colloidal and residential suspended matter.
- ✓ Turbidity is measured in terms of NTU (Nephelometric Turbidity units), JTU (Jackson Turbidity Units) and FTU (Formazin Turbidity Units).

  NTU is the standard measure.





- **TOTAL SOLIDS:**

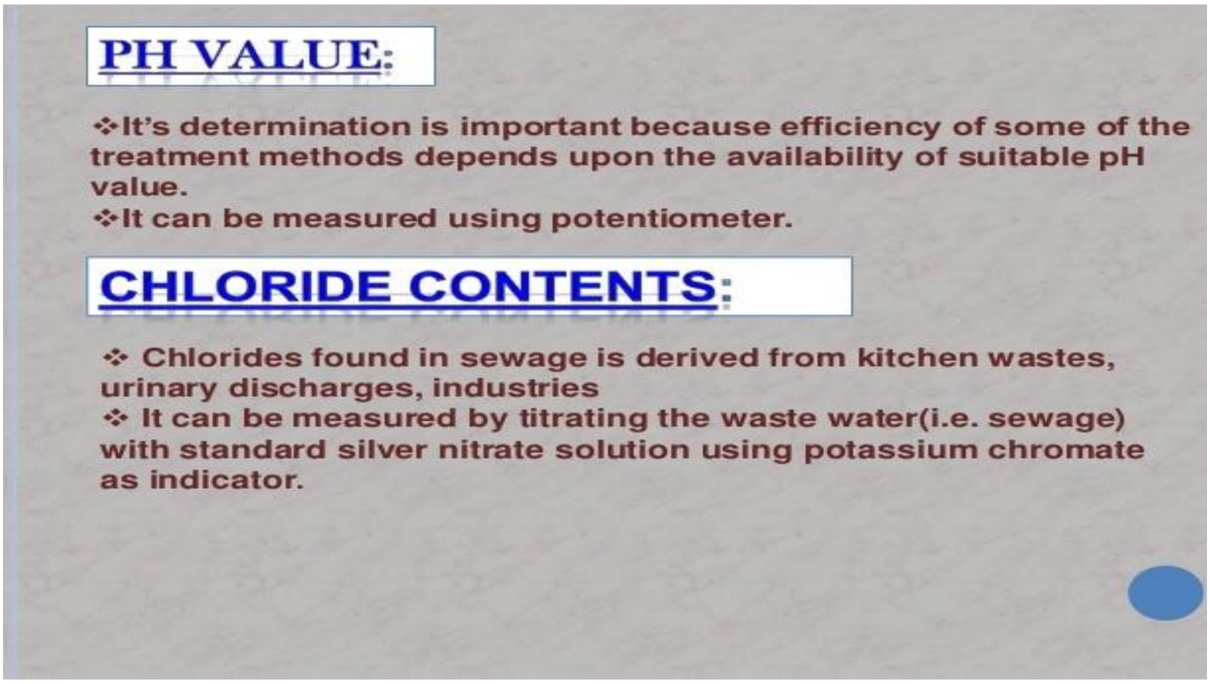
- ✓ In liquid sewage, minimum of 0.01 % solid particles are present. The total quantity of solid particles present in the sewage is called Total Solids.
- ✓ Those solids that are not dissolved in wastewater are called suspended solids. Size of suspended solids is more than 1 µm.

- ✓ Solids which remain dissolved in the sewage with the size of less than 10^{-3}µm.
- ✓ Finely divided solids remaining either in solution or in suspension (size varies within 1and 10^{-3}µm) and are called Colloidal solids.
- ✓ Those suspended solids that settle are called settleable solids, grit, or sludge. The size is more than 10 µm.
- ✓ When suspended solids float, they are called floatable solids or scum.
- ✓ Total solids are classified based on their chemical behavior:

  Organic Solids

  Inorganic Solids

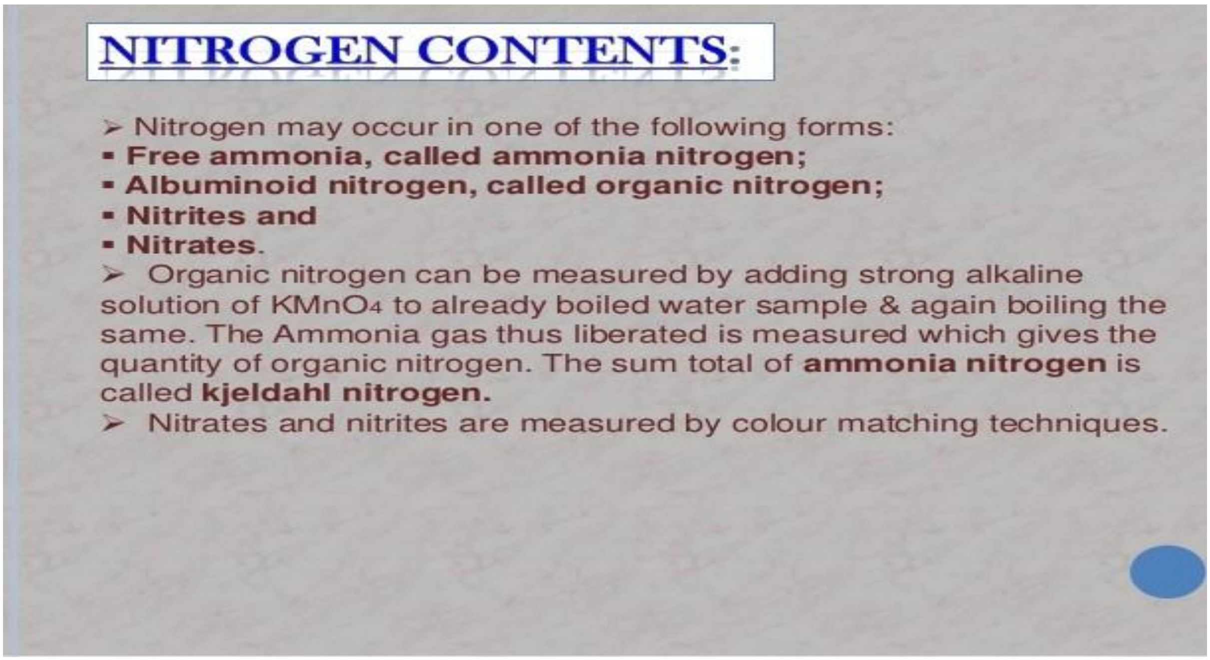
- ➢ **TOTAL SUSPENDED SOLIDS:**
- ➢ Those solids that are not dissolved in wastewater are called suspended solids. Size of suspended solids is more than 1 µm.
- ✓ Total suspended solids (TSS) are referred to as non-filterable residue.
- ✓ TSS is expressed in the unit mg/L.
- ➢ **FIXED AND VOLATILE SOLIDS:**
- ✓ The residue for total solids, total suspended solids or total dissolved solids tests is ignited to constant weight at 500 ^{o}C ± 50.
- ✓ The weight lost on ignition is called volatile solids, whereas the remaining solids represent the fixed total suspended or dissolved solids.
- ✓ The determination of volatile portion of solids is useful in controlling waster water treatment plant operations because it gives a rough estimation of the amount of organic matter present in the solid fraction of waste water, activated sludge and industrial waste.
- ✓ Those solids that do not burn or evaporate at 500°C to 600°C, but remain as a residue, are called fixed solids.
- ✓ Fixed solids are usually inorganic in nature and may be composed of grit, clay, salts, and metals.
- ➢ **pH:**
- ✓ sewage is slightly alkaline in pH.
- ✓ pH is used to describe the acid or base properties of water solutions.
- ✓ The pH of sewage is initially high and drops when the sewage becomes septic but becomes increases again with the treatment processes.

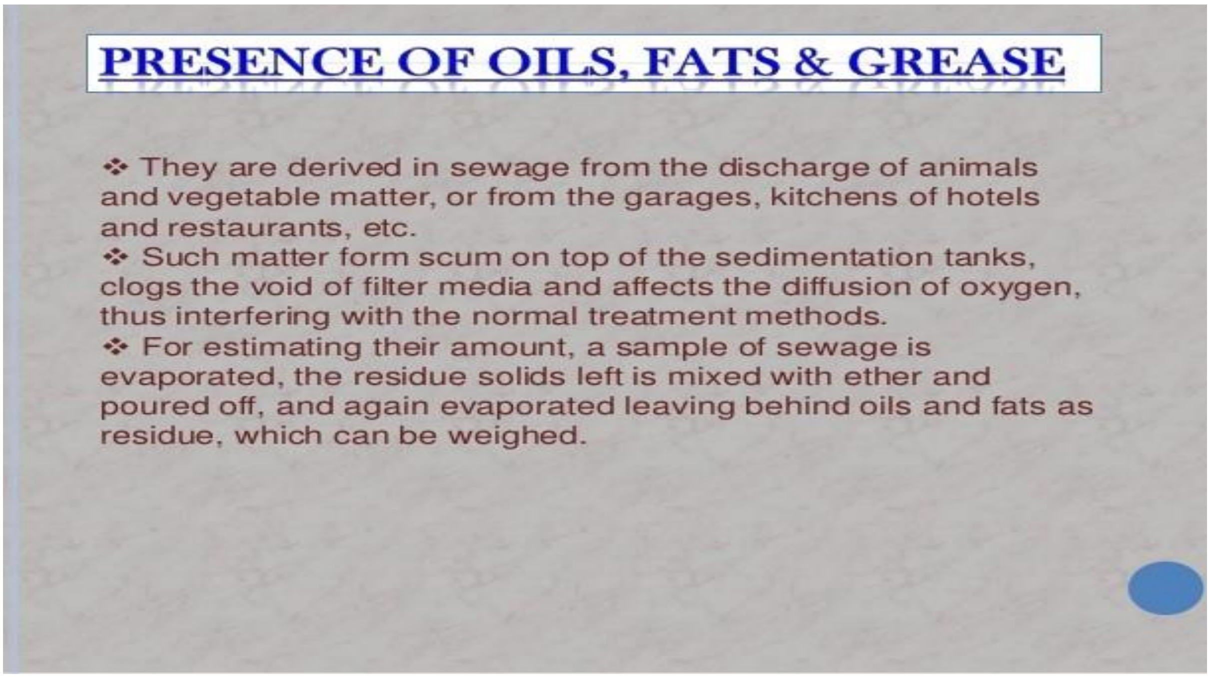


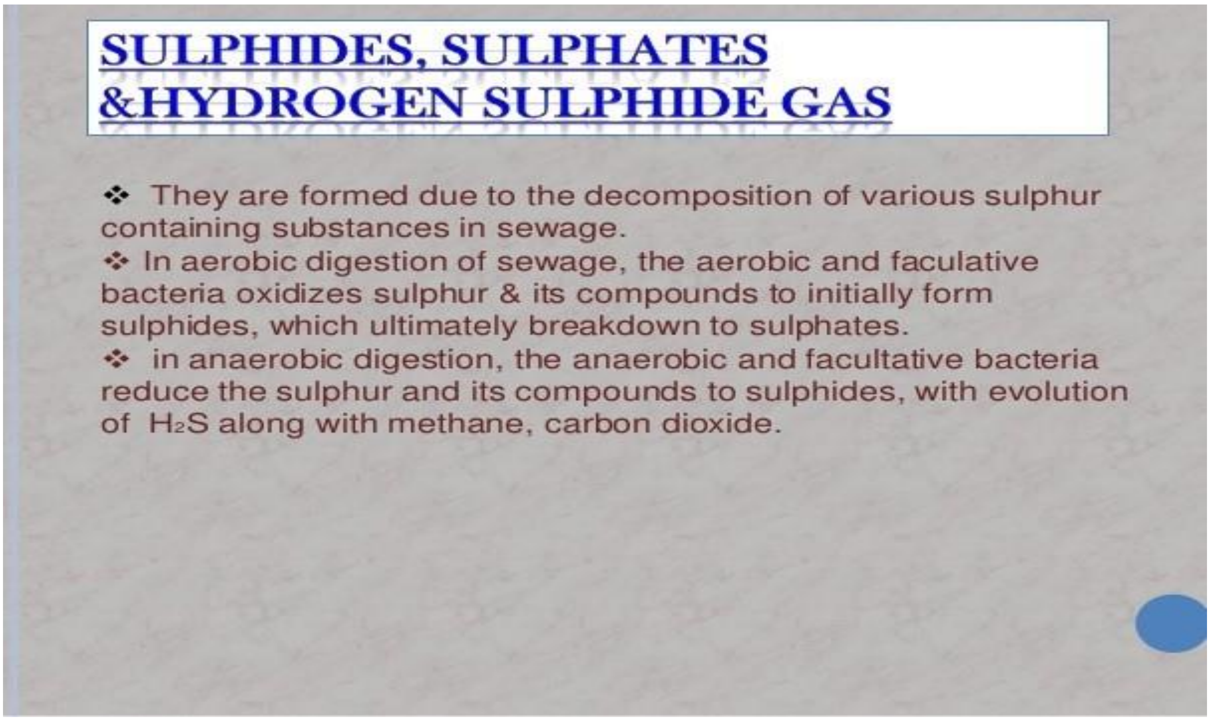
- **CHLORIDE:**

✓ Human beings discharge large amount (8-15gm/day) of chloride in the form of NaCl, especially through urine and sweat.

✓ So domestic sewage from toilet and bathroom contains higher level of chloride.







- **TOTAL ORGANIC CARBON:**

- ✓ Another important method of expressing organic matter is in terms of its carbon content.
- ✓ Carbon is the primary constituent of organic matter.
- ✓ Total organic carbon is the amount of carbon found in an organic compound and is often used as a non-specific indicator of water quality or cleanliness of pharmaceutical manufacturing equipment.

CHEMICAL OXYGEN DEMAND (C.O.D.)

- It is the measured amount of oxygen needed to chemically oxidize the organic matter using a strong oxidizing agent like potassium dichromate under acidic condition.

- It can be used to measure both biodegradable and non biodegradable organic matter.

BIOLOGICAL OXYGEN DEMAND (B.O.D.)

It is defined as the amount of oxygen required by the microorganisms (mostly bacteria) to carry out decomposition of biodegradable organic matter under aerobic conditions.

- The BOD test is widely used to determine the pollution strength of domestic and industrial wastes in terms of the oxygen that they will require if discharged into natural watercourses. It is the one of the most important test in stream pollution control activities.
- This test is of prime importance in regulatory work and in studies designed to evaluate the purification capacity of receiving bodies of water.
- It is also useful in design of wastewater treatment plant and also to measure the efficiency of some treatment processes.
- of some treatment processes.

BOD TEST:

•The sample is first diluted with a known volume of aerated water. The initial D.O of the diluted sample is measured. The diluted sample is then incubated for 5 days at 20 ^{0}C. The D.O. of the diluted sample after the incubation period is found out. The difference between the initial D.O. of the diluted sample after the incubation period is found out. The difference between the initial D.O value and the final D.O. Value will indicate the oxygen consumed by the sewage sample in aerobic decomposition in 5 days. The BOD in mg/lit or ppm is then calculated by using the equation:

•BOD= [D.O. consumed in the test by the diluted sample x (Volume of the diluted sample/ Volume of undiluted sewage sample)]

- **DISSOLVED OXYGEN (DO):**

- ✓ The determination of dissolved oxygen present in sewage is important because of while discharging the treated sewage into some river stream, it is necessary the treated sewage of 4 ppm of D.O in it.
- ✓ Otherwise fish are likely to be killed, creating nuisance near the vicinity of the disposal.
- ✓ In order to ensure this, D.O tests are performed during sewage disposal treatment processes.
- ✓ If the temperature of sewage is more, D.O content will be less.
- ✓ Due to high level of microbial cells and biodegradable organic matters, sewage have very low level of dissolved oxygen.
- ✓ In some sewage, DO is completely absent.
- ✓ Level of Do depends on age and condition of sewage.
- ✓ Low level DO is also due to lower solubility of oxygen in sewage.
- ✓ The solubility of oxygen in sewage is 95 % of that in distilled water.
- ✓ The D.O content of sewage is determined by Winkler's method.

- **POPULATION EQUIVALENT:**

- ✓ Population Equivalent = Total of the industrial wastewater (Kg/day) / BOD value per capita/day

$$\text{Population Equivalent} = \frac{\text{Total of the industrial wastewater (Kg/day)}}{\text{BOD value per capita/day}}$$

- ✓ Population Equivalent is used to indicate the strength of the industrial wastewater required for,
- ✓ Estimating the treatment required.
- ✓ Charging suitable levy on the industries to meet out the cost of treatment.

➢ **RELATIVE STABILITY:**

It is defined as the ratio of oxygen available in the effluent to the total oxygen required to satisfy its first stage B.O.D demand.

It is expressed as percentage of the total oxygen required and can be expressed by the equation.

Relative stability, S = 100 (1 – (0.794) t_{20}

Relative stability, S = 100 (1 – (0.630) t_{37}

Where, S – Relative Stability

- ✓ t_{20} & t_{37} - represent the time in days for a sewage sample to decolourise a standard volume of methylene blue solution, when incubated at 20° or 37° respectively.
- ✓ Dilution Factor = $\dfrac{\text{Volume of diluted sample}}{\text{Volume of undiluted sample of sewage}}$

BOD = Depletion of oxygen X Dilution Factor

PROBLEMS

1. If 25 ml of raw sewage has been diluted to 250 ml and the DO concentration of the diluted sample at the beginning of BOD test was 8 mg/l & 5 mg/l after 5-day incubation at 20°C. Find BOD of raw sewage.

Solution:

Volume of sewage = 2.5 ml

Volume of diluted sample = 250 ml

Dilution Factor = $\dfrac{\text{Volume of diluted sample}}{\text{Volume of undiluted sample of sewage}}$

= 250/2.5 = 100

Loss of D.O during the test = D.O before testing – D.O after testing

= 8 – 5 = 3 mg/l.

BOD of sewage = Loss of D.O X Dilution Factor

= 3 X 100 = 300 mg/l.

2. A 2 % solution of a sewage sample is incubate for 5 days at 20°C. The depletion of oxygen was found to be 4 ppm. Determine the BOD of sewage.

Solution:

$$\text{Dilution Factor} = \frac{100}{\%\text{ of solution}} = 100/2 = 50\ \%.$$

Depletion of oxygen = 4 ppm.

BOD = Depletion of oxygen X Dilution Factor

= 4 X 50 = 200 ppm.

3. The domestic sewage of a town was tested for total solids and following results are obtained.

Volume of sample of sewage – 1000 ml.

Volume of solids after evaporation of liquid – 0.952 gm.

Volume of dry residue after ignition – 0.516 gm.

Determine Total, Fixed and Volatile solids.

Solution:

Total Solids, S_T = 0.952 / 1000 X 10^6 = 952 ppm.

Fixed Solids, S_F = 0.516 / 1000 X 10^6 = 516 ppm.

Volatile Solids, $S_V = S_T - S_F$= 952 – 516 = 436 ppm.

4. In order to conduct 5-day BOD test, sample of wastewater was diluted with specially prepared dilution water with D.F – 150, contents of DO in beginning and end of test were found to be 11 and 7 ppm. Find 5-day BOD and its nature.

Solution:

BOD_5 = Oxygen Consumed X Dilution Factor

= (11 – 7) X 150 = 600 ppm.

Hence the wastewater is very strong and requires heavy treatment before disposal.

5. The average sewage flow from a city is 80 X 10^6 l/day. If the average 5 day BOD is 285 mg/l, compute the total daily 5 day oxygen demand in Kg. and the population equivalent of sewage. Assume per capita BOD of sewage per day is 75 gm.

Solution:

Quantity of sewage flowing /day = 80 X 10^6

Average 5-day BOD = 285 mg/l

Total daily 5-day oxygen demand = 285 X 80 X 10^6 = 22800 X 10^6 mg

= 22800 kg.

Population Equivalent = 22800 / 0.075 = 304000

6. Calculate the population equivalent of a city

The average sewage from the city is 95 X 10^6 l/day

The average 5-day BOD is 300 mg/l.

Solution:

Average 5-day BOD = 300 mg/l

Average sewage flow = 95 X 10^6 l/day

Total BOD in sewage = 300 X 95 X 10^6 = 28500 Kg/day

(Assuming Domestic Sewage to be 0.08 Kg/per/day)

Population Equivalent = 28500 / 0.08 = 356250.

BACTERIOLOGICAL CHARACTERISTICS OF SEWAGE:

- **BACTERIA:**

- ✓ The bacteria are more active and exist in abundance.
- ✓ The bacterial characteristics of sewage are due to the presence of microorganisms, which include bacteria and other living organisms such as algae, fungi, protozoa etc.
- ✓ There are various types of micro-organisms. The most fundamental and the simplest wholly contained life systems are bacteria.
- ✓ Most of the bacteria types are harmless and under conditions, beneficial to humans. Animals and crops. Such bacterias are called non -pathogenic bacterias or non-pathogens.
- ✓ Certain other bacteria are the deadly foes of man and animals and may enter their tissues causing serious diseases. Such bacterias are known as pathogenic bacterias or pathogens.
- ✓ However, pathogenic (disease-causing) organisms such as typhoid, dysentery, and other intestinal disorders may be present in wastewater.
- ✓ These bacteria are responsible for the decomposition of complex compounds to stable compounds with the help of some extracellular and intracellular enzymes.
- ✓ Most of the bacterias require oxygen for their survival.
- ✓ These bacterias consume dissolved oxygen from the water and decompose the refuge and organic matter present in water or sewage, thus doing their cleaning up job.

- ✓ Depending upon the mode of action of bacteria may be divided into the following three categories:

- • Aerobic Bacteria
- • Anaerobic Bacteria
- • Facultative Bacteria

- ➢ **ALGAE:**
- ✓ Some algae found in sewage includes Chlorella phormidum, Ulothrix etc.
- ✓ Algae are used in trickling filter in sewage treatment plant.
- ➢ **FUNGI:**
- ✓ Fungi like Fusarium and Sporotricum are found in sewage which play important role in trickling filter.
- ➢ **VIRUS:**
- ✓ Some viruses causing human disease such as Poliovirus, Rotavirus, Hepatitis A are found in sewage which get access through stool of patients.
- ➢ **PROTOZOA:**
- ✓ Some protozoa that cause disease of intestinal tract enter into sewage together with stool of patient.
- ✓ Examples: Entamoeba histolytica, Giardia, Balantidium coli etc are pathogenic protozoa
- ✓ Few protozoa such as Vorticella and Opercularia are found in trickling filter.

DECOMPOSITION OF SEWAGE

- ➢ The organic matter decomposed by bacteria under biological action is called biodegradable organic matter.
- ➢ Most of the organic matter present in sewage is biodegradable and hence undergo biological decomposition can be divided into two types:
- ✓ Aerobic decomposition (Aerobic Oxidation)
- ✓ Anaerobic decomposition (Putrefaction)
- ✓ The organic matter in sewage consists of urea from urine, proteins, carbohydrates, fats and oils and soaps.
- ✓ These are normally composed of a combination of carbon, hydrogen and oxygen, together with nitrogen in some cases.

- ✓ Other important elements, such as Sulphur, phosphorus, and iron, may also be present.
- ✓ The organic matter present in sewage is unstable and decomposes readily through chemical and bacterial action.
- ✓ In the process of decomposition which is bio-chemic in nature, highly complex organic matter present in sewage is decomposed into materials or constituents of much simpler chemical structure.
- ✓ The organic matter which can be decomposed by bacteria under biological action is called biodegradable organic matter.
- ✓ The decomposition of such organic matter takes place through the agency of different types of bacteria viz., aerobic bacteria, anaerobic bacteria and facultative bacteria.
- ✓ The nitrogenous and carbonaceous materials present in sewage serve as food for these bacteria.
- ✓ The decomposition of organic matter by bacteria under biological action is termed as biological decomposition.

➢ **AEROBIC DECOMPOSITION:**

- ✓ If air or oxygen is available freely to the waste water in dissolved form, then the biodegradable organic matter will undergo aerobic decomposition.
- ✓ Aerobic decomposition is caused by both aerobic bacteria as well as facultative bacteria operating aerobically.
- ✓ These bacteria will then utilize the free oxygen as electron acceptor, thereby oxidizing the organic matter to stable and unobjectionable end products.
- ✓ During this process, organic matter is broken up and oxidized to form stable and non-objectionable end products such as carbon dioxide, nitrates, sulphates are formed.
- ✓ Sewage treatment units which work on aerobic decomposition process alone are aeration tanks, trickling filters, contact beds, oxidation ponds, etc.

