Waste Water Engineering/ Sanitary Engineering

Definitions of some common terms

Refuse

This is the most general term to indicate the wastes which include all the rejects left as worthless.

Garbage

- It is a dry refuse which includes, waste papers, sweepings from streets and markets, vegetable peelings etc.
- The quantity of garbage per head per day amounts to be about .14 to .24 kg for Indian conditions.
- Garbage contains large amount of organic and putrefying matter and therefore should be removed as quickly as possible.

Rubbish

- It consists of sundry solid wastes from the residences, offices and other buildings.
- Broken furniture, paper, rags etc., are included in this term.
- It is generally dry and combustible.

Sullage

It is the discharge from the bath rooms, kitchens, wash basins etc., it does not include discharge from the lavatories, hospitals, operation theatres, slaughter houses which has a high organic matter.

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 amount 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.

Sewers

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

Sewerage

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

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.

Bacteria

These are the microscopic organisms.

Types of bacteria based on air requirement

- **Aerobic bacteria-** they require oxygen &light for their survival.
- **Anaerobic bacteria**-they do not require free oxygen and light for survival.
- **Facultative bacteria**- they can exist in the presence or absence of oxygen. They grow more in absence of air.

Invert

It is the lowest point of the interior of the sewer at any cross section.

Sludge

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

Sources of Sewage

- 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 supplied by water works authorities or provided from private sources for manufacturing various products and thus develop the sewage.
- Water supplied to schools, cinemas, hotels, railway stations, etc., when gets used develops sewage.
- Infiltration of Ground water into sewers through leaky joints.
- Unauthorized entrance of rain water in sewer lines.

Importance of sewerage system

One of the fundamental principles of sanitation of the community is to remove all decomposable matter, solid waste, liquid or gaseous away from the premises of dwellings as fast as possible after it is produced, to a safe place , without causing any nuisance and dispose it in a suitable manner so as to make it permanently harmless.

Necessity for sanitation

- Every community produces both liquid and solid wastes.
- If proper arrangements for the collection, treatment and disposal are not made, they will go on accumulating and create foul condition.

- If untreated water is accumulating, the decomposition of the organic materials it contains can lead to the production of large quantity of mal odorous gases.

- It also contains nutrients, which can stimulate the growth of aquatic plants and it may contain toxic compounds.
- Therefore in the interest of community of the city or town, it is most essential to collect, treat and dispose of all the waste products of the city in such a way that it may not cause any hazardous effects on people residing in town and environment.
- **Waste water engineering is defined as the branch of the environmental engineering where the basic principles of the science and engineering for the problems of the water pollution problems.**
- The ultimate goal of the waste water management is the protection of the environmental in manner commensurate with the economic, social and political concerns.

Systems of sewerage

1) **Separate System of Sewage**
2) **Combined System of Sewage**
3) **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 is 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 clogging problem will be there.

- 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 Sewerage

- 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, clogging problems are less and easy to clean.
- It proves economical as one 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 separate and combined systems.
- Silting problem is completely eliminated.

Disadvantages

- During dry weather, the velocity of flow may be low.
- The storm water is unnecessary put load on to the treatment plants to extend.
- Pumping of storm water causes unnecessary over-load on the pumps.

Suitable conditions for separate sewerage systems

- 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, where 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.

Conclusions

- After studying the advantages and disadvantages of both the systems, present day construction of sewers is largely confined to **the separate systems** except in those cities where combined system already exists.
- In places where rainfall is confined to one season of the year, like **India** and even in temperate regions, **separate system are most suitable.**

Comparison of Separate and combined system

S.No	Separate system	Combined system
1	The quantity of sewage to be treated is less, because no treatment of storm water is done.	As the treatments of both are done, the treatment is costly.
2	In the cities of more rainfall this system is more suitable.	In the cities of less rainfall this system is suitable.
3	As two sets of sewer lines are too laid, this system is cheaper because sewage is carried in underground sewers and storm	Overall construction cost is higher than separate system.
4	In narrow streets, it is difficult to use this system.	It is more suitable in narrow streets.
5	Less degree of sanitation is achieved in this system, as storm water is disposed without any treatment.	High degree of sanitation is achieved in this system.

UNIT I PLANNING AND DESIGN OF SEWERAGE SYSTEM

Characteristics and composition of sewage-- population equivalent -Sanitary sewage flow estimation – Sewer materials – Hydraulics of flow in sanitary sewers – Sewer design – Storm drainage-Storm runoff estimation – Maintenance of sanitary sewerage and storm drainage– sewer appurtenances – corrosion in sewers –prevention and control – sewage pumping drainage in buildings-plumbing systems for drainage.

Characteristics and composition of sewage

Characteristics of Wastewater

The three main characteristics of wastewater are classified below.

1. Physical Characteristics

- Turbidity
- Color
- Odor
- Total solids
- Temperature

2. Chemical Characteristics

- Chemical Oxygen Demand (COD)
- Total Organic Carbon (TOC)
- Nitrogen
- Phosphorus
- Chlorides
- Sulphates
- Alkalinity
- pH
- Heavy Metals
- Trace Elements
- Priority Pollutants

3. Biological Characteristics due to Contaminants

- Biochemical Oxygen Demand (BOD)
- Oxygen required for nitrification
- Microbial population

Physical Characteristics

Turbidity

- Sewage is highly turbid.
- Turbidity in wastewater is caused by suspended matter, such as clay, silt, finely divided organic and inorganic matter, soluble coloured organic compounds, and plankton and other microscopic organisms.
- The turbidity increases as sewages become stronger.
- Turbidity imparts an enormous problem in waste water treatment.

Colour

- Colour of sewage indicates its strength and age.
- Fresh domestic sewage is grey in colour but septic sewage is dark in colour.
- When industrial effluent is mixed it give characteristic colour to sewage.