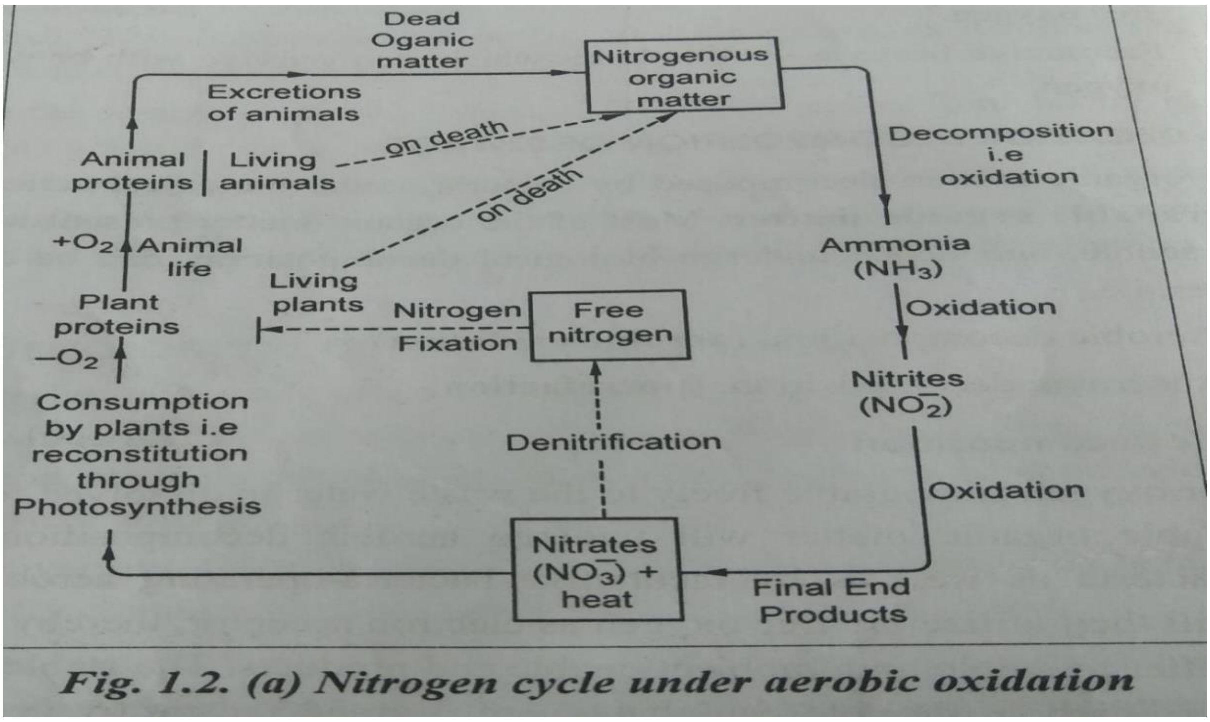


Figure No.2

- It may be noted that during the decomposition of nitrogenous organic matter, the ammonia formed in the initial stages, may linger on till the end depending upon the available oxygen, retention time, temperature, biological activity etc. because the facultative bacteria are incapable or break ammonia to nitrates.
- **STEPS IN THE NITROGEN CYCLE:**
- Nitrogenous organic matter gets oxidized to ammonia, then to nitrites and finally to nitrates, which when consumed by plants through photosynthesis.
- The plant proteins when consumed by animal from animal proteins.
- The wastes produced by animals and their dead bodies will again form nitrogenous organic matter thus completing nitrogen cycle.
- Some short circuits of the cycle as shown by dotted lines that dead plants may also on death lead to formation of organic matter directly without changing into animal proteins.
- Similarly nitrates on denitrification get converted into free nitrogen which may be converted into plant proteins as it may be used by certain bacteria residing in the plant roots.

  This is called Nitrogen Fixation.

SULPHUR CYCLE

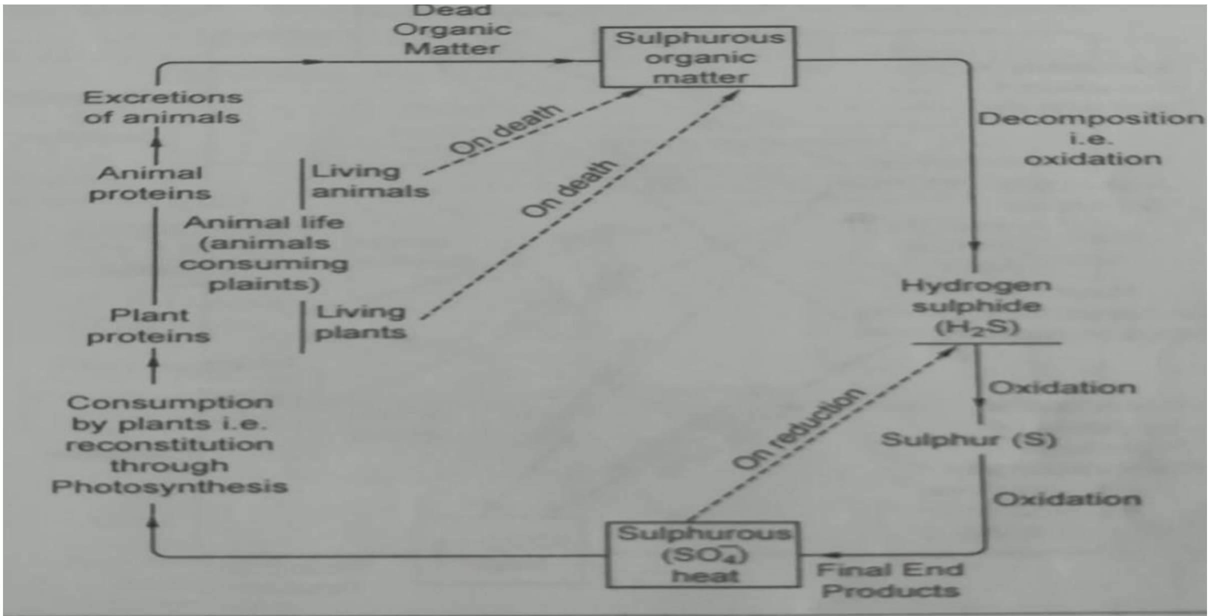


Fig. 1.2. (b) Sulphur cycle under aerobic oxidation

Figure No.3

- ✓ **STEPS IN THE SULPHUR CYCLE:**
- ✓ The sulphurous organic matter on oxidation produces H_2S gas which on further oxidation changes to Sulphur and then finally to sulphates.
- ✓ Sulphates when consumed by plants through photosynthesis change into plant proteins which eaten by animals changes into animal proteins.
- ✓ The wastes produced by animals and their dead bodies will again form sulphurous organic matter thus completing the Sulphur cycle.
- ✓ Some short circuits of the cycle as shown by dotted lines that organic sulphurous matter may be directly formed by the death of plants without formation of animal proteins.
- ✓ Similarly sulphates in the absence of O_2 will be converted into H_2S by the process of reduction.

CARBON CYCLE

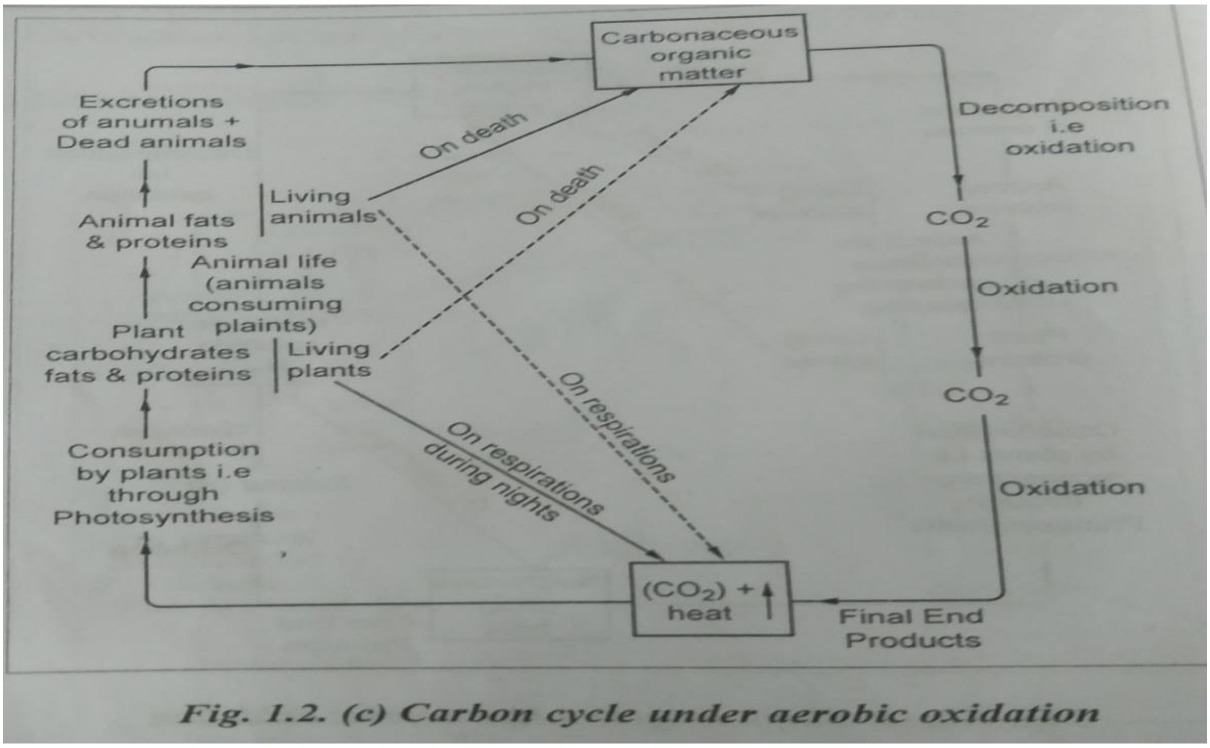


Figure No.4

- **STEPS IN THE CARBON CYCLE:**

- ✓ The carbonaceous organic matter on oxidation releases CO_2 which is its final end product.
- ✓ This CO_2 when used by plants through photosynthesis gets converted into plant carbohydrates, fats and proteins which when eaten by animals, change into animal fats and proteins.
- ✓ The wastes produced by animals and their dead bodies will again form carbonaceous organic matter, thus completing the carbon cycle.
- ✓ Some short circuits in the cycle as shown by the dotted lines that organic carbonaceous matter may be directly formed by the death of plants.
- ✓ Similarly, plant life gives off CO_2 at night, animal life gives off CO_2 during respiration.

NITROGEN, CARBON & SULPHUR CYCLE

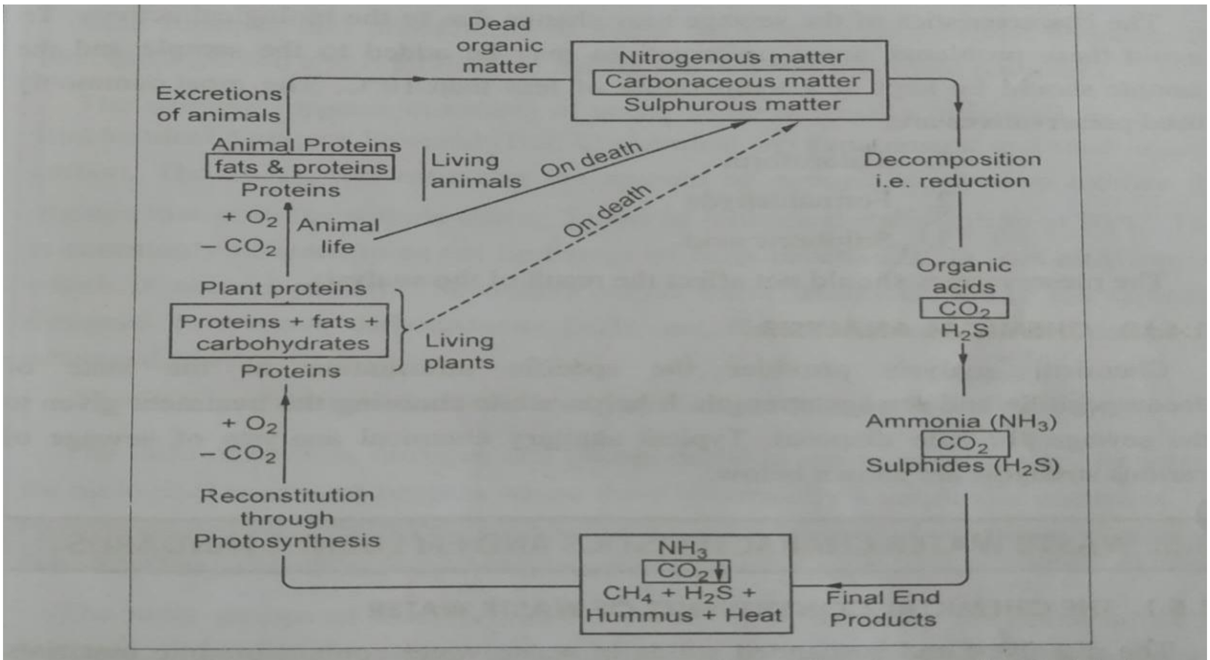


Fig. 1.3. Nitrogen, Carbon and Sulphur cycles under Anaerobic Oxidation

Figure No.5

- **ANAEROBIC DECOMPOSITION:**

✓ If free dissolved oxygen is not available to the sewage, then anaerobic decomposition called putrefaction will occur.

✓ Anaerobic bacteria as well as facultative bacteria operating an aerobically will then flourish and convert the complex organic matter into simplest organic compounds of nitrogen, carbon and sulphur.

✓ These anaerobic bacteria survive by extracting and consuming the bounded molecular oxygen present in compounds like nitrates and sulphates.

✓ Gases like ammonia, nitrogen, hydrogen sulphide, methane etc. are also evolved in this decomposition producing obnoxious odours.

✓ Sewage treatment units which work on putrefaction alone are septic tanks, Imhoff tanks, sludge digestion tanks, etc.

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SCHOOL OF BUILDING AND ENVIRONMENT

DEPARTMENT OF CIVIL ENGINEERING

UNIT – IV – TREATMENT OF SEWAGE – SCI 1306

OBJECTIVES OF WASTEWATER TREATMENT

- The purpose of waste water treatment is to remove contaminant from water so that the treated water can meet the acceptable quality standard.
- The quality standard usually depends whether the water will be reused or discharged into river.
- Before disposing of sewage into river or land, sewage has to be treated to make it safe and to make it harmless.
- Methods of waste water treatment depends on composition of waste water and required quality for treated water.
- Treatment process are broadly classified as physical, chemical and biological treatments.
- Physical treatment methods utilize physical separation of pollutant such as by filtration etc.
- Chemical treatment methods utilize chemical characteristics of pollutant for purification. For e.g. Coagulation etc.
- Biological treatment methods utilize biological characteristics of pollutants such as bacteria, viruses by purification.
- Other purpose of waste water treatment includes:

✓ To reduce strength of sewage

✓ To make waste water less offensive

✓ To prevent public health from toxic effect of pollutant

✓ To conserve nature

LAYOUT OF SEWAGE TREATMENT PLANT

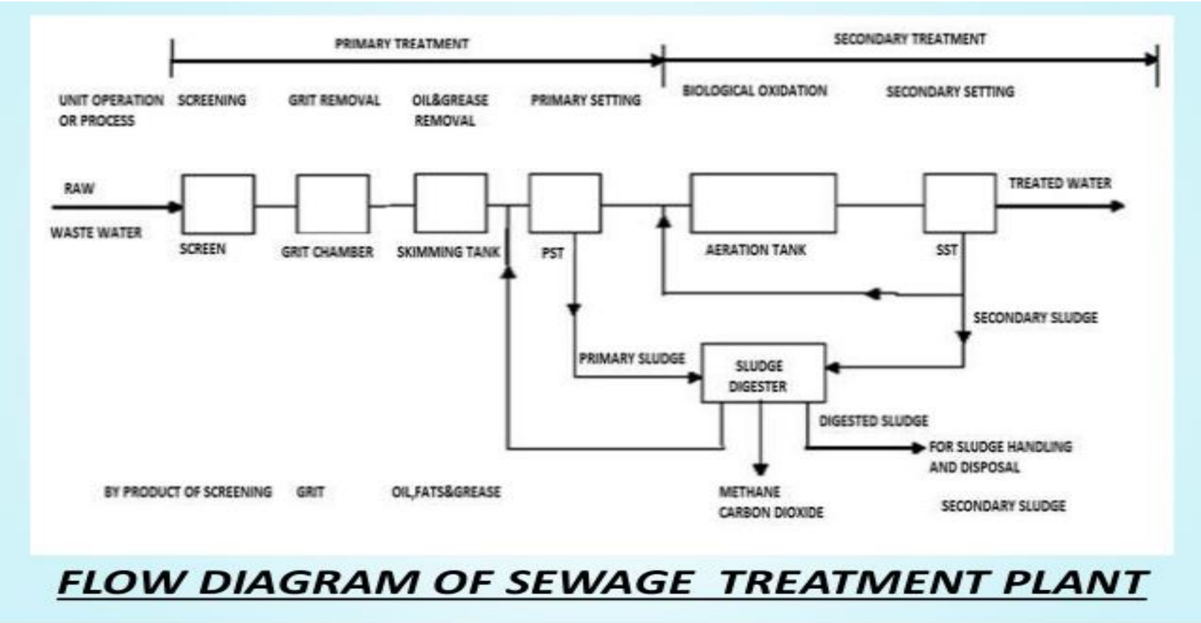


Figure No.1

UNIT OPERATIONS:

- ✓ Unit operations are the treatment methods, in which the applications of physical forces are carried out.
- ✓ Example: Screening, Flocculation, Sedimentation.

UNIT PROCESSES:

- ✓ Unit processes are the treatment methods, in which the chemical or biological activities are involved.
- ✓ Example: Chemical Preparation, Gas Transfer, Adsorption, Disinfection, Combustion etc.

STEPS OF SEWAGE TREATMENT PROCESS:

- ➢ The four processes are:
- ✓ Preliminary Treatment
- ✓ Primary Treatment
- ✓ Secondary or Biological Treatment
- ✓ Tertiary or Advanced or Final Treatment.

PRELIMINARY TREATMENT OF WASTEWATER:

- It is the first stage in treatment process, in which the floating materials such as tree branches, dead animals, papers, pieces of rags, wood etc. are separated from the sewage.
- **FUNCTIONS OF PRIMARY TREATMENT:**

Removes oils and greases.

Reduces the BOD of sewage about 25 %.

Removes larger settleable, in-organic solids etc.

- Some of the treatment technique applied for preliminary treatment purpose are:

✓ Screening

✓ Grit removal

✓ Skimming

- **SCREENING:**

✓ Screening is the first unit operation in waste water treatment plants.

✓ Screens are devices with openings of uniform size and the screening units may consists of parallel bars, rods, gratings or wire mesh or perforated plates.

✓ Screens may be of any shape and generally they are rectangular or circular.

- **PURPOSE:**

✓ Screening is used to remove the floating matters of comparatively larger in size like plastics, clothes, dead animals from waste water.

Figure No.2

- ✓ If the larger materials are not removed, they will clog or damage the valves, appurtenances, small pipes and pumps etc.
- ➢ **LOCATION:**
- ✓ The screens are generally located just prior to the grit chambers.
- ✓ If the quality of grit is not much importance, the screens may be placed after grit chambers.
- ✓ Sometimes the screens may be located along with grit chambers.
- ✓ The screens are generally placed in inclined position with an angle of 45° (varies from 30° to 60°) with horizontal direction of flow.
- ✓ **TYPES OF SCREENS:**
- ✓ Screens are classified,
- ✓ According to the size of openings:
- ✓ Coarse Screen
- ✓ Medium
- ✓ Fine Screen

According to the movement of screens:

- ▪ Fixed Screen
- ▪ Movable Screen
- ▪ Moving Screen
- ➢ **COARSE SCREEN:**
- ✓ The coarse screens are also called as racks are having the space between the bars of 40 mm.
- ✓ The coarse screens reduce the organic load of sewage considerably.
- ✓ Hand cleaned coarse screens are generally set at an angle of 45 inclination to the direction of flow.
- ✓ Mechanically cleaned coarse screens are generally set almost vertically.
- ➢ **MEDIUM SCREEN:**
- ✓ Medium screens are having the opening of 6 mm to 40 mm.
- ✓ It removes organic load of sewage to small extent and it is not much significance in the further treatment.

- **FINE SCREEN:**

- ✓ Fine screens are mechanically cleaned devices using perforated plate of very closely spaced bars with clear openings of less than 6 mm.
- ✓ They are used for pre-treatment of industrial wastes to remove materials which tend to produce excessive scum or foam on the top of the digestion tank contents.
- ✓ Fine screens are generally not suitable for sewage because of clogging of screens.
- ✓ Fine screens are mechanically cleaned and may be of drum or disc type and continuously operated by electric motors.
- ✓ Fine screens are generally made of metal plates.

- **FIXED SCREEN:**

- ✓ Fixed screens are permanently set in position.
- ✓ A perforated platform is provided to receive the material collected from the screen bars.

- **MOVABLE SCREEN:**

- ✓ The movable screens are stationary during their operation.
- ✓ But during cleaning and maintenance, they can be lifted up and removed from their position.

- **MOVING SCREEN:**

- ✓ The moving screens are moving during their operating period and they are automatically cleaned when they are in motion.

- **DISPOSAL OF SCREENINGS:**
- Following four methods are generally adopted for the disposal of screenings:
  - ✓ Burial
  - ✓ Incineration
  - ✓ Disintegration
  - Fertilizer

- **BURIAL:**

- ✓ In this method, screenings are buried in the ground and this is adopted only for small works.
- ✓ Sometimes screenings are buried along with quick lime.
- ✓ The major disadvantage of this method requires very deep excavation in order to get complete decomposition of screenings and to avoid bad odours.

- ✓ A cover of about 300 mm to 500 mm depth of porous earth is to be provided on the top of the screenings.

- ➢ **INCINERATION:**

- ✓ It is defined as the process of burning the screenings at high temperatures, about 760° C to 840° C.
- ✓ The screening, after dewatering are then burnt in coal, gas furnace at high temperatures.
- ✓ This is the most effective method for large works.
- ✓ In this method, screenings are dewatered either by pressing or centrifuging.
- ✓ In pressing method, the screenings are placed in a cylindrical drum and then it is pressed by using a piston of heavy weight under pressure.
- ✓ In centrifuging method, the cylinder is rotated.

- ➢ **DISINTEGRATION:**

- ✓ In this method, the screenings are diluted with water, the dilution factor being kept as about 60 to 100.
- ✓ The diluted screenings are then passing through the disintegrators.
- ✓ The disintegrator breaks the screening into small pieces.
- ✓ These small pieced screenings are then allowed to join the flow of sewage on the upstream of the screen.

- ➢ **FERTILIZER:**

- ✓ The screenings contain good fertilizing value and with some special precautions, screenings may be used as fertilizer.
- ✓ It is not advisable to use the screenings for crops which are consumed or eaten raw.

- ➢ **GRIT BASINS or GRIT CHANNELS:**

- Sewage contains both organic and inorganic materials, and grit is the heavy mineral material found in raw sewage, it may contain sand, gravel, silt, cinders, broken glass, small fragments of metal and other inorganic solids.
- Grits are small, non-biodegradable particles which are heavier than suspended organic matters.
- Grits are removed by carefully regulating the flow velocity of sewage in grit removal tank.
- They reduce the excessive accumulation of grit in such units.

- ✓ Grit chambers are provided to remove grit, sand and other inorganic matter from the sewage.

- ✓ Grit chambers are provided to protect moving mechanical equipment from abrasion.
- ✓ They reduce the formation of heavy deposits in channels, pipelines or conduits.

➢ **LOCATION:**

- ✓ Grit chambers are placed after pumping stations and before the screens.
- ✓ Due to some practical considerations, grit chamber may be placed after screens also.

➢ **SOURCES:**

- ✓ The grit in sewage is obtained from domestic sewage, floors of garages and service stations, first storm of the season etc.
- ✓ Grit may enter the sewage through storm water discharge of road washings and from kitchens.