Odour

- Fresh domestic sewage is almost odourless.
- Septic or stale sewage is putrid in odour which is due to generation of H_2S during anaerobic decomposition of organic matters.
- When industrial effluent is mixed, it gives characteristics odour to sewage.

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.

Total Solids

- **Suspended Solids**
- **Dissolved solids**
- **Settleable solids**

Total solids (TS)

The amount of all solids which are determined by drying a known volume of the sample in a pre-weighed crucible dish at 105°C.

After cooling in desiccator, the crucible dish is again weighed.

$$TS = (W_1 – W_2) / V$$

Where

W_1 - mass of crucible dish after drying at 105°C (mg)

W_2 - mass of initial crucible dish (mg)

V - Volume of sample (L)

Suspended solids (SS)

The solids retaining in a filter and is usually determined by filtration using glass fibre filters. In all analytical procedures for determination of suspended solids, weighed filters are used for sample filtration, the filters are dried at about 105°C after filtration, cooled in desiccator to room temperature and the weight of the loaded filter is determined.

SS is determined by

$$SS = (W_4 – W_5) / V$$

Where

W_4 - mass of filter after drying at 105°C (mg)

W_5 - mass of initial filter (mg)

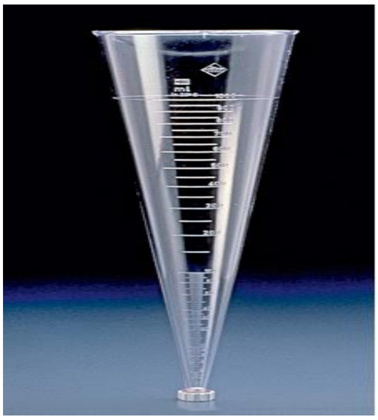
V- Volume of sample (L)

Dissolved solids (DS) or filterable solids

- It can be determined by subtracting SS from TS.
- The solids passing through the filter consist of colloidal and dissolved solids.

Settleable solids

Solids that will settle to the bottom of an Imhoff cone (a cone shaped container) in one hour and determined by allowing a wastewater sample to stand for one hour in an Imhoff cone which enables to read the volume of the settled solids. It is expressed as mL/L and is important, because it is related to the efficiency of sedimentation tanks.



Volatile solids (VS)

The amount of solid that volatilises when heated at 550°C.

This is a useful estimation for organic matter present in wastewater and is determined by burning the total solid at 550°C for about 2 hours in a muffle furnace.

After cooling in desiccator to room temperature, it is weighed.

VS is determined by

$$VS = (W_1 – W_3)/V$$

Where

W_1 - mass of crucible dish after drying at 105°C (mg)

W_3 - Mass of crucible dish after ignition at 550°C (mg))

V - Volume of sample (L)

Fixed solids (FS)

The amount of solids that does not volatilise at 550°C.

This measure is used to gauge the amount of mineral matter in wastewater.

It is the difference between TS and VS.

It can be divided in a suspended and a filterable fraction.

Volatile suspended solids (VSS)

VSS are the one portion of SS which are defined as that part of SS which can be removed by heating the solids at 550°C in a muffle furnace.

The suspended solids is burned at 550°C for 2 hours in a muffle furnace and weighed after cooling in desiccator to room temperature.

VSS is determined by

$VSS= (W_4 – W_6)/V$

W_4 - mass of filter after drying at 105 °C (mg)

W_6 - mass of filter after ignition at 550 °C (mg)

V - Volume of sample (L))

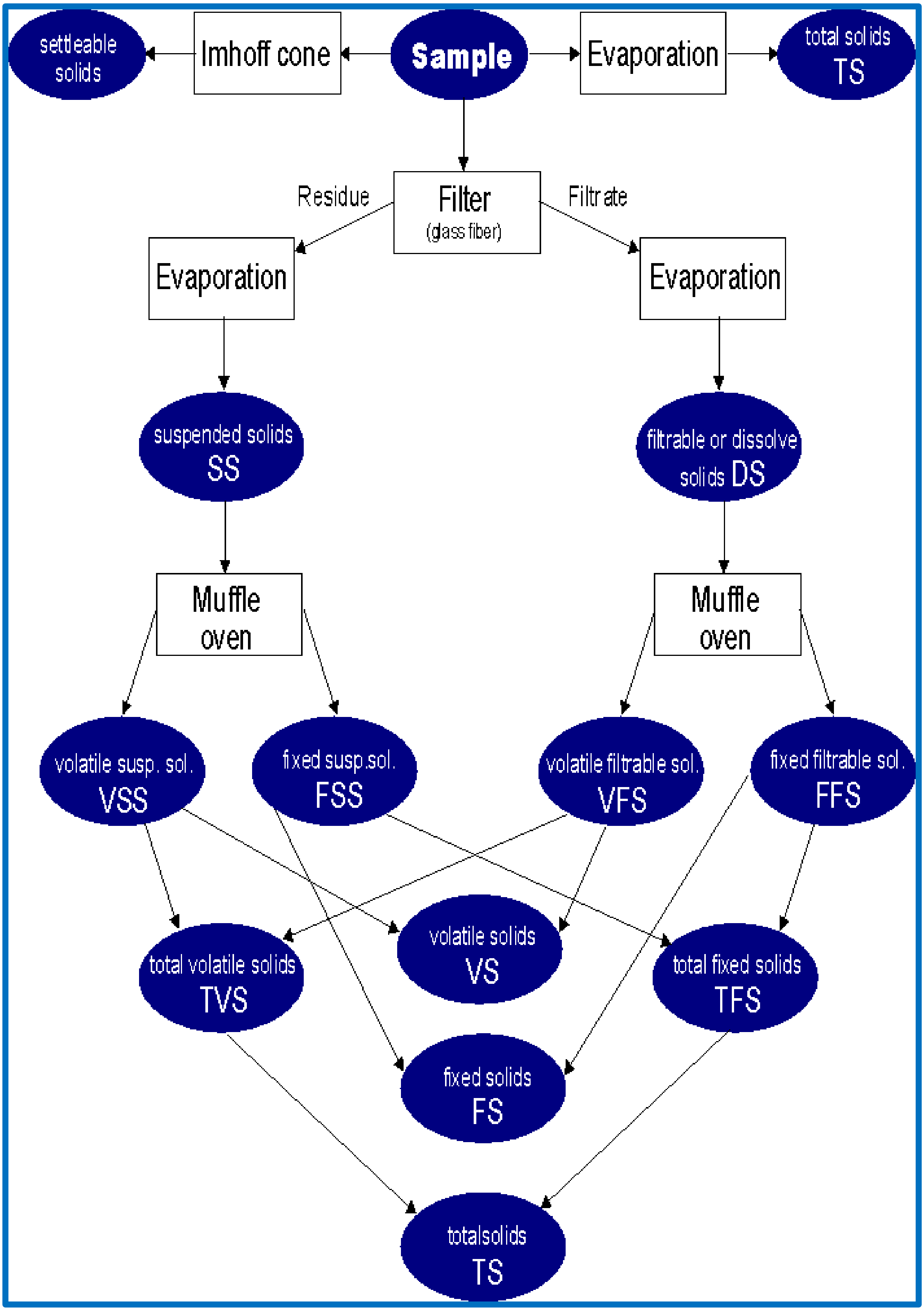
Fixed suspended solids (FSS)