➢ **TYPES OF GRIT CHAMBERS:**

- ✓ Horizontal Flow Type
- ✓ Vertical Flow Type

➢ **CLEANING DEVICES:**

The grit accumulated at the bottom of the grit chambers can be cleaned periodically by the following three methods.

- ✓ Manual Cleaning
- ✓ Mechanical Cleaning
- ✓ Hydraulic Cleaning

✓ **MANUAL CLEANING:**

- Grit chambers are cleaned by labour.
- The maintenance of good sanitary conditions is also not always possible in this method.
- However, it is always to be provided manual cleaning of grit chambers, when the sewage is very dirty.

✓ **MECHANICAL CLEANING:**

- In this type, mechanical devices such as buckets, scrapers, elevators are used to remove the grit from grit chamber.
- It is possible to maintain the mechanically cleaned grit chamber in good sanitary conditions.

✓ **HYDRAULIC CLEANING:**

- Grit may be removed by making use of hydraulic pressure from the bottom of the grit chamber.

- This method is not suitable for all situations and when other two methods fail; this method is being used.
- This will cause unhealthy conditions.
- **DISPOSAL OF GRIT:**
- Grit is disposed of mostly in the low-lying areas to reclaim such lands. It can also be mixed with poor soil to condition it.

➢ **OIL AND GREASE REMOVAL:**

✓ Grease in sewage includes fats, waxes, free fatty acids, calcium and magnesium soaps, mineral oils and other non-fatty materials.

✓ Oil and grease are obtained from restaurants, kitchens, garages, soap and candle factories, oil refineries and slaughter houses.

✓ The oil and grease create following severe problems and difficulties in sewerage system.

- If sewage with oil and grease is disposed into the stream, the foul odour may be produces at the surface of the stream.
- They reduce the efficiency of other treatment units and clog the trickling filter.
- The digestion of oils and grease is a difficult one for sludge digestion tank.
- They affect the biological action of microorganism.
- They can be removed from sewage either by floatation or as a scum or sludge.
- Formation of scum is promoted by diffusing air through sewage.

➢ **SKIMMING:**

✓ Skimming is the process of removal of fatty and oily material from sewage.

✓ In this method, sewage is placed in skimming tank and it is aerated from bottom so that fats and oils are collected at top of the liquid which are then removed by skimming.

✓ The tank in which scum formation is carried out by diffusion of air through the sewage is called skimming tanks.

➢ **DISPOSAL OF SKIMMIMGS:**

✓ The oil and greasy materials removed by skimming tanks are disposed either by burning or burial.

✓ Sometimes, the disposal of skimmings can be converted into soap lubricants, candle and other non-edible products.

✓ Sometimes, it may be digested in digesters, when the vegetable and organic matters present are more, and when this is more, digest easily and produces high fuel value gases.

PRIMARY TREATMENT OF WASTEWATER

- After removal of floatable solids, grits and fats, next step in treatment is removal of remaining suspended solids as much as possible.
- The main objective of primary treatment is to reduce strength of sewage by removing suspended materials.
- Some common technique applied for primary treatment of sewage are:
- ✓ Sedimentation tanks
- ✓ Imhoff tanks
- ✓ Septic tanks
- ✓ Chemical precipitation tanks
- **SEDIMENTATION:**
- ✓ Sedimentation tank is used for removal of suspended solids and some organic matters.
- ✓ The process of sedimentation reduces the strength of sewage to the extent of about 30 to 35 percent.
- ✓ The quantity of settleable solids in the sewage is reduced to the extent of about 80 to 90 %.
- ✓ About 30 to 35 % of BOD is removed.
- ✓ If the velocity of flow of sewage is reduced, the suspended particles present in the sewage, tend to settle at the bottom of the tank.
- ✓ The material collected at the bottom of the tank is called sludge and the partially treated sewage are called effluent.
- ✓ Sedimentation tanks are also known as settling tanks or wastewater clarifiers.

TYPES OF SEDIMENTATION TANK:

- Classification based on the purpose:
- ✓ Grit Chamber
- ✓ Plain sedimentation
- ✓ Chemical Precipitation tank
- ✓ Septic tank
- ✓ Imhoff tank
- ✓ Secondary settling tank
- Classification based on direction of flow:
- ✓ Horizontal flow settling tank

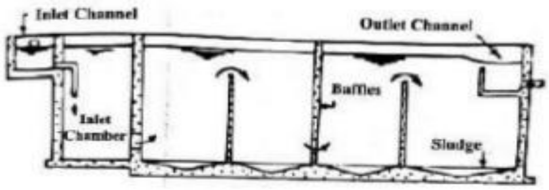
- ✓ Vertical flow settling tank
- ✓ Radial flow settling tank
- ➢ Classification based on nature of working:
- ✓ Fill and Draw type
- ✓ Continuous flow type
- ➢ Classification based on location:
- ✓ Primary sedimentation tank
- ✓ Secondary sedimentation tank

Fill and Draw Type Sedimentation Tank

- Water from inlet is stored for some time.
- The time may be 24 hours. In that time, the suspended particles are settled at the bottom of the tank.
- After 24 hours, the water is discharged through outlet.
- Then settled particle are removed. This removal action requires 6-12 hours.
- Here 1 complete action of sedimentation requires 30-40 hours.

Continuous Flow Type Sedimentation Tank

- water is not allowed to rest.
- Flow has very small velocity.
- During this flow, suspended particles are settle at the bottom of the tank.
- The flow may be either in ***horizontal direction*** or ***vertical direction***.



4 major zones in sedimentation tank

- I. Inlet zone II. Outlet zone III. Settling zone IV. Sludge zone

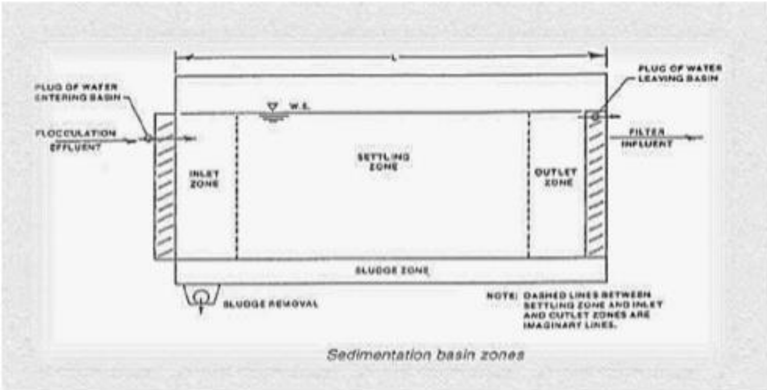


Figure No.3

Horizontal flow type sedimentation tank

- Generally rectangular in shape.
- They have more length twice its width. (Because they need to flow more distance to settle all suspended particles)
- Maximum permissible velocity in this case is 0.3m/sec.

Vertical flow type sedimentation tank

- The vertical flow type sedimentations tanks are generally in circular shape
- Flow takes place in vertical direction.
- Hopper bottom is provided at the bottom of the tank to dispose the collected sludge.

RECTANGULAR SEDIMENTATION TANK

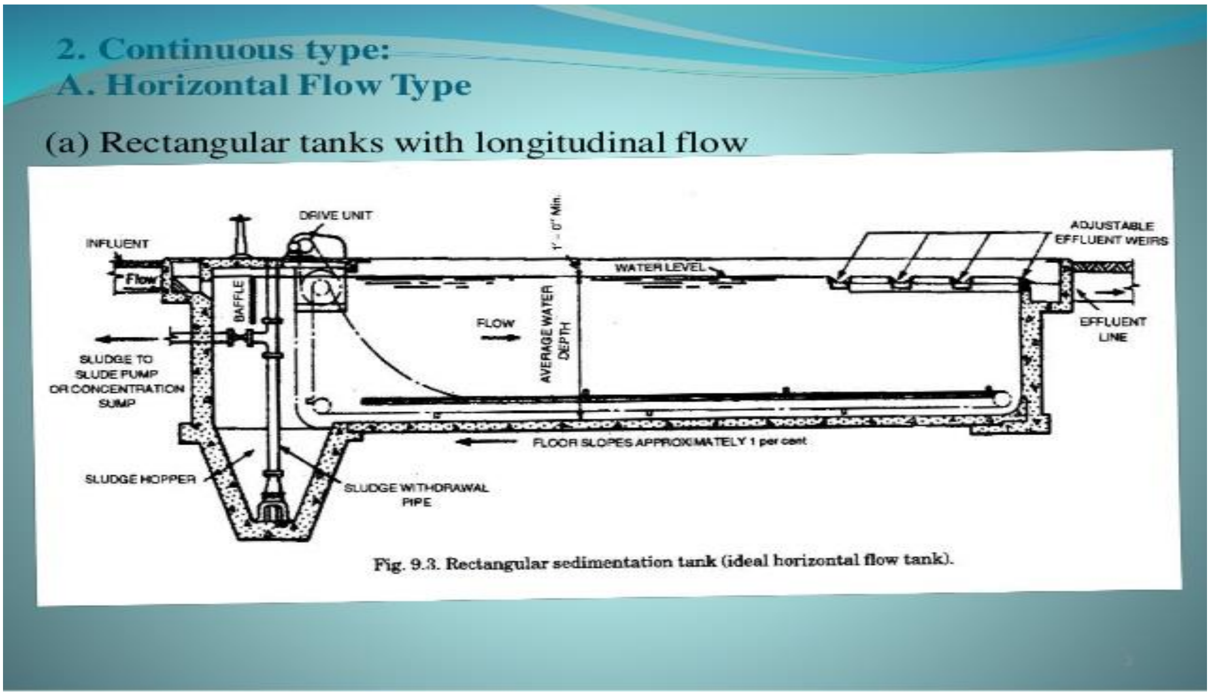


Figure No.4

CONSTRUCTION DETAILS OF RECTANGULAR TANK:

- Inlet and Outlet Arrangements
- Baffles
- Skimming Troughs
- Cleaning and Sludge Removal

INLET AND OUTLET ARRANGEMENTS:

In order to distribute the uniform flow, some special arrangement is to be made for smooth entry of sewage.

The most suitable type of an inlet for a rectangular tank is in the form of a channel extending to full width of the tank with a submerged weir type baffle wall.

The similar type of outlet arrangement is used for the smooth exit of the sewage.

It consists of an outlet, extending for full width of the tank and receiving the waste water after it has passed over a weir.

- **BAFFLES:**

Baffles are required to prevent the movement of organic matter and its escape along with effluent.

Baffles are provided in the form of troughs or boards for the following purposes:

- ✓ To prevent the entry of floating substances into the outlet channel.
- ✓ To distribute the sewage uniformly through the cross section of the tank.
- ✓ **SKIMMING TROUGHS:**

When the amount of oils and greasy matters present in sewage is small, it is uneconomical to provide a separate skimming tank.

In such cases, a skimming trough is provided near its outlet end of sedimentation tank.

In manually operated tanks, skimmings that float on surface may be pushed into trough by squeezes with hand.

In mechanically operated tanks, skimmings may be pushed by a same scraper blades which collect sludge while moving bottom and push the skimmings into trough when they move near the surface along with endless chain to which they are attached.

- **CLEANING AND SLUDGE REMOVAL:**

- ✓ Suspended organic solids settle down at the bottom of tank and is to be removed periodically.
- ✓ It is necessary before it becomes stale and septic.
- ✓ It is necessary because it reduces the capacity of tank and its detention period.
- ✓ Also, it leads to the evolution of foul gases formed due to anaerobic decomposition.
- ✓ Hence cleaning is to done from time to time at frequent intervals, either manually or mechanically.
- ✓ For tanks without mechanical sludge removing equipment additional minimum depth of about 0.8 - 1.2 m should be provided for storage of settled materials and is called sludge zone.

ADVANTAGES OF RECTANGULAR SEDIMENTATION TANK:

Rectangular Sedimentation Tank

- Easy to operate.
- Low maintenance costs.
- Large capacity plants.
- Used in municipal & industrial applications.
- Sometimes baffle walls are provided to prevent short circuiting.

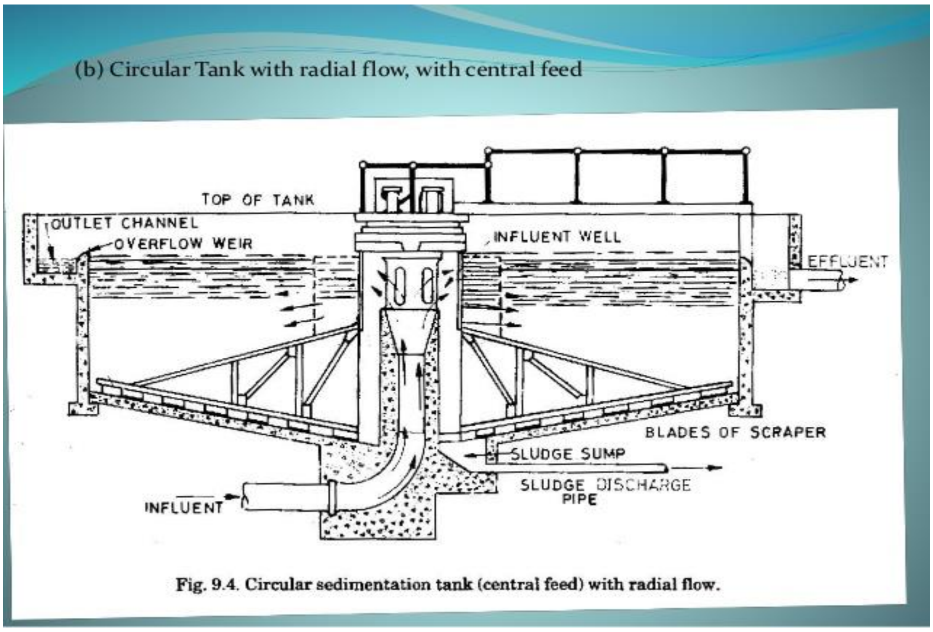


Fig. 9.4. Circular sedimentation tank (central feed) with radial flow.

Figure No.5

2) Circular Tank

- Circular sedimentation tank is costly at the view of construction.
- For dispose the sludge mechanical scraper available at bottom of the tank.
- Over flow rate of this type of tank is 1500 lit/hour/m^2.

I. Radial flow

- The water enters in this tank through the central pipe placed in-side the deflector box.
- Mostly to reduce the velocity of flow there is provide circular baffle box.

- All the impurities settled at the base of tank. The sludge is removed by scraper(known as raking arm).which continuously move around the floor at very small velocity.
- The maximum velocity of raking arm does not exceed 4.5 m/h.

ADVANTAGES & DISADVANTAGES OF CIRCULAR SEDIMENTATION TANK:

Circular Sedimentation Tank

- Easy sludge removal.
- High clarification efficiency.
- Small to medium sized applications.
- For plants with constant flow rates & quality.
- Uneconomical as compared to rectangular tanks.
- high clarification efficiency.

HOPPER BOTTOM SEDIMENTATION TANK:

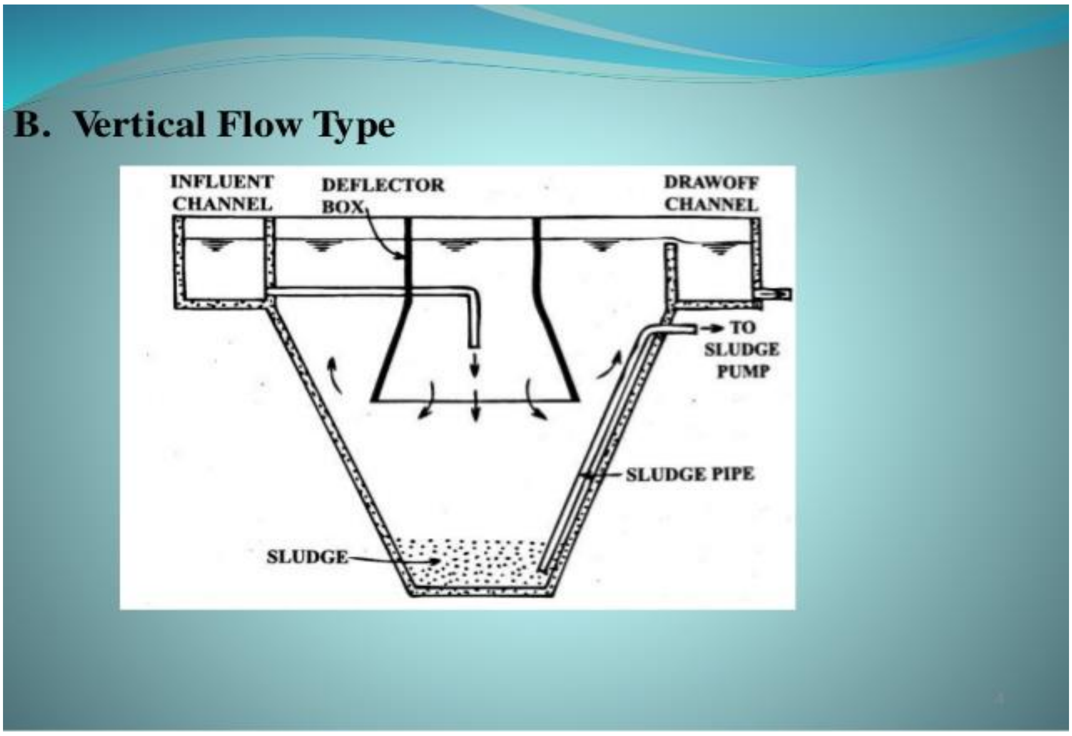
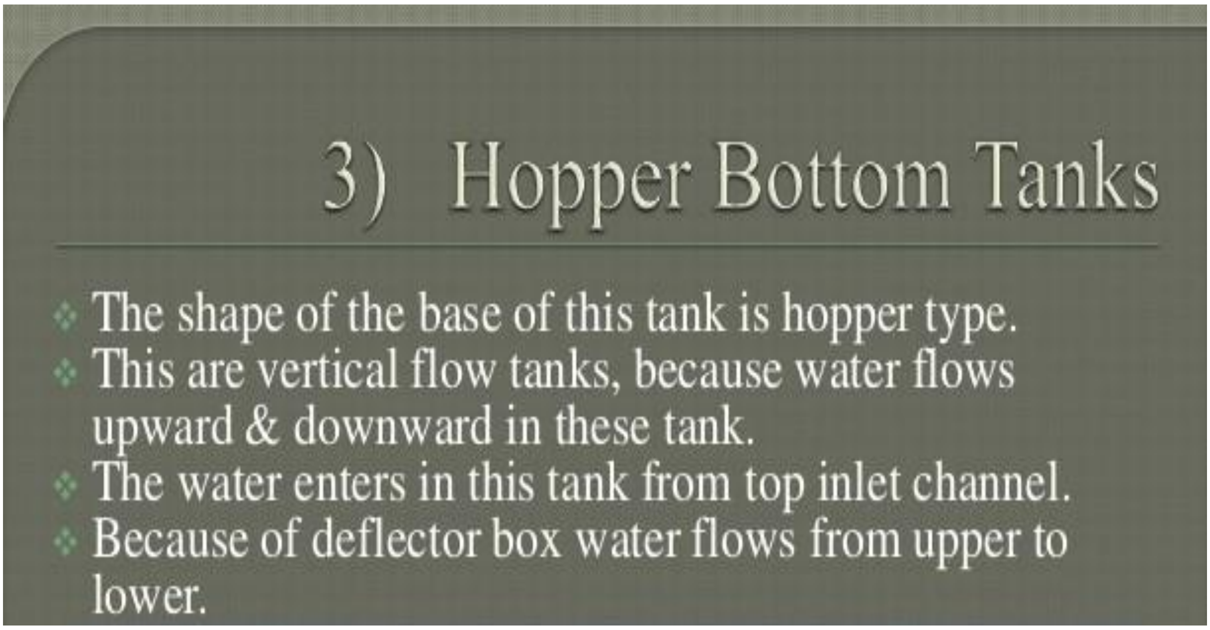
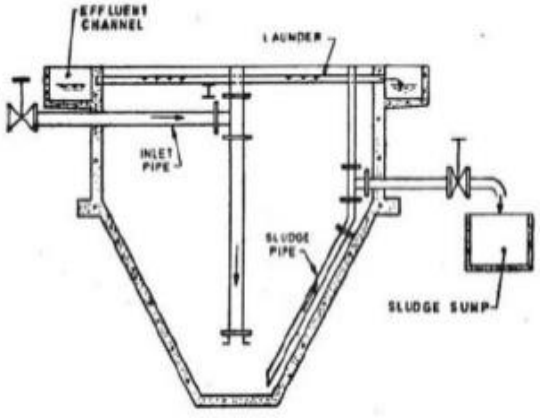


Figure No.6



Hopper Bottom Tank

- A deflector box is located at the top which deflects the influent coming from central pipe downwards.
- Sludge is collected at the bottom
- It is disposed through sludge pump.



DESIGN FACTORS FOR GRIT CHAMBER:

DEPTH: Minimum depth of 0.3 m.

DETENTION PERIOD: 45 to 90 minutes, Generally 60 minutes is adopted for design purpose.

VELOCITY OF FLOW: 0.2 m/sec to 0.32 m/sec, Generally 0.3 m/sec.

NUMBER OF UNITS: At least 2 units should be provided.

PROBLEMS (GRIT CHAMBER):

1. Design a grit chamber for the treatment of dry weather flow of 12 MLD.

Solution:

Dry weather flow = 12 MLD = 12×10^6 l/day

Design flow = $3 \times 12 \times 10^6 = 36 \times 10^6$ l/day

Assume detention period as 1 minute.

$$\text{Volume of flow} = \frac{36 \times 10^6}{24 \times 60 \times 10^3} = 25 \text{ m}^3.$$

Assume the effective depth as 1.5 m,

Surface area = 25 / 1.5 = 16.7 m^2.

Take length to width ratio as L/B = 8/1

Surface area, A = L X B

$16.7 = 8B \times B$

$16.7 = 8 B^2$

$B^2 = 16.7/8$

B = 1.44 m or 1.4 m.

L = 8 X B = 8 X 1.4 = 11.2 m or 11 m.

Provide a free board of 0.3 m,

Overall depth, D = 1.5 + 0.3 = 1.8 m.

Provide 2 Nos. of grit chambers (11 m X 1.4 m X 1.8 m), one to take care of maximum flow and other for dry weather flow.

2. A Grit chamber with a flow at its outlet to be designed to handle a sewage flow from a population of 50,000 and a per capita daily consumption of water of 135 Litres. Design the grit chamber.

Solution:

Average quantity of sewage = 135 X 50000 = 6.75 X 106 l/day.

= 6.75 X 106 / 103 X 24 X 60

= 4.6875 m3/min.

Maximum Flow = 2.5 X 4.6875 = 11.71 m3/min = 11.71/60 = 0.1953 m3/sec.

Keeping the horizontal velocity of sewage inside the grit chamber as 20 cm/sec, detention period as 1 minute and depth of water as 1 m.

Length of grit chamber, L = V X T = 20 X 60 = 1200 cm or 12 m.

Capacity of chamber, C = Q X T = 0.1953 X 60 = 11.72 m^3 or 12 m^3

Area of flow, A = C/L = 12/12 = 1 m^2

Width of chamber, B = A/D = 1/1 = 1 m.

Provide grit chamber of size 12 X 1 X 1.3 m (1 + 0.3)

DESIGN FACTORS FOR SEDIMENTATION TANK:

RATIO OF LENGTH TO WIDTH: The ratio of length to width is about 4 to 5.

DETENTION TIME: Varies from 1 to 3 hours, generally 2 hours.

OVERFLOW RATE: 40 to 50 m^3/m^2/day.

VELOCITY OF FLOW: 0.3 m/sec.

PROBLEMS (SEDIMENTATION TANK)

3. Design a primary settling tank for a town of population 34000. The formation of sewage may be assumed at 150 litres/capita/day.

Solution:

Daily flow of sewage = Rate of sewage flow X Population = 150 X 34000

= 5100000 litres.

Assume a detention period of 2 hours is assumed.

Capacity of the tank = Flow of sewage X Detention time = 5100000/24 X 2

= 425000 litres = 425 m^3.

Assume an effective depth of 2.5 m,

Surface area = 425/2.5 = 170 m^2.

If Length is 4 times the breadth, l = 4 b

l X b = 170

4 b X b = 170

4 b^2 = 170

b = 170/4 = 6.5 m.

l = 4 X 6.5 = 26 m.

Overflow rate = 5100/ (26 X 6.5) = 30.18 m^3/m^2/day

The overflow rate limit should be within 40 to 50 m^3/m^2/day. Hence the above design is neglected and redesigning should be done by assuming a detention period of 1 hour 20 minutes.

Tank Capacity = 5100/24 X 1.33 = 282.625 m^3.

Surface Area = 282.625/2.5 = 113.05 m^2

If Length is 4 times the breadth, l = 4 b

l X b = 113.05

4 b X b = 113.05

4 b^2 = 113.05

b = 113.05/4 = 5.32 m.

l = 4 X 5.32 = 21.28 = 21.3 m.

Overflow rate = 5100/ (21.3 X 5.32) = 45.05 m^3/m^2/day.

Hence the design is o.k.

Provide 4 m for inlet and outlet arrangements.

Total length of the tank = 21.3 + 4 = 25.3 m.

Provide 1 m depth for sludge accumulation and 0.5 m for free board.

Total Depth = 2.5 + 1 + 0.5 = 4 m.

Dimension of the tank is 25.3 m X 5.3 m X 4 m.

Provide one addition unit as stand by unit.

For circular tank, Surface area = 113.05 m^2

π X $d^2/4$ = 113.05

d^2 = 113.05 x 4/ π = 143.93

d = 11.99 m = 12 m.

Diameter of the tank = 12 m.

4. Design a rectangular sedimentation tank for treating 4.5 million litres per day adopting L:B ratio as 2, overflow rate 20 m^3/m^2/day and detention time of 3 hours.

Solution:

Quantity of sewage = 4.5 X 10^6 / 1000 = 4500 m^3/day.

Capacity of the tank = Quantity x Detention Period = (4500/24) X 3 = 562.5 m^3

Surface area of the tank = Capacity of the tank/Surface loading rate

= 562.5/20 = 28.125 m^2.

If Length is 2 times the breadth, l = 2 b

l X b = 28.125

2 b X b = 28.125

2 b^2 = 28.125

b^2 = 28.125/2 , b = 3.75 m = 4 m.

l = 2 X 4 = 8 m.

Depth of the tank = Capacity of the tank/ Area of cross section = 562.5/4 X 8 = 4.4 m.

Dimension of the tank is 8 m X 4 m X 4.4 m.

5. If a circular sedimentation tank of diameter 35 m treats 20 million litres of sewage daily, what is the applicable surface loading rate?

Solution:

Surface loading rate = Quantity / Surface area = $\dfrac{20000}{\pi \text{ X } d^2/4} = \dfrac{20000 \text{ X } 4}{\pi \text{ X } 35^2}$

= 20.7876 m^3/m^2/day.

6. A primary settling tank of diameter 40 m is used for treating sewage 10 million litres daily, what is the applicable weir loading rate?

Solution:

Weir loading rate = Quantity / d = 10000 / 40

$= 250\ m^3/m^2/day.$

7. Design a circular sewage sedimentation tank for a town having population of 40,000. The average water demand is 140 l/cap/day. Assume that 70 % water reach at the treatment unit and maximum demand is 2.7 times the average demand.

Solution:

Average water required = 140 X 40000 = 5.6 X 10^6 l/day = 5.6 x 10^3 m^3/day.

Average quantity of sewage = (70/100) X 5.6 x 10^3 = 3.92 X 10^3 m^3/day.

Maximum quantity of sewage = 2.7 X 3.92 X 10^3 = 10.58 X 10^3 m^3/day.

Q = 10.58 X 10^3 /24 = 440.8 m^3 /hour = 441 m^3 /hour.

Assume detention period of 1 hour.

Capacity of tank, C = Q X T = 441 X 1 = 441 m^3

Provide effective depth of tank = 3 m.

Surface area of the tank, A = 441/3 = 147 m^2

Surface area, $A = \pi \times d^2/4$

$147 = \pi \times d^2/4$

$d^2 = 147 \times 4/\pi = 187.16$

$d = 13.68\ m = 13.7\ m.$

Surface loading rate of the tank = 441 X 24 / 147 = 72 m^3/m^2/day.

As the surface loading rate is more than 50 m^3/m^2/day, depth of the tank is to be reduced and surface area is to be increased.

Adopting the effective depth = 2 m.

Surface area of tank = 441/2 = 220.5 m^2

Surface area, $A = \pi \times d^2/4$

$220.5 = \pi \times d^2/4$

$d^2 = 220.5 \times 4/\pi$

$d = 16.75\ m = 17\ m.$

Surface loading rate of the tank = 441 X 24/220.5 = 48 m^3/m^2/day.

Assume a free board of 0.3 m, Overall depth, D = 2 + 0.3 = 2.3 m.

Provide a circular sedimentation tank of 17 m diameter and 2.3 m Overall depth.

8. Design a suitable rectangular sedimentation tank for treating the sewage from a city provided with public water supply system with a maximum daily demand of 12 MLD. Assume suitable value of detention period and velocity of flow in the tank.

Solution:

Assuming that 80 % of water supplied to city becomes sewage.

Quantity of sewage to be treated/day = (80/100) X (12 X $10^6/10^3$)

= 9600 m^3

Now assuming the detention period in the sedimentation tank as 2 hours,

Capacity of the tank, C = Q X T = (9600/24) x 2 = 800 m^3

Assume that the velocity of flow is 0.3 m/min.

Length of the tank required, L = Velocity of flow x Detention Period

= 0.3 X 2 X 60 = 36 m.

Cross section area of the tank required, A = Capacity/ Length

A = 800/36 = 22.2 m^2

Assume effective depth of tank as 3 m.

Width of the tank required, B = 22.2/3 = 7.4 m.

Since the tank is provided with mechanical cleaning arrangements, no extra space at bottom is required fore sludge zone.

Assume a free board of 0.5 m,

Overall depth of the tank, D = 3 + 0.5 = 3.5 m.

Hence a rectangular sedimentation tank with an overall size of

36 m X 7.4 m X 3.5 m.

9. Design a circular sedimentation tank unit for a primary treatment of sewage at 12 MLD. Assume suitable detention period and surface loading rate.

Solution:

Quantity of sewage = 12 X 10^6 l/day.

Assume detention period as 2 hour and surface loading rate as 40000 l/m^2/day.

Capacity of the tank, C = (12 X $10^6/10^3$ X 24) X 2 = 1000 m^3

Now, Surface loading = Q/Surface area

$$40000 = Q/(\pi \times d^2/4)$$

$d^2 = 4 \times 12 \times 10^6/(\pi \times 40000)$

$d = 19.6$ m.

Now, effective depth of the tank = capacity / C.S.Area

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

$= 3.3$ m.

Assume a free board of 0.3 m,

Overall Depth, D = 3.3 + 0.3 = 3.6 m.

Hence use a settling tank with 19.6 m diameter and 3.6 m Overall depth.

10. Design a primary settling tank of rectangular shape for a town having a population of 50000 with a water supply of 180 l/cap/day.

Solution:

Quantity of water supply = 50000 X 180 = 9×10^6 l/day.

Assuming that 80 % of water supplied to city becomes sewage.

Total sewage flow, Q = (80/100) X 9 X 10^6 = 7.2×10^6 l/day.

Assume a detention period of 2 hours.

Capacity of tank, C = $(7.2 \times 10^6/24) \times 2 = 600 \times 10^3$ l = 600 m^3

Assume an surface loading rate of 30 m^3/m^2/day.

Surface area, A = Sewage flow/Surface loading rate = $7.2 \times 10^3 / 30 = 240\ m^2$

Effective Depth, d = Capacity/Surface area = 600/240 = 2.5 m

Take length is 4 times the width, L = 4B.

A = L X B

240 = 4B X B = 4B

B = 7.74 m.

L = 4 X 7.74 = 30. m = 31 m.

Provide 4 m length for inlet and outlet arrangements.

Total Length = 31 + 4 = 35 m.

Also provide 1 m depth for sludge accumulation and 0.5 m free board.

Hence Overall Depth, D = 2.5 + 1 + 0.5 = 4 m.

Hence provide a rectangular sedimentation tank size of 35 m X 7.7 m X 4 m.

SEDIMENTATION WITH COAGULATION:

- Very fine suspended particles of wastewater cannot be removed by plain or primary sedimentation tank and they can be settled by increasing their size by changing them into flocculated particles.
- Sedimentation with coagulation is defined as the process of removing the very fine suspended particles present in the waste water that cannot be removed by primary sedimentation by increasing their size by using chemicals.
- The chemicals used for increasing the size of the particles are called coagulants.
- The various chemicals or coagulants are:
- ✓ Alum
- ✓ Ferric Chloride
- ✓ Ferric Sulphate
- ✓ Chlorinated Copperas.
- The coagulants mixed with water forms a gelatinous precipitate called floc, which attracts the fine mud particles and other colloidal matters form a bigger sized flocculated particles.
- The process of adding the chemicals is called coagulation and the formation of bigger sized flocculate particles is called flocculation.

SEPTIC TANK:

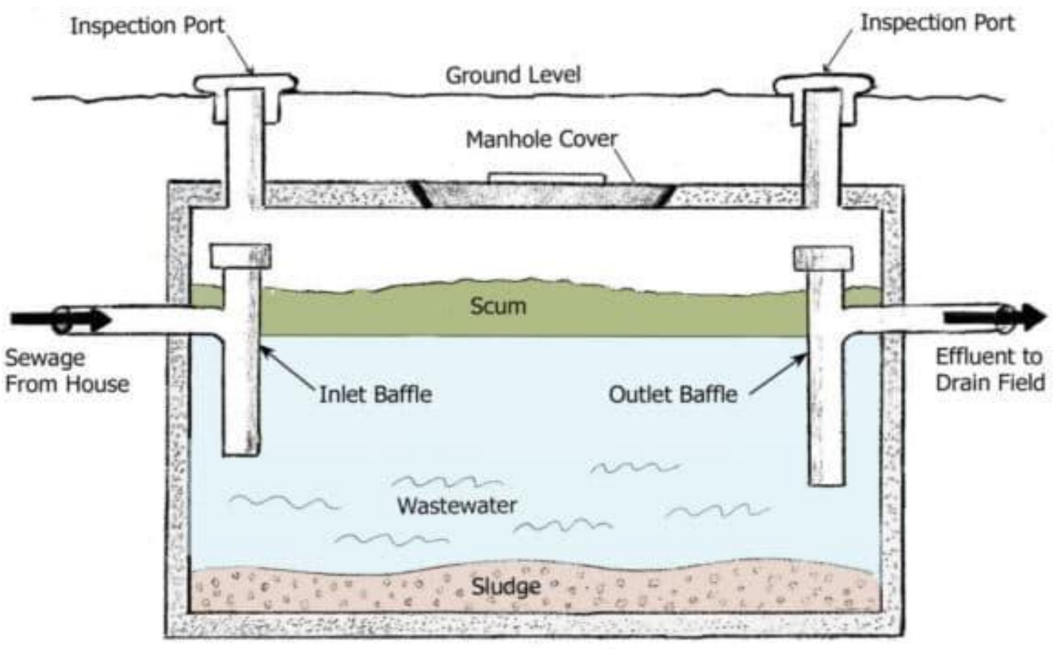


Figure No.7

- A septic tank is defined as a primary sedimentation tank with a longer detention period 12 to 36 hours with an additional provisions for digestion of the settled sludge.
- Due to anaerobic decomposition of the settled sludge, foul gases will be evolved in the tank and the septic tank will be completely covered and provided with a high air vent pipe for escape of gases.
- Septic tanks are provided in places, where sewer pipes have not been laid and especially septic tanks are provided for isolated communities, schools, hospitals, hotels and other isolated public institutions etc.

CONSTRUCTION DETAILS:

- A septic tank is a horizontal continuous flow sedimentation tank, in which the raw sewage is directly entering to the tank.
- The tank removes 60 to 70 % of the dissolved matter.
- The effluent from the septic tank is foul in nature and it should be disposed of either in soak pits or to be treated in trickling filters before it disposing of into water courses.
- The septic tank is rectangular in shape and constructed by brick masonry.
- The tank is designed to prevent the direct currents between the tank inlet and outlet.
- The standing baffle wall at the outlet of the tank is provided to work as a skimming to retain the scum in the tank.
- In order to prevent the odour, due to the bacteriological action, the tank is covered at top with RCC which prevents the escape of foul gases, prevents the accidents due to falling of animals and children and prevents wind agitation.
- An air vent pipe is provided at suitable place of the tank at a suitable height for the escape of air and foul gases for the prevention of odour.
- R.C.C manhole covers are provided at the top of the tank, for inspection, repairs and maintenance.
- The deposited and digested sludge is removed from these manhole at an interval of 6 to 12 months with the help of a portable pump.
- **ADVANTAGES:**

✓ Construction is very easy.

✓ Very reasonable cost for construction.

✓ Very little attention and skilled attendance is required.

✓ There are no moving parts for its operation.

- ✓ Sludge is relatively small, most of its being liquified and digested.
- ✓ The removal of BOD is 90 % and suspended solids removal is 80 %, considerably septic tank is having high performance.
- ✓ The sludge, effluent and scum obtained from the septic tank can be disposed off easily without causing serious nuisance.

➢ **DISADVANTAGES:**

- ✓ If the tank is not properly functioning, the effluent will be dark and foul smelling.
- ✓ The leakage of gases through the top of the septic tank leads to air pollution.
- ✓ The working of septic tank is unpredictable and non-uniform.
- ✓ The removal of sludge is a very tedious job.
- ✓ **DESIGN FACTORS FOR SEPTIC TANK:**

Detention Period: It varies between 12 to 36 Hours, Commonly adopted as 24 Hours.

Length to Width Ratio: For Rectangular tank, length is 2 to 4 times the width.

Depth: Range between 1.2 to 1.8 m.

Space for Digestion: 0.0425 m^3/cap.

Sedimentation: For Indian Conditions, surface area will be 0.92 m^2 for every 10 lpm peak flow rate.

Cleaning Period for Sludge: 6 months to 3 Years, generally taken as 12 Months.

Free Board: 0.3 to 0.6 m.

12. Design a septic tank for a small residential colony having a population of 500 persons. The rate of water supply is 150 litres per head per day. Design also the soak well, if the effluent from the septic tank is to be discharged in it?

Solution:

Quantity of water supply = Per capita demand X Population

= 500 X 150

= 75000 litres/day.

Assuming that the 80 % of water supply appears as sewage.

Quantity of sewage produced = 75000 X (80/100)

= 60000 l/day.

Assume the detention period of 24 hours.

Capacity of the tank, C = 60000 X 24/24 = 60000 litres.

Assuming the rate of deposited sludge as 30 litres/capita/year and assuming the period of cleaning is one year.

Volume of sludge accumulated = Rate of sludge deposition X Population X period of Cleaning

= 30 X 500 x 1 = 15000 litres.

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

= 60000 + 15000

= 75000 litres = 75 m^3.

Assuming a depth of 1.5 m.

Surface area of the tank = Capacity/depth = 75/1.5 = 50 m^2.

Take ratio of length to width is taken as 1:2 to 1:4.

Assuming L:B = 1:3 or L = 3B

Surface area, A = L X B

A = L X B

50 = 3B X B

50 = $3B^2$

B^2 = 50/3 = 16.66

B = 4.083 m = 4.1 m.

Length of the tank, L = 3 X 4.1 = 12.25 m = 12.3 m.

Assume a free board as 0.3 m, Overall Depth, D = 1.5 + 0.3 = 1.8 m.

Dimension of the tank is 12.3 m X 4.1 m X 1.8 m.

Design of Soak pit:

Assuming the percolating capacity of filter media of soak pit as 1250 litres/m^3/day or 1.25 m^3/m^3/day required for soak pit.

Volume required for soak pit = Volume of the tank/Percolating capacity of filter media

= 75 / 1.25 = 60 m^3

If the depth of the soak pit is 4 m, area of the soak pit will be,

Area of the soak pit = Volume of the soak pit/ Depth of soak pit

= 60/4 = 15 m^2

π X $d^2/4$ = 15

$d^2 = 15 \times 4 / \pi$

$d = 4.37$ m or 4.4 m.

13. Design a septic tank for 50 users, assuming the rate of water supply as 60 l/cap/day.

Solution:

Assuming the detention period as 24 hours and the time of cleaning the sludge as 3 years.

Space required for Settling = 50 X 60/10^3 = 3 m^3.

Space required for Digestion = 50 X 0.0425 = 2.125 m^3.

Space required for Storage of sludge = 50 X 0.085 = 4.25 m^3.

Total space required = 3 + 2.125 + 4.25 = 9.375 m^3.

Providing depth as 1.4 m,

Surface area, A = Total Space / Depth = 9.375/1.4 = 6.69 = 6.7 m^2.

Assume L:B = 1:2, L = 2B

Surface area A = L X B = 2B X B

$6.7 = 2B^2$

$B^2 = 6.7/2$

B = 1.83 m = 1.8 m.

L = 2 X B = 2 X 1.8 = 3.6 m.

Providing a free board as 30 cm,

Overall Depth, D = 1.4 + 0.3 = 1.7 m.

Hence provide the septic tank of size 3.6 m X 1.8 m X 1.7 m.

14.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 l/person/day. Assume any data you may need.

Solution:

Quantity of water supplied = per capita rate X population = 120 X 150

= 18000 l/day.

Assuming that 80 % of water supplied becomes sewage.

Quantity of sewage produced = (80/100) X 18000 = 14400 l/day.

Assume the detention time as 24 hours.

Capacity of the tank, C = 14400 X 24/24 = 14400 litres.

Now, assuming the rate of deposited sludge as 30 l/capita/year and period of cleaning as 1 year.

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

Total capacity of tank = 14400 + 4500 = 18900 litres or 18.9 m^3.

Assuming the depth of the tank as 1.5 m.

Surface area of the tank = 18.9/1.5 = 12.6 m^2.

Assume L:B = 1:3 or L = 3B

Surface area, A = L X B

12.6 = 3B X B

12.6 = $3B^2$

B^2 = 12.6/3

B = 2.05 m = 2.1 m.

L = 3 X 2.1 = 6.3 m = 6 m.

Assume a free board of 0.3 m,

Overall depth, D = 1.5 + 0.3 = 1.8 m.

Hence provide the septic tank of size 6 m X 2.1 m X 1.8 m.

15. Design a septic tank for a hostel housing 125 persons.

Solution:

DESIGN OF SEPTIC TANK:

The estimated peak discharge for 125 persons is equal to 300 lpm.

Let us assume sludge withdrawal once in a year.

Surface area of tank @ 0.92 m^2 for every 10 lpm is = (0.92/10) X 300 = 27.6 m^2.

Assume depth for sedimentation is 0.3 m. Also provide a free board of 0.3 m.

Space for sedimentation = 27.6 X 0.3 = 8.28 m^3

Space for digestion = 0.032 X 125 = 4 m^3

Space for sludge storage = 0.049 X 125 = 6.125 m^3

Space for free board = 27.6 X 0.3 = 8.28 m^3

Total space required = 26.685 m^3

Total depth of the tank = Total Space/ Surface area

= 26.685/27.6 = 0.96 m or 1 m.

Assume L:B = 1:2.5 or L = 2.5 B

Surface area, A = L X B

27.6 = 2.5 B X B

$27.6 = 2.5B^2$

$B^2 = 27.6/2.5$

B = 3.32 m = 3.3 m.

L = 2.5 X 3.3 = 8.3 m.

Hence dimensions of the septic tank are 8.3 m X 3.3 m.

IMHOFF TANK:

- These tanks are the improvements over the septic tanks.
- Karl Imhoff of Germany invented this tank.
- The Imhoff tank, is a two-storey septic tank, composed of an upper sedimentation compartment, and a bottom sludge digestion compartment.
- The Imhoff tank is a primary treatment technology for raw wastewater, designed for solid-liquid separation and digestion of the settled sludge.

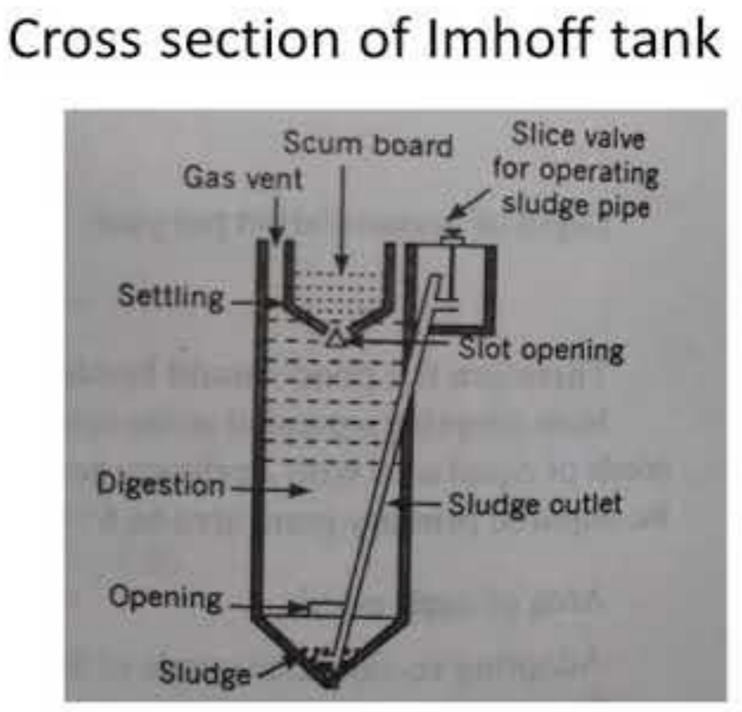


Figure No.8

- **CONSTRUCTION DETAILS:**

- ✓ Design of upper flow tank is done on the basis of plain sedimentation tank with 1.5 to 2.5 hours detention period.
- ✓ Depth of upper flow chamber is kept about 2.5 m.
- ✓ The minimum total depth of tank is kept 5 m.
- ✓ Design of sludge storage capacity is done on the basis of 0.02 m^3/cap.
- ✓ Surface overflow rate is kept less than 30000 l/m^2/day.
- ✓ Gas vent area is provided between 20 to 25 % of the total plan area.
- ✓ Minimum slope of 30° is provided to the hopper bottom for easy removal of sludge through sludge outlet.
- ✓ The vertical distance between upper sludge level and slot is known as neutral zone is kept more than 45 cm.
- ✓ Slope of side walls of the lower portion should have steep slope more than 55° to the horizontal to prevent adhesion of solids to them.

- **WORKING:**

- ✓ First the sewage enters the upper sedimentation tank whose bottom has sharp inclinations.
- ✓ The solids are allowed to settle in the upper tank from where they slip in lower hoppers through the slots.
- ✓ In hoppers, the settled solids remain stored for a long period about 30 – 45 days.
- ✓ During this period, they are acted upon by the bacterias and are converted into stable solids, organic acids and gases.
- ✓ The gases are allowed to escape in the atmosphere through gas vent pipe.
- ✓ The stabilized solids are taken out by means of a sludge pipe under hydrostatic pressure.
- ✓ The flow of solids in the lower hoppers is regulated by means of a triangular beam and in that hopper digestion starts.
- ✓ Effluent from Imhoff tank is similar to primary settling tank.
- ✓ The organic matters are digested in the lower compartments.
- ✓ The digested sludge has black colour and has no odour.
- ✓ Moisture content of this sludge is 90 – 95 %, therefore it can easily flow in the pipes.
- ✓ This moisture can be removed by passing it through sand beds and sun drying.

- **ADVANTAGES:**

- ✓ Quite economical in operation.
- ✓ Do not require skilled attention during operation.
- ✓ There are no moving parts.
- ✓ Require only preliminary treatment.
- ✓ No difficulty in sludge removal.
- ✓ Less sludge volume and weight.
- ✓ Results are good with the removal of 60 – 70 % of solids and 30 – 40 % of BOD.

- **DISADVANTAGES:**

- ✓ Because of greater depth, construction cost is high.
- ✓ Unsuitable for acidic influents.
- ✓ Give offensive odours when improperly operated.
- ✓ Very high (or deep) infrastructure, depth may be a problem in case of high groundwater table.
- ✓ Requires expert design and construction.
- ✓ Low reduction of pathogens.
- ✓ Effluent, sludge and scum require further treatment.