The solids which left after ignition at 550°C of suspended solids are known as FSS.

It is determined by

$$FSS = SS-VSS$$

Interrelationships of solids found in wastewater



Composition of sewage

Domestic waste water has a solids content of about 0.1%.

The solids can be suspended (about 30%) as well as dissolved (about 70%).

Chemically, wastewater is composed of organic (70%) and inorganic (30%) compounds as well as various gases.

Organic compounds consist primarily of carbohydrates (25 %), proteins (65 %) and fats (10 %), which reflect the diet of the people.

Inorganic components may consist of heavy metals, nitrogen, phosphorous, pH, sulphur, chlorides, alkalinity, toxic compounds, etc.

However, since wastewater contains a higher portion of dissolved solids than suspended, about 85 to 90% of the total inorganic component is dissolved and about 55 to 60% of the total organic component is dissolved.

Gases commonly dissolved in wastewater are hydrogen sulphide, methane, ammonia, oxygen, carbon dioxide and nitrogen. The first three gases result from the decomposition of organic matter present in the wastewater.

Chemical Characteristics of waste water

p^H

The p^H of sewage indicates the negative log of hydrogen ion concentration present in sewage.

It is an indicator of the alkalinity of the sewage.

p^H < 7.0 – The sewage is acidic.

p^H > 7.0 – The sewage is alkaline.

p^H $= 7.0$ – The sewage is neutral

The **fresh sewage is alkaline** in nature but when the time passes its p^H tends to fall due to the production of acids by bacterial action in anaerobic process or in nitrification process.

Significance of p^H

The determination of pH value of sewage is important because the efficiency of certain treatment methods depends upon the availability of pH.

Measurement

p^H- measured by potentiometer

Chloride content

- The normal chloride content for water supplies is 250 mg/l. However, large amounts of chlorides may enter from industries.
- Hence, when the chloride content of given waste water is found to be high, it indicates the presence of industrial waste.
- The chloride content can be measured by treating the waste water with standard silver nitrate solution, using potassium chromate as indicator, as is done for testing water supplies.

Nitrogen content

The presence of nitrogen in waste water indicates the presence of organic matter, and may occur in one or more of the following forms:

- Free ammonia called as ammonia nitrogen;
- Albuminoid nitrogen called Organic nitrogen;
- Nitrates
- Nitrites

Forms of nitrogen

- **The free ammonia** indicates the very first stage of decomposition of organic matter;
- **Albuminoid nitrogen** indicates the quality of nitrogen present in waste water before the decomposition of organic matter is started.
- **The nitrites** indicate the presence of partly decomposed organic matter.
- **Nitrates** indicate the presence of fully oxidised organic matter.

Measurement

- The amount of free ammonia present in waste water can be easily measured by simply boiling the waste water, and measuring the ammonia gas which is consequently liberate.
- The amount of Albuminoid nitrogen can be measured by adding strong alkaline solution of potassium permanganate ($KMnO_4$) to the already boiled waste water sample and again boil the same, when ammonia gas is liberated, which is measured, so as to indicate the amount of Albuminoid nitrogen present in waste water.

- If however an un-boiled sample is used to add $KMnO_4$ before boiling, the evolved ammonia gas will measure the sum total of ammonia nitrogen as well as organic nitrogen; known as **Kjedahl nitrogen**.
- The amount of nitrates or nitrites present in the waste water sample can be measured by the colour matching method.
- For nitrites, the colour is developed by adding sulphonic acid and naphthamine; whereas
- For nitrates, the colour is developed by adding phenol-di-sulphonic acid and potassium hydroxide.
- The colour developed in waste water is finally compared with the standard colours of known concentrations.

Presence of fats, oils and gases

- Grease, Fats and Oils are derived in waste water from the discharge of animals and vegetable matter, or from the industries like garages, kitchens of hotels and restaurants etc.,
- Such matters form scum on the top of the sedimentation tank and clog the voids of the filtering media.
- They thus interfere with the normal treatment methods, and hence need proper detection and removal.
- The amount of Fats and greases in the waste water sample is determined by making use of the fact that oils and greases are soluble in ether, and when the ether is evaporated, it leaves behind the ether-soluble matters, which represents the quantity of fats and oils.
- Hence, in order to estimate their amount, a sample of waste water is, first of all, evaporated.
- The residual solids left are then mixed with ether (hexane).
- The solution is then poured off and evaporated, leaving behind the greases and fats as residue, which can be easily weighed.