PROBLEMS (IMHOFF TANK)

1. Design an Imhoff tank to treat the sewage from a town with 40000 population. The suspended solid in the influent sewage are 150 ppm. The water content of sludge is 5 %. If the rate of sewage flow is 135 l/cap/day. Design the tank with two months storage.

Solution:

Quantity of sewage flow = 135 X 40000 = 54 X 10^5 l/day or 225000 l/hr.

Assume the detention period as 2 hours.

Design of upper flow channel:

Capacity of the channel = 225000 X 2 = 45 X 10^4 l or 450 m^3

Provide 2 channels 4 m wide, 33 m long with 1 m vertical depth and 1.5 m inclined depth.

Overall depth = 1 + 1.5 = 2.5 m.

Total volume of both the channels = 2 [4 x 33 x 1 + 4 X 33 X 1.5/2]

= 462 m^3 > 450 m^3

Surface loading = Quantity/Surface area = 225000 X 24 /(2 X 4 X 33)

= 20455 $l/m^2/day$ < 30000 $l/m^2/day$.

Hence Safe.

2. Design an Imhoff tank for a town having population of 17000 persons. The rate of sewage is 150 l/day. Assume suitably any other data need.

Solution:

Total flow of sewage = 17000 X 150 = 255 X 10^4 l/day.

Assume detention period as 2 hours.

DESIGN OF UPPER FLOW CHANNEL:

Capacity of flow channel = 255 X 10^4 X 2 /(24 X 1000) = 212.5 m^3

Provide 2 channels of 2 m X 32 m having 1 m vertical depth and 1.5 m sloping depth.

Volume of the channels = 2 X [2 X 32 X 1 + 2 X 32 X 1.5/2]

= 224 m^3 > 212.5 m^3

Hence Safe.

DESIGN OF DIGESTION TANK:

Assuming 0.05 m^3/cap space required.

Total Capacity = 0.05 X 17000 = 850 m^3

Provide 5 m width, vertical depth 4 m and inclined depth 3 m.

Volume of the tank = 5 X 32 X 4 + 5 X 32 X 3/2 = 880 m^3 > 850 m^3

Hence Safe.

SECONDARY TREATMENT OF WASTE WATER

- The effluent from the primary sedimentation tank consists of 45 to 60 % of unstable organic matters, originally present in the sewage.
- The larger and medium sized solids have been removed by settling in sedimentation tanks and the organic matter present in the sewage as colloidal matter is carried away by effluent from the settling tanks.
- The further treatment of sewage is called secondary treatment or biological treatment and in which the conversion of organic matter into stable forms by oxidation or nitrification.
- The secondary treatment of sewage involves various methods and are classified into two important processes.

✓ Filtration process

- ✓ Activated-sludge process.
- ➢ All the secondary treatment processes are designed to work on aerobic bacterial decomposition.
- ➢ In secondary treatment, dissolved or colloidal organic matters are present in sewage are removed by utilizing microorganisms.
- ➢ In this steps, microorganisms utilizes organic matter and converts them into inorganic minerals.
- ➢ Following changes occurs in sewage during secondary treatment:
  - ➢ Organic matter (carbon) is oxidized into CO_2 and H_2O
  - ➢ Organic nitrogen compounds are first converted into NH3 and then into NO3
  - ➢ Colloidal matters are coagulated or precipitated out.
- ➢ Thus main purpose of secondary treatment of sewage is to reduce BOD level.
- ➢ **FILTRATION PROCESS:**
- ✓ In secondary treatment, the filter units consists of open beds of coarse aggregate overwhich the sewage is spreaded or sprinkled intermittently.
- ✓ The necessary contact surface for the growth of aerobic bacteria is provided by the aggregates in the bed.
- ✓ By doing this, the aeration is provided by nature.
- ➢ **DIFFERENT TYPES OF FILTERS:**
- ✓ Contact Beds
- ✓ Intermittent Sand Filters
- ✓ Trickling Filters

CONTACT BEDS

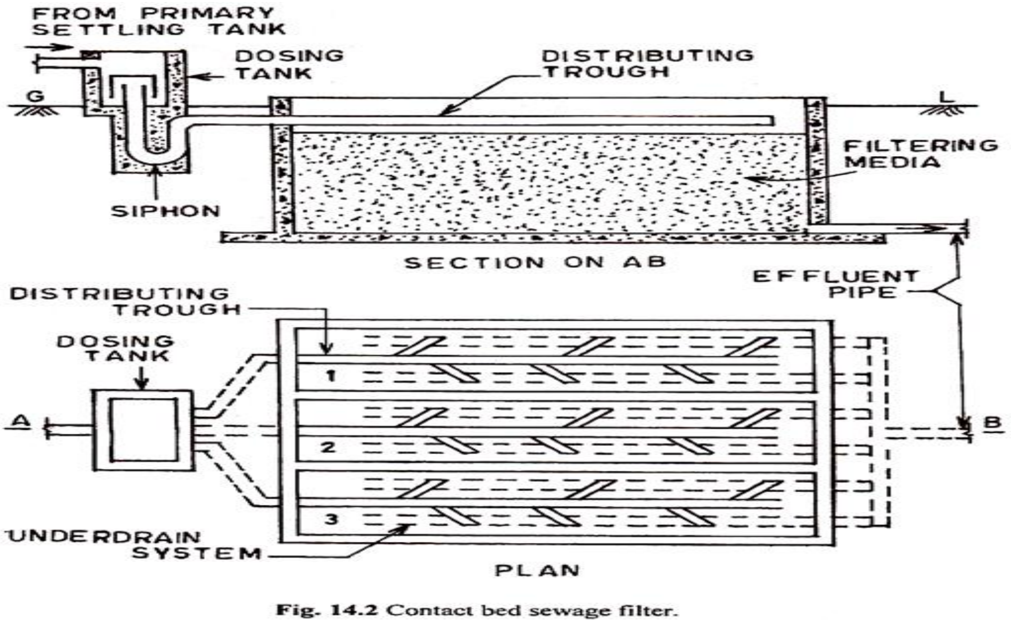


Figure No.9

- In ancient time contact beds were very popular in the treatment of sewage, but now a days these are similar in construction to the intermittent sand filters, the only difference being in the filtering media.
- The filtering media consists of 2 to 2.5 cm size broken stone ballast or brick ballast.
- The depth of the filtering media is between 90-150 cm.
- The sewage is uniformly applied over the whole surface of the filtering media, by means of distribution troughs and is collected at the bottom by means of a system of under drain pipes.

OPERATION OF THE CONTACT BEDS:

- **FILLING:**

✓ In this operation the sewage is applied on the surface of contact beds as quickly as possible by means of dosing siphon.

✓ The sewage is allowed to be filled 5-10 cm above the top surface of filter media. The filling process may take 1 to 1.5 hours.

- **CONTACT:**

✓ In this operation, the dosing is stopped and the applied sewage is allowed to come in contact for about 2 hours.

✓ During this period, the colloidal matters and dissolved matters get transferred to the filter media and comes in contact with the bacterial film covering the filter media..

✓ Within this time the soluble contents of sewage are absorbed by the organic film and are stabilized.

- **EMPTYING:**
- ✓ The contact beds are then slowly emptied and drained.
- ✓ This operation is carried out for 1 to 2 hours.
- ✓ So that the absorbed soluble contents of the sewage are not washed out with the sewage, which is being drained.
- **RESTING:**
- ✓ After emptying, the contact beds are allowed to remain at rest for 5-6 hours and this period is called second contact period.
- ✓ Within this period the atmospheric air enters in the voids of the contact media and makes it ready for taking another sewage load.
- ✓ By supplying oxygen to the aerobic bacteria, which oxidize the organic matter present in the sewage which is transferred by sewage on the surface of the filtering media.
- ✓ The complete cycle of operation takes 8-12 hours.
- ✓ The stabilized organic matter from the voids is finally taken in the next cycle of operation.
- ✓ As these contact beds are intermittent in action, therefore more numbers of units are constructed in parallel and the sewage is applied in turn to each unit.
- ✓ For this purpose continuous supervision is required.
- ✓ The effluent obtained from these beds is also clear and odourless.
- ✓ These beds remove 80 to 90% suspended solids and 60 to 75% B.O.D.
- ✓ The rate of loading is very low 4500 to 6500 m^3/hectare/day.
- ✓ The voids inside the filtering media continuously go on reducing due to accumulation of the solids in them.
- ✓ After 4-5 years the filtering media is taken out, washed, dried and filled again.
- ✓ Similarly the under drain pipes are also washed and cleaned after 3-4 years.
- ✓ These are also not common these days.
- ✓ Generally, the contact beds are also intermittent in their operation.
- **EFFICIENCY:**
- ✓ Bacterial Removal – 50 to 75 %.
- ✓ Organic matter Removal – 60 to 80 %.
- ✓ Suspended matter Removal – 80 to 90 %.

➢ **ADVANTAGES:**

✓ Contact bed can be operated without exposing the sewage to view.

✓ Contact bed consumes relatively small amount of head.

✓ No nuisance of filter flies.

✓ Odour problems are also very less.

➢ **DISADVANTAGES:**

✓ For effective working of contact bed, primary treatment of sewage is necessary otherwise the contact bed will be easily clogged.

✓ The cost of the contact bed is relatively more.

✓ The operation of contact bed requires skilled supervision.

✓ The rate of treatment of sewage is very low.

✓ It requires long rest period.(about 8 hours)

➢ **USES:**

✓ The contact beds are the best treatment method for small isolated structures, where the quantity of sewage is very less and head availability is also less and further pumping is not required.

INTERMITTENT SAND FILTERS:

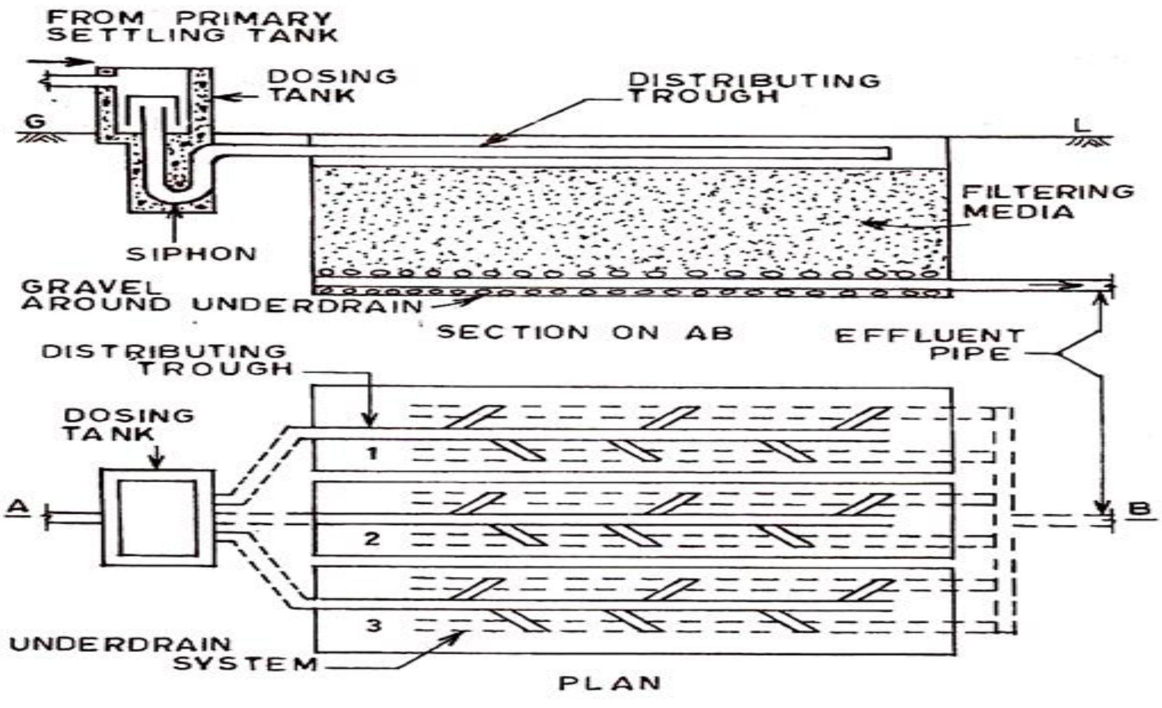


Fig. 14.1 Intermittent sand filters.

Figure No.10

- These are the early development of sewage treatment units.
- These are similar in Construction to the slow-sand filter of water treatment.
- These require larger area, due to which these are not commonly employed in modern sewage treatment works.
- The filter media is finer than that in the contact beds.
- There is no concrete lining around the filter media, as was there in contact beds.
- **CONSTRUCTION:**

- ✓ It consists of layers of sands with an effective size of 0.2 to 0.5 mm and of uniformity coefficient 2 to 5.
- ✓ The depth of the sand media is about 75 cm to 100 cm.
- ✓ The bottom of the tank is sloping gently towards the under drains.
- ✓ The under drains are placed at about 9 m apart in trenches below the bottom of the filter media.
- ✓ If the soil itself is sandy, there is no need of providing extra sand.
- ✓ But if the soil is of other variety, sands of the above specifications are laid in a depth of about 100-120 cm.
- ✓ To carry off the effluent the open joint drainage pipes are laid in the bottom of the sand bed in 90 to 120 cm depth.
- ✓ Their drainage pipes are surrounded with layers of coarse stone and gravel graded from coarse to fine, to keep and the sand out.
- ✓ In some cases when the soil itself-sandy, the percolating effluent may reach the ground water table, and no effluent may reach the drainage pipes.
- ✓ The sewage is applied evenly on the surface of the sand bed by influent waste water troughs.
- ✓ The distribution trough has side openings to distribute the sewage uniformly.
- ✓ To prevent the scouring and displacement of sand the distribution trough is kept on concrete apron or protective stone.
- ✓ The effluent from the intermittent sand filters is very clear and contains suspended solids less than 10 ppm which is well nitrified and stable.
- ✓ The effluent also has B.O.D. less than 5ppm and is free from odours.
- ✓ Therefore, the plant works without creating any nuisance at the site.
- ✓ If the quantity of sewage is more 3 to 4 such beds can be constructed in parallel.
- ✓ For cleaning these filters, the sand from the top is scraped from time to time and are refilled with fresh clean sand.

- **ADVANTAGES:**
  - Smaller head is required.
  - It does not require skilled supervision.
  - There is no trouble of odour or insects.
  - In some cases, no further treatment is needed except chlorination.
  - The effluent obtained from this filter is of good quality with suspended solids level of less than 10 mg/l and BOD of less than 5 ppm.
- **DISADVANTAGES:**
  - Very slow process.
  - Requires larger area of land.
  - Not suitable for very cold climates.
  - Their rate of loading is very small.
  - They cannot treat large quantity of sewage, therefore cannot be employed at big plants.
- **USES:**
  - It is the best treatment for small isolated structures such as hotels, hospitals etc, where land and sand is easily available.
  - These filters are also sometimes used to treat the effluent of coagulated sedimentation tanks or trickling filters.
  - For such cases, the rate of filtration is kept as about 200000 to 250000 litres/hectare/hour.
  - The effluent thus treated has an attractive appearance and it is free from any suspended matters.

TRICKLING FILTERS:

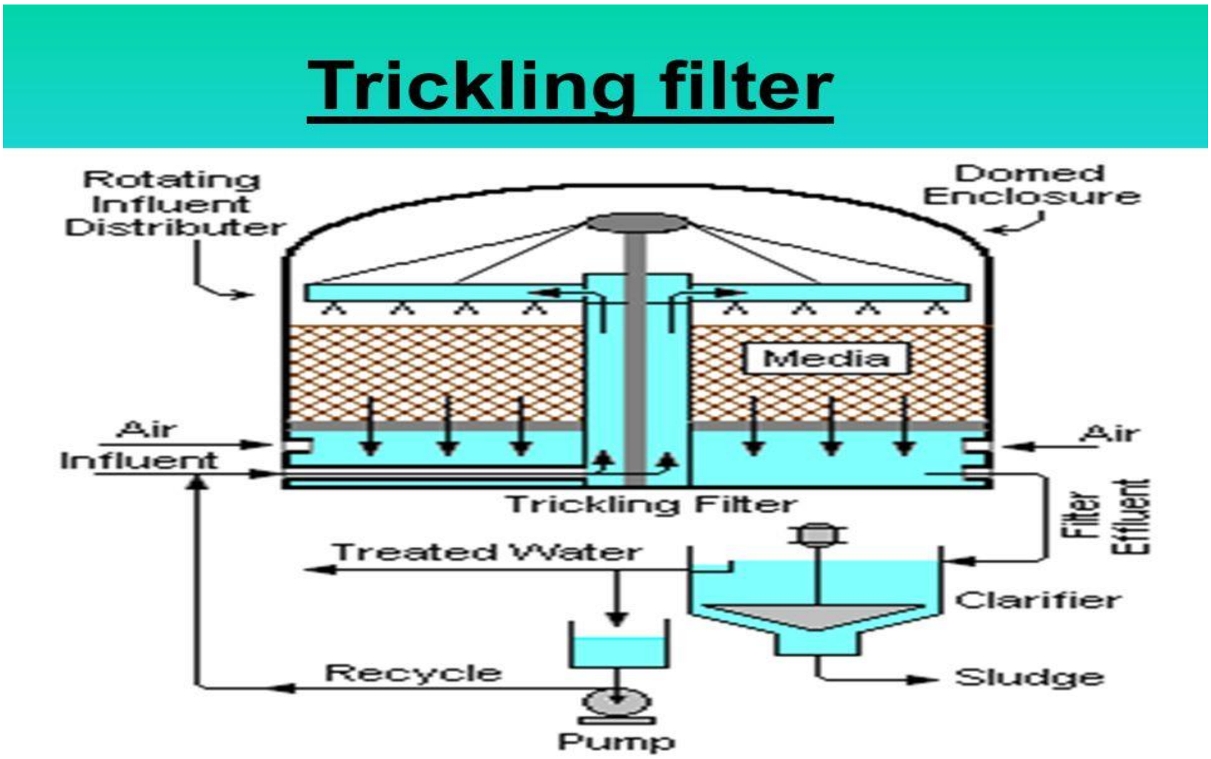


Figure No.11

- Trickling filters (TFs) are used to remove organic matter from wastewater.
- The TF is an aerobic treatment system that utilizes microorganisms attached to a medium to remove organic matter from wastewater.
- This type of system is common to a number of technologies such as rotating biological contactors and packed bed reactors (biotowers).
- These systems are known as attached-growth processes.
- Trickling filter is an attached growth process i.e. 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.
- The wastewater in trickling filter is distributed over the top area of a vessel containing non-submerged packing material.
- Air circulation in the void space, by either natural draft or blowers, provides oxygen for the microorganisms growing as an attached biofilm.
- During operation, the organic material present in the wastewater is metabolized by the biomass attached to the medium.
- The biological slime grows in thickness as the organic matter abstracted from the flowing wastewater is synthesized into new cellular material.

- The thickness of the aerobic layer is limited by the depth of penetration of oxygen into the microbial layer.
- The micro-organisms near the medium face enter the endogenous phase as the substrate is metabolized before it can reach the micro-organisms near the medium face as a result of increased thickness of the slime layer and loose their ability to cling to the media surface.
- The liquid then washes the slime off the medium and a new slime layer starts to grow. This phenomenon of losing the slime layer is called sloughing.
- The sloughed off film and treated wastewater are collected by an underdrainage which also allows circulation of air through filter.
- The collected liquid is passed to a settling tank used for solid- liquid separation.
- **ADVANTAGES:**

- ✓ Can be operated at a range of organic and hydraulic loading rates.
- ✓ The mechanical wear and tear is small as it contains less mechanical equipment.
- ✓ Resistant to shock loadings.
- ✓ Efficient nitrification (ammonium oxidation)
- ✓ High effluent quality in terms of BOD and suspended solids removal; in combination with a primary and tertiary treatment also in terms of pathogens.
- ✓ The moisture content of sludge obtained from the trickling filters is as high as 99 %.
- ✓ Low power requirements.
- ✓ The working of trickling filters is simple and it does not require skilled supervision.
- ✓ The trickling filters may reduce the B.O.D and colloidal matter to the extent of about 75 % and 80 % respectively.
- ✓ The trickling filters are flexible in operation.

- **DISADVANTAGES:**

- ✓ The cost of construction of trickling filters is high.
- ✓ Requires large land area and regular operator attention.
- ✓ Vector and odour problems.
- ✓ Incidence of clogging is relatively high.
- ✓ The process requires primary treatment of sewage and hence, the raw sewage cannot be purified by this process.

- **USES:**

✓ The process of trickling filters is becoming popular at present and the trickling filters, especially of high rate type are adopted in the modern treatment plant of sewage.

TYPES OF FILTERS:

- Conventional or Ordinary or Standard rate or Low rate trickling filter.
- High rate trickling filter.

Efficiency of Low rate trickling filter, $\eta = \dfrac{100}{1 + 0.44\sqrt{U}}$

Where, U – Organic loading Kg/ m^3/day

Efficiency of high rate trickling filter, $\eta = \dfrac{100}{1 + 0.44\sqrt{Y/VF}}$

Where, Y – Total Org. loading in Kg/day.

V - Filter Volume in m^3

F – Recirculation Factor.

COMPARISON OF LOW RATE & HIGH RATE TRICKLING FILTER

Table 4.3. Comparison between Standard Rate and High Rate Trickling Filters

Sl. No.	Feature	Standard rate trickling filter	High rate trickling filter
1.	Cost of operation	It is more.	It is less for equal performance
2.	Depth	1.8m to 2.4m.	900mm to 1.8m.
3.	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.
4.	Effluent	The effluent is highly nitrified and stabilized.	The effluent is nitrified up to nitrite stage only and hence, it is of inferior quality.
5.	Land requirement	It requires more area of land.	It requires less area of land.
6.	Method of operation	Continuous application, less flexible and requires less skilled supervision.	Continuous application, more flexible and requires more skilled supervision.
7.	Quality of secondary sludge produced.	It is black and highly oxidized with slight fine particles.	It is brown and not fully oxidized with fine particles.
8.	Rate of filter loading in the following units: (i) kg of B.O.D. per hectare- metre of filter media.	1000 to 2200	8000 to 14000
	(ii) kg of B.O.D. per day per 100 m3 of filter media.	15 to 30	Above 45
	(iii) Million litres per hectare of surface area per day.	25 to 40	100 to 300
9.	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.
10.	Size of filter media.	30 mm to 80 mm.	30 mm to 60 mm.

PROBLEMS

1.The sewage flows from a primary settling tank to a standard rate trickling filter at a rate of 5 ML/day having 5 day BOD of 150 mg/l. Determine the depth and volume of filter adopting a surface loading of 2500 l/m^2/day and an organic loading of 165 gm/m^3/day. Also determine the efficiency of filter unit using NRC formula.

Solution:

Total 5 day BOD/day = $5 X 10^6 X 150 X 10^{-3} = 75 X 10^4$ gm.

Volume of filter media required = Total BOD/Organic loading = $75 X 10^4 /165$

= $4545.5 m^3$

Surface area required = Total Flow/Hydraulic loading

$A = 5 X 10^6 /2500 = 2000 m^2$

Depth of bed = Volume/surface Area = 4545.5/2000 = 2.273 m or 2.3 m.

Hence provide a filter depth of 2.3 m.

$A = \pi X d^2/4$

$2000 = \pi X d^2/4$

$d^2 = 2000 X 4/ \pi$

$d = 50.5$ m.

Hence provide a filter of 50 m diameter.

Actual surface area = $\pi X 50^2/4$ = $1963.5 m^2$

Actual Volume = $1963.5 X 2.3 = 4516 m^3$

Actual Org.loading,U = Total BOD/Volume of filter = $75 X 10^4 / 4516$

= $166.1 gm/m^3$/day

U = $166.1 gm/m^3$/day or $0.1661 Kg/m^3$/day

Efficiency, $\eta = \dfrac{100}{1 + 0.44\sqrt{U}}$

$= \dfrac{100}{1 + 0.44\sqrt{0.1661}}$

= 84.8 %.

2. The sewage is flowing @ 4.5 ML/day from a primary clarifier to a standard rate trickling filter. The 5 day BOD of influent is 160 mg/l. Organic loading is 160 gm/m/day and surface loading 2000 l/m/day. Determine the volume, depth and efficiency of filter.

Solution:

Total 5 day BOD/day = 4.5 X 10^6 X 160 X 10^{-3} = 72 X 10^4 gm.

Volume of filter media required = Total BOD/Organic loading = 72 X 10^4 /160

= 4500 m^3

Surface area required = Total Flow/Hydraulic loading

A = 4.5 X 10^6 /2000 = 2250 m^2

Depth of bed = Volume/surface Area = 4500/2250 = 2 m.

Hence provide a filter depth of 2 m.

A = π X d^2/4

2000 = π X d^2/4

d^2 = 2250 X 4/ π

d = 53.52 m or 54 m.

Hence provide a filter of 54 m diameter.

Actual surface area = π X 54^2/4 = 2290.2 m^2

Actual Volume = 2290.2 X 2 = 4580.4 m^3

Actual Org.loading,U = Total BOD/Volume of filter = 72 X 10^4 / 4580.4

= 157.19 gm/m^3/day or 0.1567 Kg/ m^3/day

Efficiency, η = $\frac{100}{1 + 0.44\sqrt{U}}$

= $\frac{100}{1 + 0.44\sqrt{0.1}_{57}}$

= 85.1 %.

3.Determine the size of a high rate trickling filter for the following data:

Flow - 4.5 MLD

Recirculation Ratio (R/I)= 1.4

BOD of raw sewage = 250 mg/l.

BOD removed in primary clarifier = 25 %

Final effluent BOD desired = 50 mg/l.

Calculate also the size of the standard rate trickling filter to accomplish the above requirement.

Solution:

Total BOD present in raw sewage/day = 4.5 X 250 = 1125 X ($10^6/10^6$) = 1125 Kg.

BOD removed in the primary clarifier = 25 %

BOD entering/day in the filter units = 1125 X (75/100) = 843.75 Kg.

BOD concentration in the effluent = 50 mg/l.

BOD allowed to go into the effluent = 50 X 4.5 X ($10^6/10^6$) = 225 Kg.

BOD removed by the filter/day = 843.75 – 225 = 618.75 Kg.

Efficiency of filter = (BOD removed/Total BOD) X 100

= (618.75/843.75) X 100 = 73.3 %

Efficiency of high rate trickling filter, $\eta = \dfrac{100}{1 + 0.44\sqrt{Y/VF}}$

$$F = \frac{1 + R/I}{[1 + 0.1\,(R/I)]^2} = \frac{1 + 1.4}{(1 + 0.1 \times 1.4)^2} = 1.85$$

$$73.3 = \frac{100}{1 + 0.44\sqrt{Y/VF}}$$

V = 665.4 m^3.

Assume a depth of filter as 1.5 m.

Surface area required, A = 665.4/1.5 = 413.6 m^2.

$$A = \pi \times d^2/4$$

$$413.6 = \pi \times d^2/4$$

$$d^2 = 413.6 \times 4/\pi$$

$$d = 23.8 \text{ m.}$$

For an equivalent standard filter, F = 1.

$$73.3 = \frac{100}{1 + 0.44\sqrt{Y/VF}}$$

V = 1231 m^3.

Using depth of filter as 1.5 m, A = 1231/1.5 = 820.8 m^2.

$$A = \pi \times d^2/4$$

$$820.8 = \pi \times d^2/4$$

$$d^2 = 820.8 \times 4/\pi$$

$$d = 32.3 \text{ m.}$$

ACTIVATED SLUDGE PROCESS

- In secondary treatment, the ASP consists of aeration tanks of long detention period, in which activated sludge is mixed with sedimented sewage is agitated and aerated.
- The sludge coming from the secondary sedimentation tank is called activated sludge and contains more quantity of biologically active oxygen.
- In the sewage treatment there are two de-composition process takes place.
- ✓ Aerobic Decomposition Process
- ✓ Anaerobic Decomposition Process

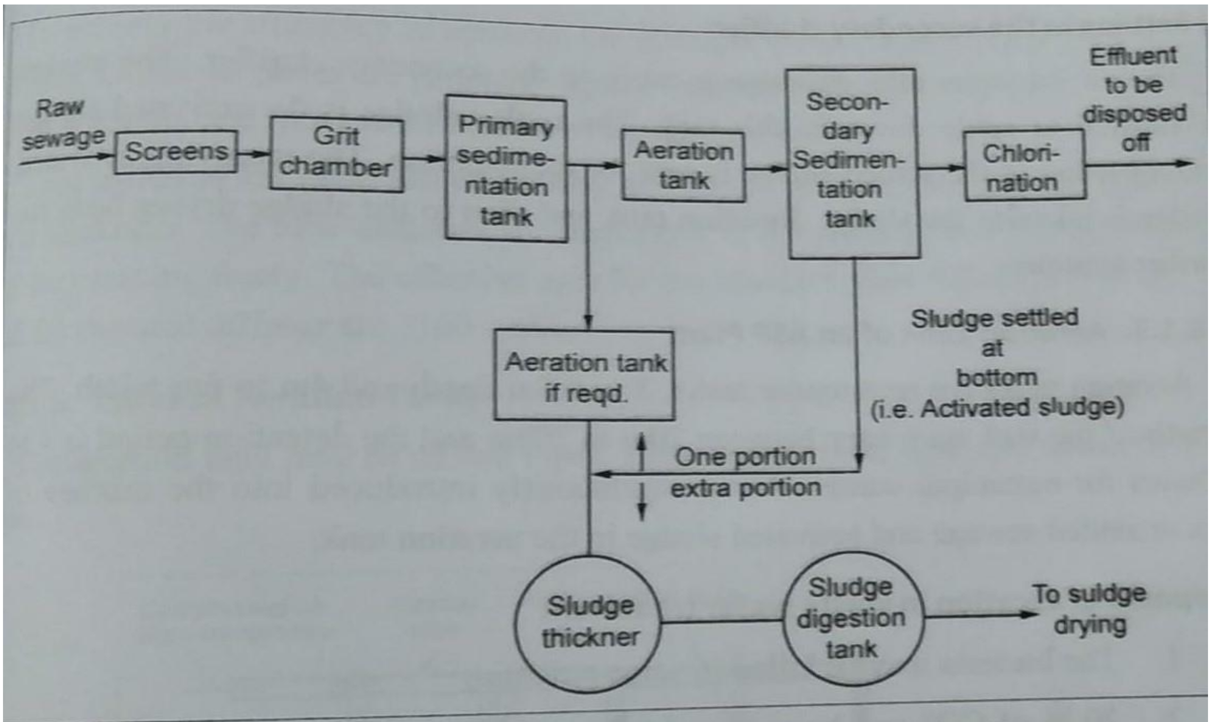


Fig. 4.12. Flow diagram of Activated Sludge Process

Figure No.12

- In secondary treatment process, only aerobic decomposition occurs and aerobic decomposition has the following advantages over anaerobic decomposition.
- ✓ Aerobic decomposition does not produce bad smells and gases.
- ✓ More active than anaerobic bacteria – the rate of doing work by aerobic bacteria is three times the work doing by anaerobic bacteria at 30°C.
- Activated sludge process is a process for treating sewage and waste water commonly referred as effluent using bacteria (to degrade the biodegradable organics) and air (Oxygen for respiration).
- Activated sludge refers to a mixture of microorganisms and suspended solids.
- The sewage effluent from the primary sedimentation tank is mixed with 25 % of its own volume of activated sludge.
- The activated sludge contains a larger concentration of highly active aerobic micro-organism.
- The mixture of sewage effluent and activated sludge enters an aeration tank, where micro-organism is mixed together with a large quantity of air, for a period of about 4 to 8 hours.
- Under this condition, the micro-organisms will oxidize the organic matter and the suspended and colloidal matter tends to coagulate and form a precipitate.
- This precipitate settles down in the secondary sedimentation tank instantly.

- The settled sludge called activated sludge is again recycled to the head of aeration tank and again mixed with raw sewage.
- Activated sludge is being produced continuously by this process and a portion of produced activated sludge is utilized in aeration tank.
- The excess of activated sludge is disposed of properly along with the sludge collected during primary treatment after digestion.
- **PROPERTIES OF ASP:**

- ✓ It contains fertilizing constituents.
- ✓ The colour of activated sludge indicates the degree of aeration.
- ✓ The colours of under-aerated, well-aerated and over-aerated sludges are light brown, golden brown and muddy brown respectively.
- ✓ The moisture content of the activated sludge is about 95 to 97 %.

- **PURPOSE OF ASP:**
- In a sewage (or industrial wastewater) treatment plant, the activated sludge process can be used for one or several of the following purposes:

- ✓ Oxidizing carbonaceous matter: biological matter.
- ✓ Oxidizing nitrogenous matter: mainly ammonium and nitrogen in biological materials.
- ✓ Removing phosphate.
- ✓ Driving off entrained gases carbon dioxide, ammonia, nitrogen, etc.
- ✓ Generating a biological floc that is easy to settle.
- ✓ Generating a liquor low in dissolved or suspended material.

- **OPERATIONS OF ASP:**

- ✓ Mixing of activated sludge
- ✓ Aeration
- ✓ Settling in the secondary clarifier.
- ✓ **MIXING OF ACTIVATED SLUDGE:**

- The activated sludge is mixed with raw or settled sewage properly.

- ✓ **AERATION:**

- The mixed liquor containing activated sludge and effluent is agitated or aerated in the aeration tank or aeration chamber.
- The removal of grit and larger solids by screening, grit chambers and primary sedimentation tank is necessary for aeration.

- The pre-removal of these settleable solids is helpful in preventing deposits on aeration devices and thereby not reducing their efficiencies.
- Moreover, the grit and larger solids are not pre-removed they may settle down in aeration tank and reduce the speed and efficiency of aeration process.

✓ **SETTLING IN THE SECONDARY CLARIFIER:**

- The mixed liquor after agitation is taken to the secondary clarifier.
- The sludge is allowed to settle down in this tank.
- The settled sludge is the activated sludge and a portion of the settled sludge is sent for recirculation.
- The removing activated sludge is taken to the sludge digestion tank and then to the sludge drying beds for further treatment.

➢ **ADVANTAGES:**

✓ The cost of installation is low.

✓ The effluent of good quality is obtained.

✓ The process requires small area of land and hence the design may be made compact.

✓ There is comparatively very small loss of head through the treatment plant.

✓ There is freedom from fly and odour nuisance due to high degree of treatment given to the sewage in this process.

➢ **DISADVANTAGES:**

✓ The cost of operating the process is relatively high.

✓ The process is sensitive to certain types of industrial wastes.

✓ The process requires skilled supervision for its efficient working.

➢ **FOOD TO MICRO-ORGANISM RATIO (F/M RATIO):**

$$\text{F/M RATIO} = \frac{\text{Daily BOD load given to aeration system (in gram)}}{\text{Total microbial mass in the aeration system (in gram)}}$$

➢ **SLUDGE VOLUME INDEX:**

✓ The sludge volume index is defined as the volume occupied by one gram of activated sludge after a settling period of 30 minutes.

✓ The term SVI is used to indicate the degree of concentration of sludge and it reflects the physical state of sludge.

UPFLOW ANAEROBIC SLUDGE BLANKET :

➢ Upflow anaerobic sludge blanket (UASB) technology, normally referred to as UASB reactor, is a form of anaerobic digester that is used for wastewater treatment.

- The UASB reactor is a methanogenic (methane-producing) digester that evolved from the anaerobic clarigester.
- UASB uses an anaerobic process whilst forming a blanket of granular sludge which suspends in the tank.
- Wastewater flows upwards through the blanket and is processed (degraded) by the anaerobic microorganisms.
- Biogas with a high concentration of methane is produced as a by-product, and this may be captured and used as an energy source, to generate electricity for export and to cover its own running power.

OXIDATION POND:

- Oxidation pond is a type of wastewater treatment which also refers as lagoons or water stabilization pond.
- It is a secondary treatment of wastewater coming from industries, residential areas etc.
- It makes the use of microorganisms like bacteria, algae and light energy (sunlight) to stabilize the wastewater.
- Oxidation pond is constructed 1-1.5m deep inside the soil and have inlet and outlet systems.
- Oxidation pond can define as the stabilization pond that stabilizes the domestic, trade, industrial wastes etc. by the microbial interaction, primarily bacteria and algae.
- It is the large, shallow ponds having 2-6 feet height of water body.
- Oxidation pond requires the presence of sunlight and oxygen for the secondary treatment of domestic and trade wastes.
- The secondary treatment of the organic and inorganic waste coming from raw sewage and industrial effluents is necessary.
- The direct disposal of the wastewater to the aquatic system can affect the life of water-bodies and the quality of water as well.

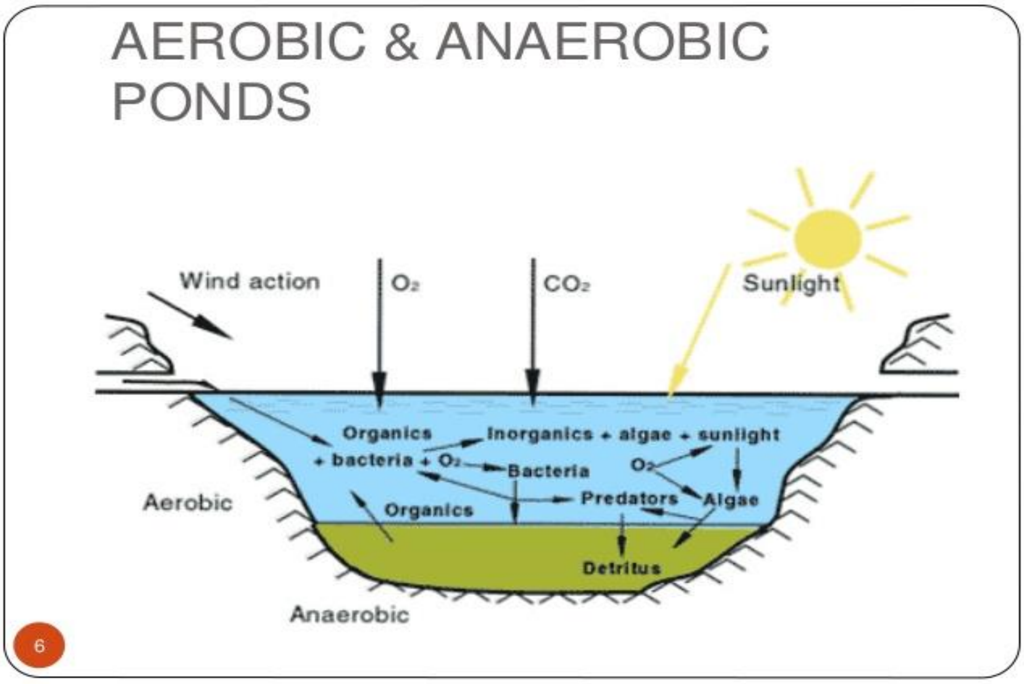


Figure No.13

- **ADVANTAGES:**

✓ The stabilization pond can reduce the biological oxygen demand up to 90% naturally.

✓ It is a simple method to operate, does not require sophisticated equipment.

✓ Oxidation pond is a practical and effective method for the wastewater treatment of domestic and trade wastes in the tropical areas.

✓ The operation of a stabilization pond does not require much labour-power.

✓ It is an economical method for the treatment of wastewater from small and isolated units.

- **DISADVANTAGES:**

✓ The construction of a stabilization pond requires more land area.

✓ The maintenance is quite intricate.

✓ Sometimes, it gives a foul smell and mosquito menace during the process if not appropriately maintained.

✓ There may get a chance of effluent seepage into the ground water, which can ultimately cause ground water pollution.

TERTIARY OR FINAL TREATMENT OF WASTE WATER:

- Tertiary treatment of waste water is final treatment process in which all the chemical and biological agents are completely removed from sewage before disposal into river.

- After the primary and secondary treatment of sewage, the sewage is a stabilized and a harmless one.
- However, the primary and secondary treatments remove only conventional constituents like TSS, BOD, COD, Organic carbon. Nitrogen, phosphorus etc.
- The non conventional compounds and other emerging compounds may still be present in sewage.
- Also sewage contains some roundworms and bacterial pathogens that are difficult to control.
- All these factors affect the public health and therefore, the sewage needs to undergo tertiary treatment before disposal or reuse for industrial, agricultural and municipal purposes.
- The tertiary treatment required will be always based on the type of water reuse and degree of quality of the reclaimed water.
- **OBJECTIVES OF TERTIARY TREATMENT PROCESS:**

✓ Removal of suspended solids

✓ Removal of dissolved solids like salts

✓ Removal of nitrate and phosphate

✓ Killing of microorganisms

- **REMOVAL OF SUSPENDED SOLIDS:**

Suspended solids are removed by two methods:

✓ Microstraining:

- In this method, sewage is placed in rotating drum filter of pore size 25-35 µm and then drum is rotated.
- During rotation, clear water comes out of drum and suspended solids remains inside drum.

✓ Chemical coagulation and filtration:

- In this method, precipitating agents such as alum is added in sewage.
- Fine suspended solids adsorbs to the surface of Al(OC)3 precipitate, finally precipitate with adsorbed solids are separated by filtration.

- **REMOVAL OF DISSOLVED SOLIDS LIKE SALTS:**

✓ Adsorption by activated carbon:

- Dissolved solids can be removed by filtering the water through filter containing activated carbon particle.

✓ Reverse osmosis:

- Reverse osmosis removes dissolved solids like NaCl and microbial cells.

➢ **REMOVAL OF NITRATE AND PHOSPHATE:**

✓ If sewage after treatment is to be discharge into river, nitrate and phosphate should be removed from sewage before disposal.

✓ It is because nitrate and phosphate causes eutrophication.

✓ These plant nutrients are removed by biological process.

✓ At first sewage is placed in a tank containing nitrifying bacteria.

✓ These bacteria converts ammonium salt and nitrite into nitrate.

✓ Then the sewage is placed into second tank containing denitrifying bacteria.

✓ These bacteria converts nitrate into Nitrogen gas that leaves the sewage.

✓ Phosphate is also removed by bacteria by microbial assimilation process.

➢ **KILLING OF MICRO-ORGANISMS:**

✓ Finally microorganisms in sewage are killed by disinfection like chlorination.

CHLORINATION OF SEWAGE:

➢ The process of killing the pathogenic bacteria present in the waste water is called disinfection of sewage.

➢ Chlorination is the process of treating the sewage with chlorine in order to disinfect the pathogens, either before or after the treatment.

➢ Chlorine is added to the sewage for the following purposes,

✓ To remove the odours.

✓ To break down the sulphur compounds.

✓ To kill the bacteria cells.

✓ To prevent the flies in trickling filters.

✓ To remove the grease.

➢ When chlorine is added to the treated sewage as a final step in the treatment is called post-chlorination.

➢ The post chlorination is carried out for the sewage having low bacterial count and will reduce the bacteria and BOD of the treated sewage.

➢ When chlorine is added to the raw or partially treated sewage in order to control the bacterial growth is called pre-chlorination.

➢ Pre chlorination is used to control the odour of sewage before it enters to the sedimentation tank, prevent the flies in trickling filter and helps to remove the grease in skimming units.

- Chlorine may be added to the sewage at the beginning and end of the treatment process is called split chlorination.

ADVANCES IN SEWAGE TREATMENT

- Advanced treatment of waste water is defined as the additional treatment needed to remove the suspended, colloidal and dissolved constituents remaining after conventional secondary treatment.
- **NEED FOR ADVANCED WASTEWATER TREATMENT:**

✓ To remove the organic matter and TSS beyond what can be removed by secondary treatment.

✓ To remove nutrients, organic and inorganic constituents for re-use purposes.

TECHNOLOGIES USED FOR ADVANCED TREATMENT:

- Depth Filtration
- Adsorption
- Gas-stripping
- Ion-exchange
- Advanced oxidation process
- Distillation
- **DEPTH FILTRATION:**

✓ Depth filtration is an advanced wastewater treatment method, which involves the removal of particulate material suspended in sewage and also used to remove chemically precipitated phosphorous.

✓ The various techniques available in depth filtration are,

- Deep bed down flow filters
- Deep bed up flow continuous backflow filters.
- Pulsed bed filters
- Travelling bridge filters
- Synthetic medium filters

- **ADSORPTION:**

✓ Adsorption is defined as the process of accumulating substances that are in solution on a suitable interface.

✓ Adsorption is a mass transfer operation, in that a constituent in the liquid phase is transferred into solid phase.

- ✓ The adsorbate is the substance that is being removed from the liquid phase at the interface.
- ✓ The adsorbent is the solid, liquid or gas phase onto which adsorbate accumulates.
- ✓ Activated carbon process is an example for the adsorption of advanced sewage treatment method.

- ➢ **GAS-STRIPPING:**

- ✓ Gas stripping involves the mass transfer of a gas from the liquid phase to the gas phase.
- ✓ The transfer is completed by contacting the liquid containing the gas that is to be stripped with a gas that does not containing any gas initially.

- ➢ **ION-EXCHANGE:**

- ✓ Ion-exchange is a unit process in which ions of a given species are displaced from an insoluble exchange material by ions of a different species in solution.
- ✓ The most widely used method of ion-exchange is domestic water softening method.
- ✓ Ion exchange method has been used in waste water application for the removal of nitrogen, heavy metals and TSS.
- ✓ Ion exchange process can be operated in a batch or continuous mode.
- ✓ In a batch process, the resin is stirred with water to be treated in a reactor, until the reaction is complete.
- ✓ The used resin is removed by settling and simultaneously regenerated and reused.
- ✓ In a continuous process, the exchange material is placed in a bed or a packed column and the water to be treated is passed through it.

- ➢ **ADVANCED OXIDATION PROCESS:**

- ✓ Advanced oxidation processes are used to oxidize the complex organic constituents found in wastewater, that are difficult to de-grade biologically into simpler end products.
- ✓ When chemical oxidation is used, it may not be necessary to oxidize completely a given compound or group of compounds.

- ➢ **DISTILLATION:**

- ✓ Distillation is a unit operation in which the components of a liquid solution are separated by vaporization and condensation.
- ✓ Along with reverse osmosis, distillation can be used to control the formation of salts in critical reuse applications.

- ✓ The method of distillation for wastewater reclamation is a recent development, the current development must be consulted for the results of efficient operations and more recent applications.

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SCHOOL OF BUILDING AND ENVIRONMENT

DEPARTMENT OF CIVIL ENGINEERING

UNIT – V – DISPOSAL OF SEWAGE AND SLUDGE MANAGEMENT – SCI 1306

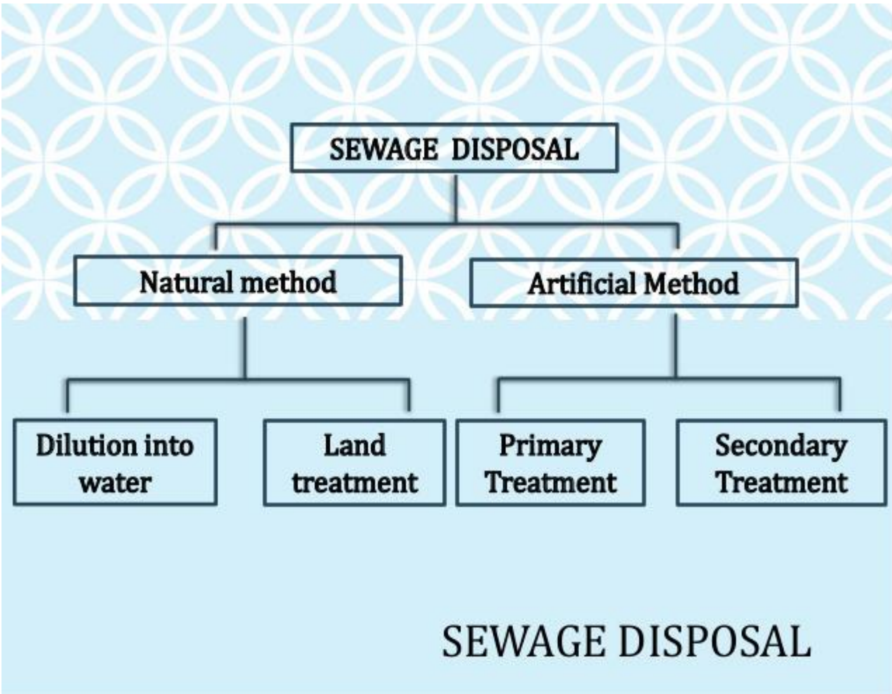
SEWAGE DISPOSAL

- Sewage disposal is defined as the process of disposing the sewage, without affecting the environment or the place of disposal.
- Scientific method of disposal of sewage will protect the health of the community and the humans from bad smell.
- Mosquitoes, gases and other foul conditions.
- Disposal of sewage by proper method will also reduce the danger of spread of disease like typhoid, dysentery, diarrhea etc.
- It also prevents the destruction of fish or other aquatic life by letting the untreated or partially treated sewage discharge into the water bodies.