Sulphates, Sulphides and Hydrogen Sulphide Gas

- The determination of Sulphides and Sulphate in the waste water is rarely called far, although their presence reflects aerobic, and/or anaerobic de-composition.
- Sulphides and Sulphates are formed due to the decomposition of various Sulphur containing substances present in waste water.

- This decomposition also leads to evaluation of hydrogen sulphide gas, causing bad smells and odours, besides causing corrosion of concrete sewer pipes.
- In aerobic digestion of waste water, the aerobic and facultative bacteria, oxidises the sulphur and its compounds present in waste water to initially form sulphides, which ultimately break down to form sulphate ions (So_4^-), which is a stable and an unobjectionable end product.
- The initial decomposition is associated with the formation of H_2S gas, which also ultimately gets oxidised to form sulphate ions.
- In anaerobic digestion of sewage, however, the anaerobic and facultative bacteria reduce the sulphur and its compounds into sulphides, with evolution of H_2S gas along with methane and carbon dioxide, thus causing very obnoxious smells and odours.
- If, however, the quantity of H_2S in raw waste water is below 1ppm, obnoxious odours are not felt.

Dissolved Oxygen (D.O)

- The determination of dissolved oxygen present in sewage is very important, because while discharging the treated waste water into some river stream, it is necessary to ensure at least 4ppm of D.O. in it; as otherwise, fish are likely to be killed, creating nuisance near the vicinity of disposal.
- To ensure this, D.O. tests are performed during waste water disposal treatment process.
- If temperature of waste water is more, the D.O. content will be less. The solubility of oxygen in waste water is 95% of that in the distilled water.
- The D.O. content of waste water is generally determined by the **Winkler's method** which is basically an oxidation-reduction process carried out chemically to liberate iodine in amount equivalent to the quantity of dissolved oxygen originally present.

Chemical Oxygen Demand (COD)

- The organic matter present in water can be measured in a number of ways, Volatile solids determination being a crude measure of organic matter.
- Organic matter is most often assessed in terms of oxygen required to completely oxidise the organic matter to CO_2, H_2O and other oxidised species.
- The oxygen required to oxidise the organic matter present in given waste water can be theoretically computed, if the organics present in waste water are known.
- Thus, if the chemical formulas and the concentration of the chemical compounds present in water are known to us, we can easily calculate the theoretical oxygen

demand of each of these compounds by writing the balanced reaction for the compound with oxygen to produce CO_2, H_2O and oxidised inorganic compounds.

- Hence, if the organic compounds and their concentrations are known, the theoretical oxygen demand of the water can be accurately calculated, but it is virtually impossible to know the details of the organic compounds present in any natural raw water or a waste water.$KMnO_4$ and $K_2Cr_2O_7$ are used as oxidising agents.

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, and hence the chemical formula of every organic compound will reflect the extent of carbon present in that compound.
- Known concentrations of such chemical compounds in given waste water will thus enable us to theoretically calculate the carbon present in waste water per litre of solution.

Bio-Chemical Oxygen Demand (B.O.D)

- The organic matter, in fact, is of two types; i.e. that which is biologically oxidised (i.e. oxidised by bacteria) and is called biologically active or biologically degradable, and that which cannot be oxidised biologically is called biologically active.
- While testing a waste water, we are mainly interested in finding out the amount of biologically active organic matter present in it; whereas, the above COD test gives us the total of biologically active as well as biologically inactive organic matter.
- Hence, further testing is carried out to determine the BOD of waste water, which directly gives us the amount of biologically active organic matter present in waste water.

Bacteriological characteristics

- The bacterial characteristics of waste water are due to the presence of bacteria and other living microorganisms, such as algae, fungi, protozoa, etc.
- The former are more active.
- The vast number of bacteria present in waste water (of the order 5-50 billion per litre of waste water) is harmless non-pathogenic bacteria.
- They are useful and helpful in bringing oxidation and decomposition of waste water.

- A little number of bacteria, however, is disease producing pathogens, and it is they who constitute the real danger to the health of the public.

Population equivalent

The population equivalent indicates the strength of the industrial waste waters for estimating the treatment required at the municipal sewage treatment plant, and also helps in assessing realistic charges for this treatment to be charged from the industries instead of charging them simply by the volume of sewage.

The population equivalent = $\frac{\text{Total BOD5 of the industry in Kg/day}}{\text{Standard BOD5 of domestic sewage per person per day}}$

Sanitary sewage flow estimation

Evaluation of Sewage Discharge

- Correct estimation of sewage discharge is necessary; otherwise sewers may prove inadequate resulting in overflow or may prove too large in diameter, which may make the system uneconomical and hydraulically inefficient.
- Hence, before designing the sewerage system it is important to know the discharge / quantity of the sewage, which will flow in it after completion of the project and at the end of design period.

Apart from accounted water supplied by water authority that will be converted to wastewater, following quantities are considered while estimating the sewage quantity:

1. Addition due to unaccounted private water supplies

- People using water supply from private wells, tube wells, etc. contribute to the wastewater generation more than the water supplied by municipal authority.
- Similarly, certain industries utilize their own source of water.
- Part of this water after desired uses is converted into wastewater and ultimately discharged in to sewers.
- This quantity can be estimated by actual field observations.

2. Addition due to infiltration

- This is additional quantity due to groundwater seepage in to sewers through faulty joints or cracks formed in the pipes.
- The quantity of the water depends upon the height of the water table above the sewer invert level.

- If water table is well below the sewer invert level, the infiltration can occur only after rain when water is moving down through soil.
- The quantity of the water entering sewers depends upon the permeability of the ground soil and it is very difficult to estimate.
- Storm water drainage may also infiltrate into sewers. This inflow is difficult to calculate. Generally, no extra provision is made for this quantity. This extra quantity can be taken care of by extra empty space left at the top in the sewers, which are designed for running ¾ full at maximum design discharge.

3. Subtraction due to water losses

The water loss, through leakage in water distribution system and house connections, does not reach consumers and hence, not appear as sewage.