OBJECTIVES OF SEWAGE DISPOSAL

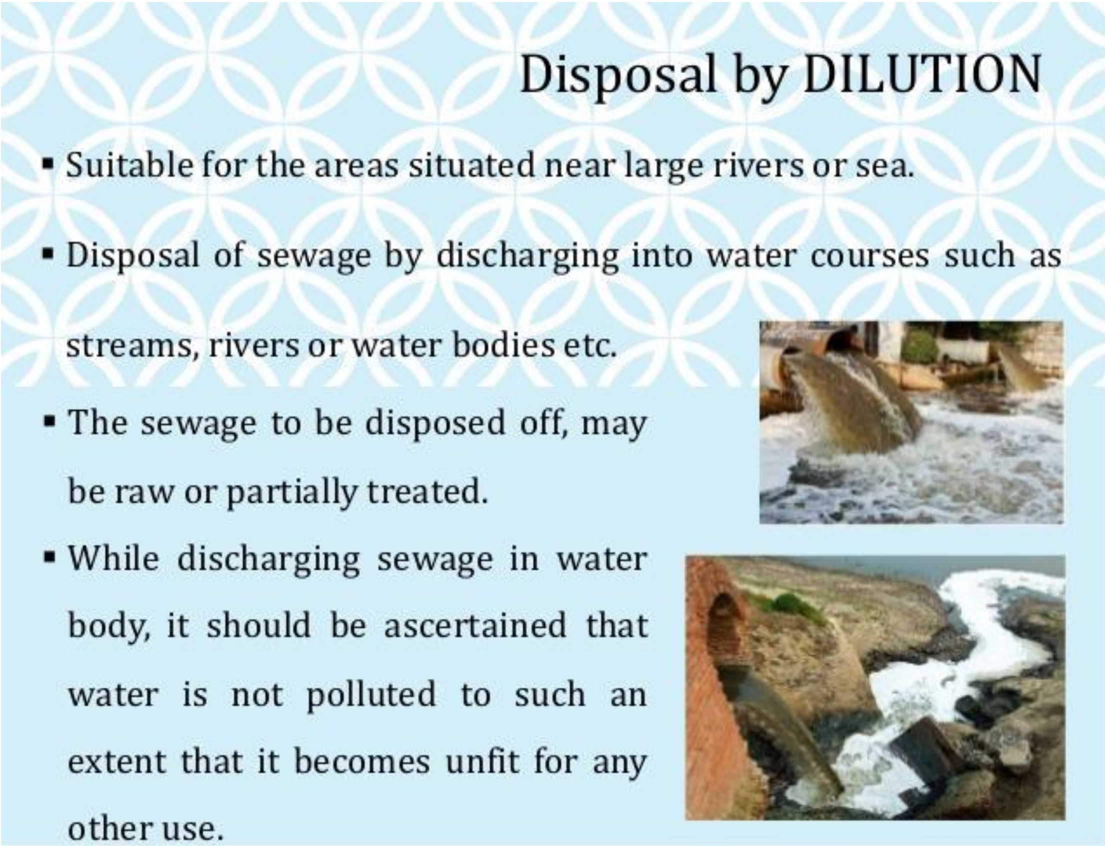
- To eliminate or reduce danger to the public health by possible contamination of water supplies.
- To render the sewage inoffensive without causing odour or nuisance.
- To prevent the life of fish or other aquatic life by allowing raw sewage into bodies of water as such.
- The destruction of fish & other Aquatic life can be prevented by the sewage disposal methods.
- With proper sewage disposal the environment or the areas does not become polluted.
- Sanitary conditions are maintained in the area.

METHODS OF SEWAGE DISPOSAL



- In natural method of disposal, the sewage or wastewater is disposed into either receiving water bodies and disposal of sewage into land for irrigation.
- In artificial method of sewage disposal, before discharging the effluent into natural water bodies, the sewage is treated for primary or secondary treatment.

NATURAL METHOD OF DISPOSAL BY DILUTION



- The sewage, in due course of time, gets purified automatically by the self purification capacity of water.
- The quantity of pure natural water required for the process of self purification should be about 6-14 times the volume of the sewage disposed.
- Diluting water must be rich in oxygen content for Dilution.
- Diluting waters are not become a source of water supply for at least some distance from the point of disposal.

CONDITIONS FOR DILUTION:

- The city should be situated near the river, sea or lake.
- The sewage is comparatively fresh (4 to 5 hours old).
- The sewage should be free from all floating and settleable solids.
- The diluting water should not become a source of water supply.
- The area of point of disposal should not provide facilities for settling of solids and formation of sludge deposits.
- Diluting water should have high oxygen content.
- Completing mixing of the sewage with diluting water should be possible.
- The diluting waters should not be used for navigational purposes.
- **DILUTION FACTOR:**

✓ The ratio of the quantity of the diluting water to that of the quantity of sewage is called Dilution Factor.

✓ If the dilution factor is less than 8, the sewage has to be completely purified under the following circumstances.

- The diluting water has more than 20 ppm of D.O in 5 days.
- The river is being used as a source of water supply on the downstream side.

- The effluent has to be used disposed of into tidal waters which may be in the form of river or sea.

Standards of Dilution Based on Royal commission Report

Dilution Factor	Standards of purification required
Above 500	No treatment is required .Raw sewage can be directly discharged into the volume of dilution water
Between 300 to 500	Primary treatment such as plain sedimentation should be given to the sewage
Between 150 to 300	Treatments such a sedimentation, screening and essentially chemical precipitation are required
Less than 150	Complete thorough treatment should be given to sewage

PRELIMINARY INVESTIGATIONS:

- When the method of disposal of dilution is to be adopted, a study of the effluent to be discharged and nature of the receiving body of water should be made.
- ✓ Analysis of diluting water with special reference to the available D.O.
- ✓ Effect of sewage disposal on water used for aquatic life.
- ✓ Hydrographic survey to determine the intensity and direction of winds, currents and tides.
- ✓ Minimum quantity of diluting water available at all time of the year.
- ✓ The degree of treatment given to sewage etc.

TYPES OF NATURAL WATERS:

- Creeks
- Estuaries
- Ground water
- Lakes
- Ocean or sea
- Perennial rivers and streams

- **CREEKS:**

- ✓ A creek is in the form of an inlet on sea coast and it may not have dry weather flow during some period of the year.

- **ESTUARIES:**

- ✓ The wide lower tidal part of a river is known as estuary.
- ✓ The dilution of sewage in estuaries is affected by ocean water in addition to the river water.
- ✓ Hence the process of dilution of sewage in estuaries is generally satisfactory.

- **GROUND WATER:**

- ✓ The sewage when applied on land ultimately filters out through different layers of solids and it meets ground water at higher depths.
- ✓ If ground water flows through favourable strata of soil, the dilution of water is satisfactory.

- **LAKES:**

- ✓ A lake is an enclosed water space and it may be used for the purpose of dilution of sewage.
- ✓ In some areas, the larger lakes are used for both water supplies and disposal of sewage.
- ✓ In such cases, the location of sewage disposal point should be carefully located, so as not to affect the water supply intake.
- ✓ The various characteristics of lake like its size, shape, nature of the surrounding area, volume of fresh water flowing in it etc. should be carefully decided before deciding its self-purifying capacity.

- **OCEAN OR SEA:**

- ✓ The ocean or sea has water in abundance and hence its capacity to dilute sewage is practically unlimited.
- ✓ The sewage of any quality can be diluted into sea.
- ✓ It is observed that the sewage reacts with sea water and forms precipitates giving milky colour to the sea water and this is known as sludge banks.
- ✓ These sludge banks are undesirable as they produce hydrogen sulphide gas by reacting with sulphate resulting in bad odour.
- ✓ The dissolved oxygen in sea water is 20 % less as compared to the stream water or fresh water and also its re-aeration is slower.
- ✓ However, these deficiencies are removed by large volumes or sea water.

Following points should be noted while discharging sewage into the sea.

- ✓ There should be sufficient depth of water near the point of swage discharge into the sea.
- ✓ The sea outfall for sewage should be carried sufficiently deep into the sea to a distance of about 1.5 Km, so as not to cause any nuisance to the baths or recreation centres on the sea shore.
- ✓ The sea outfall for sewage should be placed on firm rocky foundations.
- ✓ The sewage should be discharged below low water level at the time of lowest tides.

- ➢ **PERENNIAL RIVERS AND STREAMS:**

- ✓ The perennial rivers and streams flow throughout the year, with maximum and minimum limits.
- ✓ The minimum limit generally occurs in summer.
- ✓ The dilution in summer becomes difficult due to the fact that in summer, the high temperature of water results in low solubility of oxygen.
- ✓ The sewage under such circumstances should be properly treated before allowing dilution with perennial rivers and streams.

SELF PURIFICATION OF NATURAL WATERS:

- ➢ When sewage is discharged into natural waters. Its organic matter gets oxidized by the dissolved oxygen content in water, and the receiving water gets polluted due to the waste products, present in the sewage effluents.
- ➢ But this is not happening always due to the natural forces of purification.
- ➢ The oxidation of organic matter converts the organic matter to simple harmless substances. The deficiency of dissolved oxygen is filled by the absorption of atmospheric oxygen.
- ➢ Thus, the oxygen of water is consumed by the sewage and at the same time, the oxygen is taken from the atmosphere.
- ➢ This procedure occurs in all-natural waters is called Self-purification of natural waters.
- ➢ The rate of self-purification will depend on various factors such as rate of re=aeration, type of organic matter present in the sewage, temperature, velocity of flow, presence of available oxygen in receiving waters, sedimentation etc.
- ➢ The self-purification of process of streams polluted by sewage can be grouped in the following four zones or divisions.
- ➢ Degradation Zone
- ➢ Active-Decomposition Zone
- ➢ Recovery Zone

- Clear water Zone

ZONES OF POLLUTION IN THE STREAM

1.Zone Of Degradation:

- Situated just below outfall sewer.
- Water is dark and turbid with sludge at the bottom.
- DO reduces upto 40% of saturation level.
- CO_2 content increases.
- Conditions are unfavorable for aquatic life.

2.ZONE OF ACTIVE DECOMPOSITION:

- Water in this zone becomes grayish and darker than previous zone.
- DO concentration falls to zero.
- Fish life is absent and bacteria is present.
- At the end of this zone DO rises to 40% of saturation.
- Aquatic life starts to reappear.

3.ZONE OF RECOVERY;

- Process of recovery starts.
- Stabilization of organic matter takes place into this zone.
- BOD falls and DO content increase above 40% value.
- NO2 , SO4 and CO3 are formed.
- Near the end of this zone entire aquatic life reappears.

4.Clear Water Zone:

- Water becomes clearer and attractive in appearance.
- DO rises to saturation level.
- Oxygen balance is attained.
- Recovery is complete.

SOURCES OF GETTING OXYGEN:

✓ The oxygen required for the self-purification is obtained by natural waters from the atmosphere in the following three ways.

➢ **RAIN:**

✓ The rain water is saturated with oxygen and when combines with natural water results in increase of oxygen content.

- **SURFACE LEVEL:**

- ✓ The surface in natural water is in contact with the atmosphere.
- ✓ This surface absorbs oxygen from the atmosphere and passes it to the body of natural waters.

- **WAVES:**

- ✓ Some portion of air absorbed by waves and eddies of natural waters.
- ✓ The diffusion and dispersion due to the movement of fish in water will also encourage absorption of oxygen from the atmosphere.

FACTORS AFFECTING SELF PURIFICATION:

- DILUTION
- CURRENT
- TEMPERATURE
- SUNLIGHT

RATE OF OXIDATION

- **DILUTION:**

- ✓ When sufficient dilution water is available in the receiving water body, where the waste water is discharged, the DO level in the receiving stream may not reach to zero or critical DO due to availability of sufficient DO initially in the river water before receiving discharge of wastewater.

- **CURRENT:**

- ✓ When strong water current is available, the discharged wastewater will be thoroughly mixed with stream water preventing deposition of solids.
- ✓ In small current, the solid matter from the wastewater will get deposited at the bed following decomposition and reduction in DO.

- **TEMPERATURE:**

- ✓ The quantity of DO available in stream water is more in cold temperature than in hot temperature.
- ✓ Also, as the activity of microorganisms is more at the higher temperature, hence, the self- purification will take less time at hot temperature than in winter.

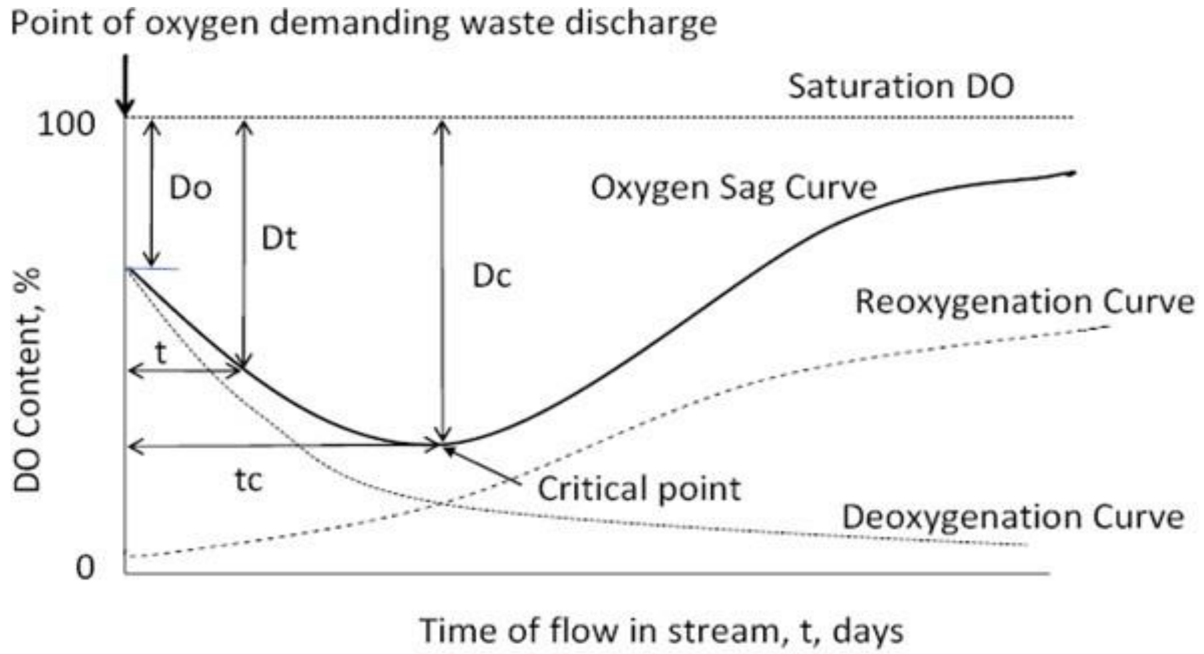
- **SUNLIGHT:**

- ✓ Algae produces oxygen in presence of sunlight due to photosynthesis.
- ✓ Therefore, sunlight helps in purification of stream by adding oxygen through photosynthesis.

- **RATE OF OXIDATION:**

- ✓ Due to oxidation of organic matter discharged in the river DO depletion occurs.
- ✓ This rate is faster at higher temperature and low at lower temperature.
- ✓ The rate of oxidation of organic matter depends on the chemical composition of organic matter.

OXYGEN DEFICIENCY OF A POLLUTED RIVER



Deoxygenation, reoxygenation and oxygen sag curve

- ➢ **DE-OXYGENATION CURVE:**
- ✓ The curve which represents (or) showing the depletion of D.O with time at the given temperature.
- ➢ **RE-OXYGENATION CURVE:**
- ✓ In order to counter balance, the consumption of D.O due to the de – oxygenation, atmosphere supplies oxygen to the water and the process is called the re – oxygenation.
- ✓ When wastewater is discharged in to the stream, the DO level in the stream goes on depleting.
- ✓ This depletion of DO content is known as deoxygenation.
- ✓ The rate of deoxygenation depends upon the amount of organic matter remaining (Lt), to be oxidized at any time t, as well as temperature (T) at which reaction occurs.

- ✓ The variation of depletion of DO content of the stream with time is depicted by the deoxygenation curve in the absence of aeration.
- ✓ When the DO content of the stream is gradually consumed due to BOD load, atmosphere supplies oxygen continuously to the water, through the process of re-aeration or reoxygenation, i.e., along with deoxygenation, re-aeration is continuous process.
- ✓ The rate of reoxygenation depends upon:
  - ✓ Depth of water in the stream: more for shallow depth.
  - ✓ Velocity of flow in the stream: less for stagnant water.

    Oxygen deficit below saturation DO: since solubility rate depends on difference between saturation concentration and existing concentration of DO.

    Temperature of water: solubility is lower at higher temperature and also saturation concentration is less at higher temperature.
- ✓ When sewage is discharged into the river, the oxygen demand by the organic matter of sewage is satisfied.
- ✓ This is presented by the de-oxygenation curve.
- ✓ The ordinates below the de-oxygenation curve indicate the oxygen remaining in natural waters, after satisfying the oxygen demand.
- ✓ When de-oxygenation takes place, the deficiency or deficit of oxygen is filled up by the process of re-aeration. This is represented by the re-oxygenation curve.
- ✓ The rate of de-oxygenation becomes equal to the rate of re-oxygenation and the rate of re-aeration depends on the deficiency of oxygen developed by the sewage.
- ✓ The rate of re-oxygenation increases and the natural waters become saturated with D.O content as before.
- ✓ By using the above two curves, the quantity of net oxygen balance can be calculated at any stage of the self-purification process.
- ✓ This is represented by Oxygen sag curve or Oxygen deficit curve.
- ✓ When the rate of de-oxygenation is equal to the rate of re-oxygenation, the critical point of maximum deficit is reached.
- ✓ This point is shown on the oxygen sag curve and after this point is reached, the rate of re-oxygenation rapidly increases.
- ✓ The oxygen sag curve indicates the net oxygen balance and the ordinates above the curve represent the balance of oxygen contained in the natural waters.
- ✓ The saturated DO content of the natural water is about 9.1 mg/l at 20 C.

- ✓ But due to the presence of algae, organic matter or rise in temperature of water. The initial DO concentration is about 8 mg/l instead of 9.1 mg/l. Thus, initial DO deficit is (9.1 – 8) = 1.1 mg/l.
- ✓ The reoxygenation of natural water is a continuous process.
- ✓ It is Carried out by turbulence, diffusion, wind velocity, movement of fishes etc.
- ✓ The entire analysis of super – imposing rates of de-oxygenation and re-oxygenation have been carried out mathematically and given in the form of Streeter Phelps Equation.
- ✓ Oxygen Deficit, D = Saturation D.O – Actual D.O

➢ **FACTORS EFFECTING NATURAL FORCES:**

- ✓ TEMPERATURE
- ✓ TURBULENCE
- ✓ HYDROGRAPHY
- ✓ DISSOLVED OXYGEN
- ✓ RATE OF REAERATION

➢ **TEMPERATURE:**

- ✓ At higher temperature concentration of dissolved oxygen is low while the rate of biological and chemical activities is high.
- ✓ This is likely to lead to anaerobic condition, the pollution is heavy.

➢ **TURBULENCE:**

- ✓ The turbulence in the body of water helps in breaking the surface of the stream or lake and helps in rapid reaeration from the atmosphere.
- ✓ Too much of turbulence scours the bottom sediment and stops algae growth.

➢ **HYDROGRAPHY:**

- ✓ Hydrography affects the velocity and surface expanse of the river-stream.
- ✓ High velocity cause turbulence and rapid aeration, while surface expanse will also have the same effect.

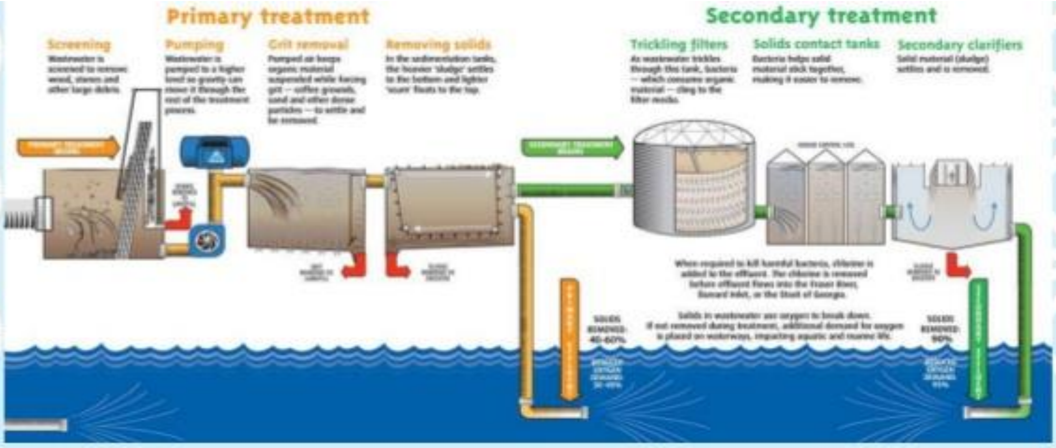
➢ **DISSOLVED OXYGEN:**

- ✓ The larger the amount of dissolved oxygen present in water the better and earlier is the self-purification process.

➢ **RATE OF REAERATION:**

- ✓ The rate at which dissolved oxygen is restored will considerably govern the self-purification process.

- ✓ The greater is this rate, the quicker will self-purification.



DISADVANTAGES

- Additional land is required.
- If land is made up of heavy, sticky and fine grained soils, its voids get chocked and may create nuisance.
- Sanitary reasons may not permit growing of crops on sewage farms.

- The process in which wastewater is evenly distributed over the ground surface which acts as a low rate filter.
- Suspended particles are strained out colloids and organic matter are absorbed by the soil particles.
- Nutrients are utilized by vegetation and more complex organic materials are decomposed to simpler inorganic compounds by soil bacteria.

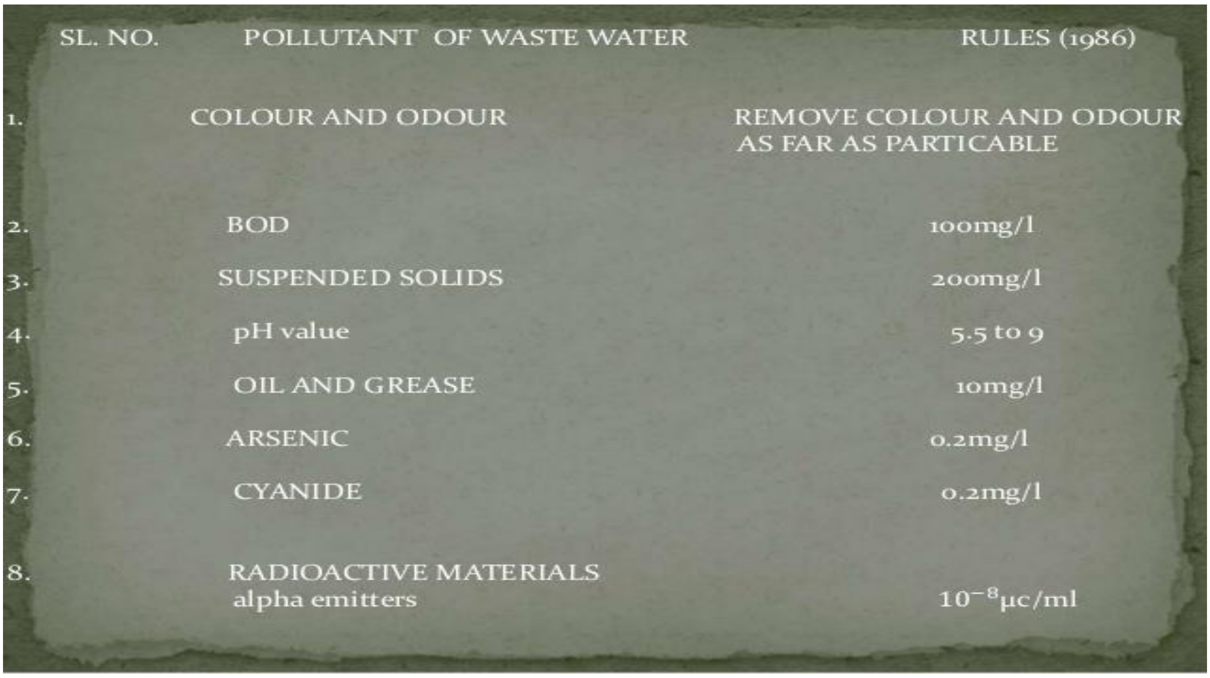
QUALITY STANDARDS FOR WASTE WATER EFFLUENTS TO BE DISCHARGED ON LAND FOR IRRIGATION

- The bureau of Indian standards previously known as Indian standard institution, has vide his code no. 3307-1965 laid down the tolerance limits for various polluting characteristics of Waste water effluents for their discharge on land irrigation.