4. Subtraction due to water not entering the sewerage system

Certain amount of water is used for such purposes, which may not generate sewage, e.g. boiler feed water, water sprinkled over the roads, streets, lawns, and gardens, water consumed in industrial product, water used in air coolers, etc.

Net quantity of sewage

The net quantity of sewage production can be estimated by considering the addition and subtraction as discussed above over the accounted quantity of water supplied by water authority as below:

Net quantity of sewage = Accounted quantity of water supplied from the water works +Addition due to unaccounted private water supplies (1) + Addition due to infiltration (2) – Subtraction due to water losses (3) – Subtraction due to water not entering the sewerage system (4)

Generally, 75 to 80% of accounted water supplied is considered as quantity of sewage produced.

Variation in Sewage Flow

Variation occurs in the flow of sewage over annual average daily flow.

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

For estimating design discharge following relation can be considered:

Maximum daily flow = Two times the annual average daily flow (representing seasonal variations)

Maximum hourly flow = 1.5 times the maximum daily flow (accounting hourly

variations)

= Three times the annual average daily flow

- For smaller population served (less than 50000) the peak factor can be 2.5, and as the population served increases its value reduces.
- For large cities it can be considered about 1.5 to 2.0.
- Therefore, for outfall sewer the peak flow can be considered as 1.5 times the annual average daily flow.
- Even for design of the treatment facility, the peak factor is considered as 1.5 times the annual average daily flow.
- The minimum flow passing through sewers is important to develop self-cleansing velocity to avoid silting in sewers.
- This flow will generate in the sewers during late night hours.
- The effect of this flow is more pronounced on lateral sewers than the main sewers.

Sewers must be checked for minimum velocity as follows:

Minimum daily flow = 2/3 Annual average daily flow

Minimum hourly flow = ½ minimum daily flow

= 1/3 Annual average daily flow

The overall variation between the maximum and minimum flow is more in the laterals and less in the main or trunk sewers. This ratio may be more than 6 for laterals and about 2 to 3 in case of main sewers.

Design Period

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

The design period depends upon the following:

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

Design period considered for different components of sewage scheme are

1. Laterals less than 15 cm diameter : Full development

2. Trunk or main sewers : 40 to 50 years

3. Treatment Units : 15 to 20 years

4. Pumping plant : 5 to 10 years

Design Discharge of Sanitary Sewage

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

Storm drainage-Storm runoff estimation

Factors Affecting the Quantity of Storm Water

The surface run-off resulting after precipitation contributes to the storm water.

The quantity of storm water reaching to the sewers or drains is very large as compared with sanitary sewage.

The factors affecting the quantity of storm water flow are as below:

- Area of the catchment
- Slope and shape of the catchment area
- Porosity of the soil
- Obstruction in the flow of water as trees, fields, gardens, etc.
- Initial state of catchment area with respect to wetness.
- Intensity and duration of rainfall
- Atmospheric temperature and humidity
- Number and size of ditches present in the area

Measurement of Rainfall

- The rainfall intensity could be measured by using **rain gauges** and recording the amount of rain falling in unit time.
- The rainfall intensity is usually expressed as **mm/hour or cm/hour**.
- The rain gauges used can be manual recording type or automatic recording rain gauges.

Methods for Estimation of Quantity of Storm Water

1. Rational Method

2. Empirical formulae method

In both the above methods, the quantity of storm water is considered as function of intensity of rainfall and coefficient of runoff.

Time of Concentration:

- The period after which the entire catchment area will start contributing to the runoff is called as the time of concentration.
- The rainfall with duration lesser than the time of concentration will not produce maximum discharge.
- The runoff may not be maximum even when the duration of the rain is more than the time of concentration.
- This is because in such case the intensity of rain reduces with the increase in its duration.
- The runoff will be maximum, when the duration of rainfall is equal to the time of concentration and is called as critical rainfall duration.
- The time of concentration is equal to sum of inlet time and time of travel.

Time of concentration = Inlet time + time of travel

Inlet Time:

The time required for the rain in falling on the most remote point of the tributary area to flow across the ground surface along the natural drains or gutters up to inlet of sewer is called inlet time.

This coefficient will have different values for different catchments.

Time of Travel:

The time required by the water to flow in the drain channel from the mouth to the point under consideration or the point of concentration is called as time of travel.

Time of Travel (T_t) = Length of drain/ velocity in drain

Runoff Coefficient:

The total precipitation falling on any area is dispersed as percolation, evaporation, storage in ponds or reservoir and surface runoff.

The runoff coefficient can be defined as a fraction, which is multiplied with the quantity of total rainfall to determine the quantity of rain water, which will reach the sewers.

The runoff coefficient depends upon

- **The porosity of soil cover,**
- **Wetness and**
- **Ground cover.**

The overall runoff coefficient for the catchment area can be worked out as follows:

Overall runoff coefficient, $C = [A_1.C_1 + A_2.C_2 + \ldots + A_n.C_n] / [A_1 + A_2 + \ldots + A_n]$

Where, A_1, A_2, …. are types of area with C_1, C_2, …. as their coefficient of runoff, respectively.

Rational method

Storm water quantity,

$$Q = C.I.A / 360$$

Where,

Q = Quantity of storm water, m^3 /sec

C = Coefficient of runoff

I = intensity of rainfall, mm/hour

A = Drainage area in hectares

(OR)

Q = 0.278 C.I.A

Where,

Q is m^3 /sec;

I is mm/hour

A is area in square kilometre

Empirical Formulae

- Empirical formulae are used for determination of runoff from very large area.
- Various empirical relationships are developed based on the past observations on specific site conditions suiting a particular region.
- These empirical formulae can be used for prediction of storm water runoff for that particular catchment.