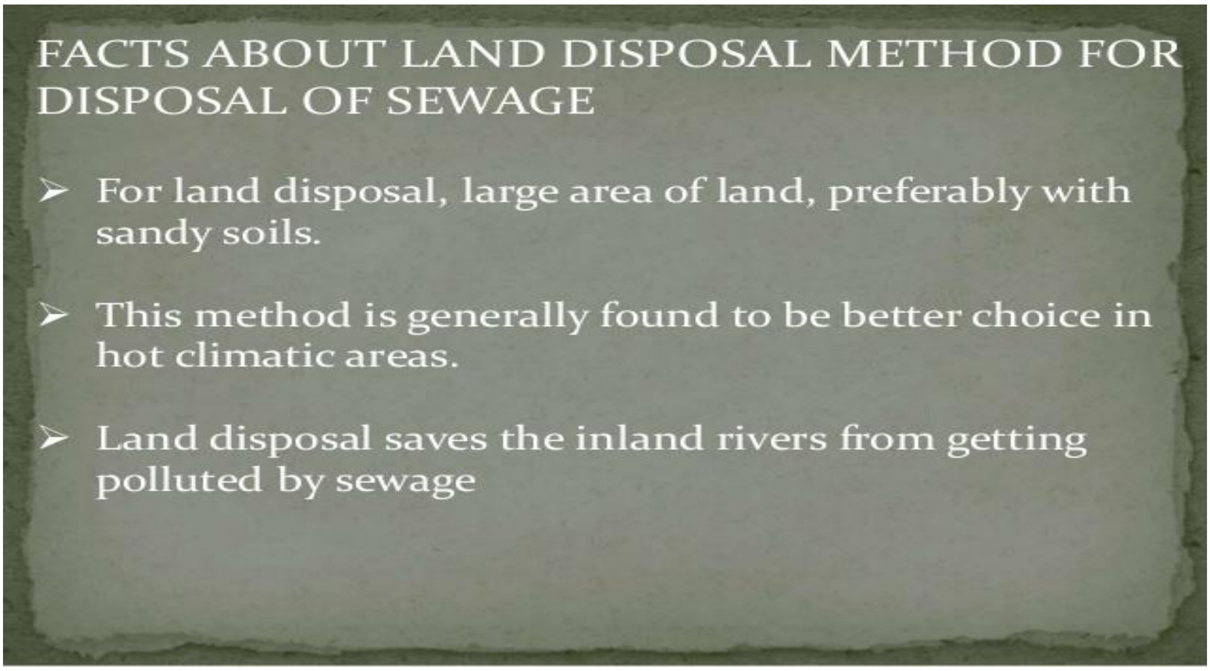
- In order to make them legally enforceable , GOI has notified the standards polluted effluents For discharge on land under environment rules 1986.

- These standards are based upon the quality of irrigation water required by the crops, thus limit the concentration of pollutants contained in sewage.

THESE PRESCRIBE BIS STANDARDS ARE SHOWN IN TABLE



SL. NO.	POLLUTANT OF WASTE WATER	RULES (1986)
1.	COLOUR AND ODOUR	REMOVE COLOUR AND ODOUR AS FAR AS PARTICABLE
2.	BOD	100mg/l
3.	SUSPENDED SOLIDS	200mg/l
4.	pH value	5.5 to 9
5.	OIL AND GREASE	10mg/l
6.	ARSENIC	0.2mg/l
7.	CYANIDE	0.2mg/l
8.	RADIOACTIVE MATERIALS alpha emitters	$10^{-8}\mu c/ml$



CONDITIONS FAVOURABLE FOR LAND TREATMENT

- The area of land treatment is composed of sandy, loamy or alluvial soils.
- Such soils are easily aerated and it is easy to maintain aerobic conditions in them.
- The depth of water table is more even in rainy season so that there are no chances of pollution of underground water sources by land treatment.
- The rainfall in the area is low as it will assist in maintaining good absorption capacity of soil.

- There is absence of river or other natural water sources in the vicinity of disposal of sewage.
- There is demand for cash crops which can be easily grown on sewage farms.
- There is availability of large open areas in the surrounding locality for practicing broad irrigation by sewage.
- **ADVANTAGES OF LAND TREATMENT:**

✓ Increased fertility of land results in profitable returns of crops.

✓ It is cheap where land is available in plenty.

✓ Application of sewage on land is the best method of supplying manure to the soil.

✓ Crops grown on land treated with sewage possess high calorific value and more vitamins.

✓ The method becomes very much useful at places where disposal of sewage by dilution is not possible.

✓ The method does not require costly equipment for its working.

✓ The method proves economical and safe where available irrigation water is scarce in quantity.

✓ The method to some extent charges the underground aquifers.

✓ Water of irrigation canal is saved when this method is practised.

✓ Adds manure to land

✓ Pollution of natural water courses is minimized.

✓ Does not require any installation of equipment involving high initial cost.

✓ Crops could be grown and hence a return value is always possible to obtain.

✓ Method especially suitable where large quantity of river water is not available at all times of the year.

- **DISADVANTAGES OF LAND TREATMENT:**

✓ If proper precautions are not taken, nuisance developed by sewage farming may lead to possible dangers to the health of men.

✓ It is therefore, necessary that the sewage farms should be operated under skilled technical supervision.

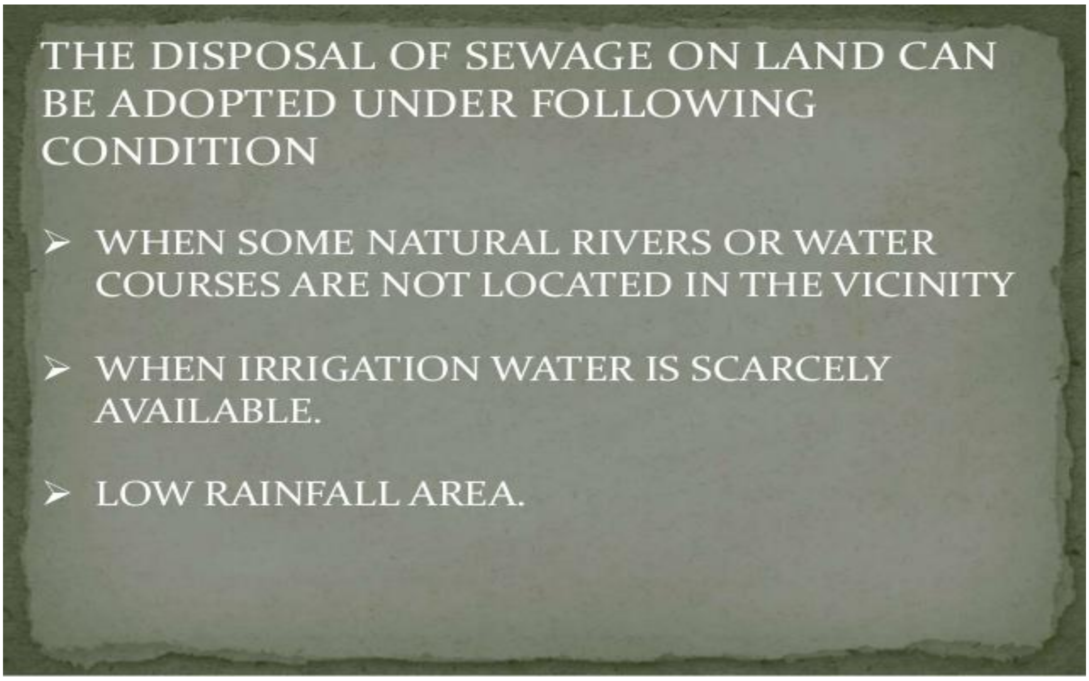
✓ Crops grown on sewage farms are generally not liked by ordinary public.

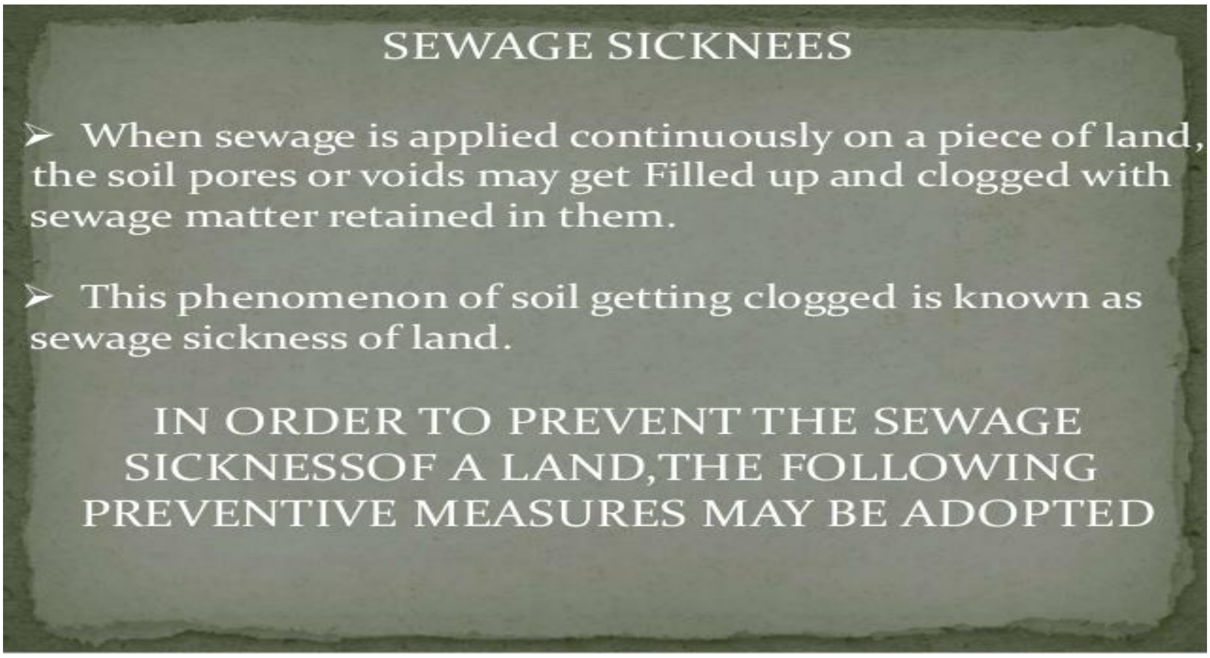
✓ The method is not applicable for all the seasons of year.

✓ In monsoon, some other arrangement of sewage disposal has to be found out.

✓ The method requires large area of land which may not be available in some cases.

- ✓ Types of crops grown on sewage treated land are limited in number.
- ✓ Difficult to get land during rainy and harvest seasons.
- ✓ Additional land is required for reserve.
- ✓ Sanitary reasons may not permit growing of crops on sewage farms.
- ✓ More land area is required is sewage volume is greater since land capacity is limited.
- ✓ If all precautions are not taken, sewage farming results in sewage sickness to land and health to life.





BROAD IRRIGATION:

- ✓ In this method, sewage is allowed to flow over cultivated lands, from which a part of the sewage evaporates, some percolates and the rest escape into surface drainage channels.
- ✓ Sewage waters the land and adds to its fertilizing value, due to the presence of nitrogen, phosphorus, potash etc.
- ✓ These fertilizing elements of sewage are consumed by the roots of crops.
- ✓ Crops like cotton, potatoes, sugarcane, grass etc, can be profitably grown. This is also called sewage farming.

SEWAGE FARMING:

The process in which sewage is used for growing crops is known as sewage farming.

- ✓ The fertilizing elements of sewage i. e nitrates, sulphates, & phosphates are used by the roots of crops.
- ✓ The nutrients of sewage make the fields fertile.
- ✓ It is a profitable business & a good income can be generated by sewage farming.

SEWAGE SICKNESS:

- ✓ If sewage is applied continuously on a piece of land, pores or voids of soil are filled up or clogged.
- ✓ Free circulation of air is thereby prevented and anaerobic conditions develop.
- ✓ At this stage, the land is unable to take any further sewage load.
- ✓ Organic matter decomposes and foul-smelling gases are produced.
- ✓ The phenomena of soil are known as sewage sickness of land.

PREVENTIVE MEASURES:

In order to prevent sewage sickness of land, the following preventive measures may be adopted

ALTERNATIVE ARRANGEMENT:

- ✓ There should be ample provision of extra land so that land with sewage sickness can be given the desired rest.
- ✓ Alternatively, sewage should be disposed of by some other method when sewage farms are taking rest.

DEPTH OF SEWAGE:

- ✓ If sewage is applied in excess, the chances of sewage sickness are increased.
- ✓ The land is unable to receive the excess sewage in a satisfactory way and it ultimately clogs up.
- ✓ 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.

DRAINAGE OF SOIL:

- ✓ Subsoil drain pipes should be laid in sufficient number to collect the percolated effluent.

INTERMITTENT APPLICATION:

- ✓ Sewage should be applied on land at intervals.

- ✓ The period between successive applications depends on general working of sewage farm and the permeability of soil.
- ✓ Depending on the nature of the soil, this period between successive applications varies from few hours to few weeks.

PRETREATMENT OF SEWAGE:

- ✓ sewage should be given some pre-treatment before it is applied on land.

ROTATION OF CROPS:

- ✓ It is desirable to grow different types of crops on a piece of land instead of one single crop.
- ✓ Rotation of crops minimizes the chances of sewage sickness.

TREATMENT TO LAND:

- ✓ The land affected by sewage sickness should be properly treated before it is put up in use again.
- ✓ Clogged surfaces should be broken by suitable equipment.

PREVENTION OF SEWAGE SICKNESS:

Primary treatment like screening & sedimentation should be given to sewage before its application to land so that suspended solids are removed & the pores of soil will not be clogged.

The sewage should be applied intermittently on land i.e by giving rest to the land for some time.

The land should be ploughed during non-supply period of sewage so that soil gets aerated.

Keeping some portion of land reserved in order to use the same in resting period.

Enough area will be required for this purpose.

By planting different crops on the same land by rotation system of crops.

The soil will be aerated & will utilize the fertilizing elements of sewage.

By providing sufficient under drainage system to collect the excessive sewage quantity.

By frequent ploughing & rotation of soil.

By not applying the sewage in excess quantity.

SOIL DISPERSION SYSTEM

A mound system for wastewater treatment is a soil absorption system placed above the natural surface of the ground.

In pressure-dosed mounds, primary treated effluent is dispersed into carefully chosen fill of permeable, well-drained sands which contain a high volume of free air within the pore space.

A proprietary dispersal system is available that treats effluent from a septic tank, releasing much cleaner water into the soil than standard dispersal systems.

CHARACTERISTICS OF SLUDGE

The sludge has an objectionable odour and it may pollute the environment.

It is bulky and contains large amount of water.

Its specific gravity may be taken as very nearly equal to that of water.

In 100 parts of sludge, about 98 % of water and remaining 2 % only the solid matter present in the sludge.

In the moisture content of the sludge is reduced to about 70 % to 80 %, the sludge become viscous.

If the moisture content is reduced to 10 %, the sludge becomes dry and assumes powder form.

The water is so firmly held in the sludge and it requires special treatment for water removal from the sludge.

SLUDGE TREATMENT

- Before disposing the sludge, it should undergo various unit processes are:
- ✓ Sludge Thickening
- ✓ Sludge Digestion
- ✓ Elutriation
- ✓ Sludge Dewatering

OBJECTIVES OF SLUDGE TREATMENT:

- The sludge from primary sedimentation tank and sludge from secondary sedimentation units contains 96 % to 99 % of moisture content in its volume.
- Before disposing the sludge, the moisture should be removed in order to reduce the volume of sludge disposal.
- To reduce the cost of transport for heavy volume of disposal.
- To minimize the land requirement.
- To save the additional fuel required for incineration method of sewage disposal.

SLUDGE DIGESTION

Sludge digestion is a biological process in which organic solids are decomposed into stable substances.

Digestion reduces the total mass of solids, destroys pathogens, and makes it easier to dewater or dry the sludge.

Digested sludge is inoffensive, having the appearance and characteristics of a rich potting soil.

Sludge, the by-product of biological wastewater treatment is also considered as biomass.

Energy recovery from sludge is possible through sludge incineration (biomass-to-energy) or by means of sludge digestion (biomass-to-biogas).

The methane generation is a key advantage of the anaerobic process.

The methane can be used to generate heat and electric power in cogeneration units while reducing the carbon footprint and greenhouse emissions of the wastewater treatment plant.

After sludge digestion, the digestate can be stabilized for landfill or used as fertilizer, depending on its composition and local legislation.

An alternative is to further mechanically dewater the sludge prior to thermal drying and incineration.

Most large sewage treatment plants use a two-stage digestion system in which organics are metabolized by bacteria anaerobically (in the absence of oxygen).

In the first stage, the sludge, thickened to a dry solids (DS) content of about 5 percent, is heated and mixed in a closed tank for several days.

Acid-forming bacteria hydrolyze large molecules such as proteins and lipids, breaking them into smaller water-soluble molecules, and then ferment those smaller molecules into various fatty acids.

The sludge then flows into a second tank, where the dissolved matter is converted by other bacteria into biogas, a mixture of carbon dioxide and methane.

Methane is combustible and is used as a fuel to heat the first digestion tank as well as to generate electricity for the plant.

Anaerobic digestion is very sensitive to temperature, acidity, and other factors.

It requires careful monitoring and control.

In some cases, the sludge is inoculated with extra hydrolytic enzymes at the beginning of the first digestion stage in order to supplement the action of the bacteria.

It has been found that this enzymatic treatment can destroy more unwanted pathogens in the sludge and also can result in the generation of more biogas in the second stage of digestion.

Another enhancement of the traditional two-stage anaerobic digestion process is thermal hydrolysis, or the breaking down of the large molecules by heat.

This is done in a separate step before digestion.

In a typical case, the process begins with a sludge that has been dewatered to a DS content of some 15 percent.

The sludge is mixed with steam in a pulper, and this hot homogenized mixture is fed to a reactor, where it is held under pressure at approximately 165 °C (about 330 °F) for about 30 minutes.

At that point, with the hydrolytic reactions complete, some of the steam is bled off (to be fed to the pulper), and the sludge, still under some pressure, is released suddenly into a "flash tank," where the sudded drop in pressure bursts the cell walls of much of the solid matter.

The hydrolyzed sludge is cooled, diluted slightly with water, and then sent directly to the second stage of anaerobic digestion.

Sludge digestion may also take place aerobically—that is, in the presence of oxygen.

The sludge is vigorously aerated in an open tank for about 20 days.

Methane gas is not formed in this process.

Although aerobic systems are easier to operate than anaerobic systems, they usually cost more to operate because of the power needed for aeration.

Aerobic digestion is often combined with small extended aeration or contact stabilization systems.

Aerobic and conventional anaerobic digestion convert about half of the organic sludge solids to liquids and gases.

Thermal hydrolysis followed by anaerobic digestion can convert some 60 to 70 percent of the solid matter to liquids and gases.

Not only is the volume of solids produced smaller than in conventional digestion, but the greater production of biogas can make some wastewater treatment plants self-sufficient in energy.

ADVANTAGES:

- Reduction of sludge volume.
- Production of biogas available for heat and electric power generation.
- Reduction of greenhouse gases.

SLUDGE DIGESTER

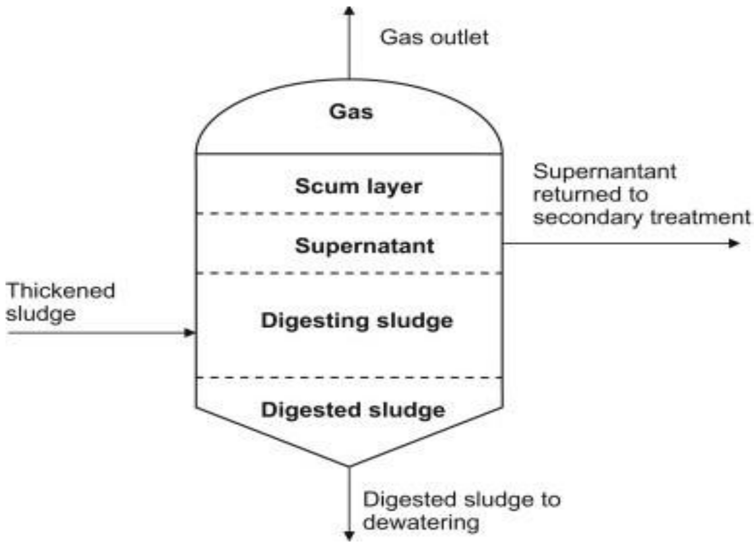


Figure No.1

The digesters are closed circular tanks 30 m in diameter and up to 12 m deep.

The digestion uses the naturally-occurring anaerobic (i.e. living without oxygen) microorganisms to break down organic materials into methane and carbon dioxide.

The sludge is heated to 37 degrees C in the primary digester to improve the rate of digestion.

The sludge then enters the secondary digester.

Anaerobic digestion is a biological process which breaks down a significant number of organic solids in the sludge and at the same time produces methane gas that is used as a boiler fuel for plant heating.

Consequently, the volume of final sludge is significantly reduced. So is the cost for sludge disposal.

The mixture of sludge and liquid in the secondary digester is hauled by truck to Edmonton’s Clover Bar Sludge Lagoons for disposal.

The digesters are equipped with gas compressors and sludge recirculation pumps to provide adequate mixing capability for better digestion of sludge and production of methane gas.

SLUDGE CONDITIONING

Sludge conditioning is a process whereby sludge solids are treated with chemicals or various other means to prepare the sludge for dewatering processes, in other words, to improve dewatering characteristics of the sludge.

MECHANISMS TO CONDITION THE SLUDGE:

There are two mechanisms involved in sludge conditioning:

1. Neutralization of charge (double layer theory)
2. Bridging of individual particles into a floc structure (polymer bridge formation)

SLUDGE DEWATERING

Digested sewage sludge is usually dewatered before disposal.

Dewatered sludge still contains a significant amount of water—often as much as 70 percent—but, even with that moisture content, sludge no longer behaves as a liquid and can be handled as a solid material.

Sludge-drying beds provide the simplest method of dewatering.

A digested sludge slurry is spread on an open bed of sand and allowed to remain until dry.

Drying takes place by a combination of evaporation and gravity drainage through the sand.

A piping network built under the sand collects the water, which is pumped back to the head of the plant.

After about six weeks of drying, the sludge cake, as it is called, may have a solids content of about 40 percent.

It can then be removed from the sand with a pitchfork or a front-end loader.

In order to reduce drying time in wet or cold weather, a glass enclosure may be built over the sand beds.

Since a good deal of land area is needed for drying beds, this method of dewatering is commonly used in rural or suburban towns rather than in densely populated cities.

SLUDGE DISPOSAL

The final destination of treated sewage sludge usually is the land.

Dewatered sludge can be buried underground in a sanitary landfill.

It also may be spread on agricultural land in order to make use of its value as a soil conditioner and fertilizer.

The suspended solids that accumulate at the bottom of the clarifiers or settling tank is called sludge.

There are different types of sludge based on the sources are:

Chemically precipitated sludge

Trickling filter sludge

Digested sludge

Sludge from settling tank

Sludge from activated sludge process.

The sewage after treatment is separated into two different parts:

Effluent

Sludge

The effluent is clear sparkling liquid and sludge is a combination of suspended solids with different proportions of water.

The disposal of effluent is not a problem whereas the disposal of sludge should be carefully done in order to avoid the pollutions.

The effluent can be used for various purposes such as street washing, fish culture, growing crops, industrial supply, watering for public park etc.