1. Burkli ziegler formula
2. Dicken's formula
3. Ryve's formula
4. Inglis formula
5. Nawab Jung Bahadur formula
6. Dredge or Burge formula

Burkli - Ziegler Formula

This is a very old empirical formula in use for the determination of peak rate of runoff.

$$Q_P = \frac{1}{455} k' \times i \times A \times \left(\frac{S_0}{A}\right)^{1/2}$$

Where,

Q_p = peak runoff in cumecs

K' = runoff coefficient depending upon the permeability of the surface - its average value is taken as 0.7,

i = maximum rainfall intensity over the entire area - usually adopted as 2.5 to 7.5 cm / h,

A = area of the basin (drainage area) in Hectares, and

S_o = the slope of ground surface of the basin in m per thousand metres.

Dicken's Formula

This formula is considered useful for Indian catchments, **particularly for North India.**

$$Q_P = CM^{3/4}$$

Where,

M = catchment area in km^2

C = a constant depending upon all those factors that influence the amount of runoff.

Ryve's Formula

This formula is similar to Dicken's model, except for the values of C and index M.

It is generally applicable to South Indian basins.

$$Q_P = C_1 M^{2/3}$$

Inglis' formula

This is applicable to **fan-shaped catchments in old Bombay state**. It states that

$$Q_p = \frac{123A}{\sqrt{A+10.4}} \text{ in cumecs } \approx 123\sqrt{A}$$

Where

A = The area of the catchment in sq. kilometres

Nawab Jung Bahadur formula:

This has been derived for **Hyderabad Deccan catchments.**

$$Q_p = C.A'^{\,[0.92 - (1/14) \log A]}$$

Q_p = Peak discharge in cumecs

C = 48 to 60, maximum value 86

A´ = Area in square miles = 0.39 A

Dredge or Burge formula

It is based on Indian records and states that

$$Q_P = 19.6 \frac{A}{L^{2/3}}$$

Where A and Q_p have the same meaning and L is the length of the drainage basin in kilometres.

Sewer design

General Consideration

Generally, sewers are laid at steeper gradients falling towards the outfall point with circular pipe cross section.

Storm water drains are separately constructed as surface drains at suitable gradient, either rectangular or trapezoidal section.

Sewers are designed to carry the maximum quantity of sanitary sewage likely to be produced from the area contributing to the particular sewer.

Storm water drains are designed to carry the maximum storm runoff that is likely to be produced by the contributing catchment area from a rain of design frequency and of duration equal to the time of concentration.

Requirements of Design and Planning of Sewerage System

- The sewerage scheme is designed to remove entire sewage effectively and efficiently from the houses to the point of treatment and disposal.
- Following aspects should be considered while designing the system.
- The sewers provided should be adequate in size to avoid overflow and possible health hazards.
- For evaluating proper diameter of the sewer, correct estimation of sewage discharge is necessary.
- The flow velocity inside the sewer should neither be so large as to require heavy excavation and high lift pumping, nor should be so small causing deposition of the solid in the sewers.
- The sewers should be laid at least 2 to 3 m deep to carry sewage from basement.
- The sewage in sewer should flow under gravity with 0.5 to 0.8 full at designed discharge, i.e. at the maximum estimated discharge.
- The sewage is conveyed to the point usually located in low-lying area, where the treatment plant is located.
- Treatment plant should be designed taking into consideration the quality of raw sewage expected to meet the discharge standards.

Difference between Water Supply Pipes and Sewer Pipes

Comparison between the water distribution network and sewage collection system

Water Supply Pipes	Sewer Pipes
It carries pure water.	It carries contaminated water containing organic or inorganic solids which may settle in the pipe. It can cause corrosion of the pipe material.
Velocity higher than self-cleansing is not essential, because of solids are not present in suspension.	To avoid deposition of solids in the pipes self-cleansing velocity is necessary at all possible discharge.

It carries water under pressure. Hence, the pipe can be laid up and down the hills and the valleys within certain limits.	It carries sewage under gravity. Therefore it is required to be laid at a continuous falling gradient in the downward direction towards outfall point.
These pipes are flowing full under pressure	Sewers are design to run partial full at maximum discharge. This extra space ensures non-pressure gravity flow. This will minimize the leakage from sewer, from the faulty joints or crack, if any.

Provision of Freeboard in Sewers

Sanitary Sewers

Sewers with diameter less than 0.4 m are designed to run half full at maximum discharge, and sewers with diameter greater than 0.4 m are designed to flow 2/3 to ¾ full at maximum discharge.

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

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

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

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

Hydraulic Formulae for Determining Flow Velocities

Sewers of any shape are hydraulically designed as open channels, except in the case of inverted siphons and discharge lines of pumping stations.

Following formulae can be used for design of sewers.

1. Manning's Formula

This is most commonly used for design of sewers.

The velocity of flow through sewers can be determined using Manning's formula as below

$$\mathbf{v = \frac{1}{n}\, r^{2/3}\, S^{1/2}}$$

Where,

v = velocity of flow in the sewer, m/sec

r = Hydraulic mean depth of flow,

m = a/p

a = Cross sectional area of flow, m^2

p = Wetted perimeter, m

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

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

2. Chezy's Formula

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

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

3. Crimp and Burge's Formula

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

4. Hazen- Williams Formula

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

The Hazen-Williams coefficient 'C' varies with life of the pipe and it has high value when the pipe is new and lower value for older pipes.

Pipe Materials	**C_H**
RCC new pipe	120
RCC old pipe	150
AC pipes	120
Plastic pipes	120
CI pipes	100
steel lined with cement	120

Modified Hazen-William's equation is also used in practice.

Minimum Velocity: Self Cleansing Velocity

- The velocity that would not permit the solids to settle down and even scour the deposited particles of a given size is called as self-cleansing velocity.
- This minimum velocity should at least develop once in a day so as not to allow any deposition in the sewers. Otherwise, if such deposition takes place, it will obstruct free flow causing further deposition and finally leading to the complete blocking of the sewers.

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

$$v_s = \sqrt{\frac{8K}{f'}(S_s - 1)gd'}$$

Where,

K= constant, for clean inorganic solids = 0.04 and for organic solids = 0.06

f' = Darcy Weisbach friction factor (for sewers = 0.03)

Ss = Specific gravity of sediments

g = gravity acceleration

d' = diameter of grain, m

- Hence, for removing the impurities present in sewage i.e., sand up to **1 mm diameter** with **specific gravity 2.65** and organic particles up to 5 mm diameter with **specific gravity of 1.2,** it is necessary that a minimum velocity of about **0.45 m/sec** and an average velocity of about 0.9 m/sec should be developed in sewers.
- Hence, while finalizing the sizes and gradients of the sewers, they must be checked for the minimum velocity that would be generated at minimum discharge, i.e., about 1/3 of the average discharge.
- While designing the sewers the flow velocity at full depth is generally kept at about 0.8 m/sec or so. Since, sewers are generally designed for ½ to ¾ full, the velocity at 'designed discharge' (i.e., ½ to ¾ full) will even be more than 0.8 m/sec.

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

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

Maximum Velocity or Non-scouring Velocity

- The interior surface of the sewer pipe gets scored due to the continuous abrasion caused by suspended solids present in sewage.
- The scoring is pronounced at higher velocity than what can be tolerated by the pipe materials. This wear and tear of the sewer pipes will reduce the life span of the pipe and their carrying capacity.
- In order to avoid this, it is necessary to limit the maximum velocity that will be produced in sewer pipe at any time.

- This limiting or non-scouring velocity mainly depends upon the material of sewer.

Limiting or non-scouring velocity for different sewer material

Sewer Material	Limiting velocity, m/sec
Vitrified tiles	4.5 – 5.5
Cast iron sewer	3.5 – 4.5
Cement concrete	2.5 – 3.0
Stone ware sewer	3.0 – 4.5
Brick lined sewer	1.5 – 2.5

The problem of maximum or non-scouring velocity is severe in hilly areas where ground slope is very steep and this is overcome by constructing drop manholes at suitable places along the length of the sewer.

Effect of Flow Variations on Velocities in a Sewer

- The discharge flowing through sewers varies considerably from time to time. Hence, there occur variation in depth of flow and thus, variation in Hydraulic Mean Depth (H.M.D.).
- Due to change in H.M.D. there occur changes in flow velocity, because it is proportional to (H.M.D.)2/3.
- Therefore, it is necessary to check the sewer for minimum velocity of about 0.45 m/sec at the time of minimum flow (1/3 of average flow) and the velocity of about 0.9 to 1.2 m/sec should be developed at a time of average flow.
- The velocity should also be checked for limiting velocity i.e. non-scouring velocity at the maximum discharge.
- For **flat ground** sewers are designed for self-cleansing **velocity at maximum discharge**. This will permit flatter gradient for sewers.
- For **mild slopping ground**, the condition of developing **self-cleansing velocity at average** flow may be economical.
- Whereas, in **hilly areas**, sewers can be designed for **self-cleansing velocity at minimum discharge**, but the design must be checked for non-scouring velocity at maximum discharge.

Example: 1

Design a sewer for a maximum discharge of 650 L/s running half full. Consider Manning's rugosity coefficient n = 0.012, and gradient of sewer S = 0.0001.

Solution

Q = A.V

$0.65 = (\pi D^2/8)\,(1/n)\,R^{2/3}\,S^{1/2}$

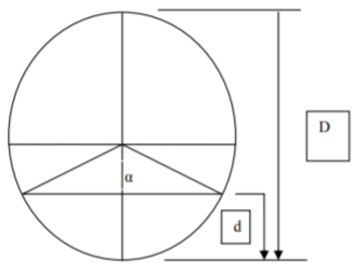
R = A/P Solving for half full sewer,

R = D/4 Substituting in above equation and solving we get

D = 1.82 m.

Comments: If the pipe is partially full it is not easy to solve this equation and it is time consuming.

Hydraulic Characteristics of Circular Sewer Running Full or Partially Full



a) **Depth at Partial flow**

$$d = \left[\frac{D}{2} - \frac{D}{2}\cos\frac{\alpha}{2}\right]$$

b) Proportionate depth

$$\frac{d}{D} = \frac{1}{2}\left[1 - \cos\frac{\alpha}{2}\right]$$

c) Proportionate area

$$\frac{a}{A} = \left[\frac{\alpha}{360^{\circ}} - \frac{\sin\alpha}{2\pi}\right]$$

d) Proportionate perimeter

$$\frac{p}{P} = \left[\frac{\alpha}{360^{\circ}}\right]$$

e) Proportionate Hydraulic Mean Depth

$$\frac{r}{R} = \left[1 - \frac{360\sin\alpha}{2\pi\alpha}\right]$$

f) Proportionate velocity

$$\frac{v}{V} = \frac{N}{n}\frac{r^{2/3}}{R^{2/3}}$$

N=n

$$\frac{v}{V} = \frac{r^{2/3}}{R^{2/3}}$$

g) Proportionate discharge

$$\frac{q}{Q} = \frac{N}{n}\frac{a}{A}\frac{r^{2/3}}{R^{2/3}}$$

In all above equations except ‘α’ everything is constant. Hence, for different values of ‘α’, all the proportionate elements can be easily calculated. These values of the hydraulic elements can be obtained from the proportionate graph prepared for different values.

Example: 2

A 300 mm diameter sewer is to flow at 0.3 depth on a grade ensuring a degree of self-cleansing equivalent to that obtained at full depth at a velocity of 0.9 m/sec. Find the required grade and associated velocity and rate of discharge at this depth. Assume Manning’s rugosity coefficient n = 0.013. The variation of n with depth may be neglected.

Given Data

Using V = 0.90 m/sec,

N = n = 0.013 and

R = D/4 = 75 mm = 0.075 m

Solution:

Manning’s formula for partial depth

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

For full depth

$$\mathbf{v = \frac{1}{N} R^{2/3} S^{1/2}}$$

$$\mathbf{0.90 = \frac{1}{0.013} 0.075^{2/3} S^{1/2}}$$

S = 0.0043

This is the gradient required for full depth.

Q = A.V = π/4 $(0.3)^2$ x 0.90 = **0.064 m^3 /s**

At depth d = 0.3D, (i.e., for d/D = 0.3)

we have a/A = 0.252 and r/R = 0.684 (neglecting variation of n)

Now for the sewer to be same self-cleansing at 0.3 m depth as it will be at full depth, we have the gradient (s_s) required as s_s = (R/r)S

Therefore, s_s = S / 0.684 = 0.0043 / 0.0684 = 0.0063

Now, the velocity v_s generated at this gradient is given by

$$v = V\frac{N}{n}\left(\frac{r}{R}\right)^{2/3}$$

$$= 1 \text{ x } (0.684)^{1/6} \text{ x } 0.9 = 0.846 \text{ m/s}$$

The discharge q_s is given by

$$q = Q\ \frac{N}{n}\ \frac{a}{A}\ \frac{r^{2/3}}{R^{2/3}}$$

q_s = 1 x (0.258) x (0.939) x (0.064) = 0.015 m^3 /s

Example: 3

A combined sewer was designed to serve an area of 60 sq. km with an average population density of 185 persons/hectare. The average rate of sewage flow is 350 L/Capita/day. The maximum flow is 50% in excess of the average sewage flow. The rainfall equivalent of 12 mm in 24 h can be considered for design, all of which is contributing to surface runoff. What will be the discharge in the sewer? Find the diameter of the sewer if running full at maximum discharge.

Given Data

Area to be designed = 60 sq. km

Average rate of sewage flow =350 L/Capita/day

Maximum flow = 50% in excess of the average sewage flow

The rainfall equivalent = 12 mm in 24 h

Solution:

Total population of the area = population density x area

= 185 x 60 x 102

= 1110 x 10^3 persons

Average sewage flow = 350 x 11.1 x 105 litres/day

= 388.5 x 106 L/day

= 4.5 m^3 /sec

Storm water flow = 60 x 106 x (12/1000) x [1/(24 x 60 x 60)]

= 8.33 m^3 /sec

Maximum sewage flow = 1.5 x average sewage flow

= 1.5 x 4.5 = 6.75 m^3 /sec

Total flow of the combined sewer = sewage flow + storm flow

= 6.75 + 8.33 = 15.08 m^3 /sec

Hence, the capacity of the sewer = 15.08 m^3 /sec

Hence, diameter of the sewer required at the velocity of 0.9 m/s can be calculated as

$\pi/4\ (D)^2 \times 0.90 = 15.08\ m^3/s$

Hence, D = 4.62 m

Example: 4

Find the minimum velocity and gradient required to transport coarse sand through a sewer of 40 cm diameter with sand particles of 1.0 mm diameter and specific gravity 2.65, and organic matter of 5 mm average size with specific gravity 1.2. The friction factor for the sewer material may be assumed 0.03 and roughness coefficient of 0.012. Consider k = 0.04 for inorganic solids and 0.06 for organic solids.

Given Data

Diameter of sewer = 40cm

Size of the sand particle = 1.0mm

Specific gravity the sand particle = 2.65

Size of the organic matter = 5mm

Specific gravity of the organic matter = 1.2

The friction factor = 0.03

Roughness coefficient =0.012

k for inorganic solids = 0.04

k for organic solids = 0.06

Solution

Minimum velocity i.e. self-cleansing velocity

$$v_s = \sqrt{\frac{8K}{f'}(S_s - 1)gd'}$$

$$v_s = \sqrt{\frac{8 \times 0.04}{0.03}(2.65 - 1)9.81 \times 0.001}$$

= 0.4155 m/sec say 0.42 m/sec

Similarly, for organic solids

$$v_s = \sqrt{\frac{8 \times 0.06}{0.03}(1.2 - 1)9.81 \times 0.005}$$

=0.396m/s say 0.40m/sec

Therefore, the minimum velocity in sewer = 0.42 m/sec

Now, Diameter of the sewer D = 0.4 m

Hydraulic Mean Depth = D/4 = 0.4/4 = 0.1 m

Using Manning's formula: $V = 1/n\ R^{2/3}\ S^{1/2}$

$0.42 = (1/0.012) \times (0.1)^{2/3} \times S^{1/2}$

S = 1/1824.5

Therefore, gradient of the sewer required is 1 in 1824.5.

Example: 5

Design a sewer running 0.7 times full at maximum discharge for a town provided with the separate system, serving a population 80,000 persons. The water supplied from the water works to the town is at a rate of 190 LPCD. The manning's n = 0.013 for the pipe material and permissible slope is 1 in 600. Variation of n with depth may be neglected. Check for minimum and maximum velocity assuming minimum flow 1/3 of average flow and maximum flow as 3 times the average. (for d/D = 0.7, q/Q = 0.838, v/V = 1.12)

Given Data:

d= 0.7D

Population = 80000 persons

The rate of supply = 190lpcd

n = 0.013

Slope = 1 in 600

Minimum flow = 1/3 of average flow

Maximum flow = 3 times the average

q/Q = 0.838

v/V = 1.12

Solution

Average water supplied = 80000 x 190 x (1/24 x 60 x 60 x 1000)

= 0.176 m^3 /sec

Sewage production per day, (considering 80% of water supply) = 0.176 x 0.8

= 0.14 m^3 /sec

Maximum sewage discharge = 3 x 0.14 = 0.42 m^3 /sec

Now for d/D = 0.7,

q/Q = 0.838,

v/V = 1.12 Therefore,

Q = 0.42/0.838 = 0.5 m^3 /sec

$$Q = \frac{1}{n}\frac{\pi D^2}{4}\left(\frac{d}{4}\right)^{2/3} S^{1/2}$$

$$0.5 = \frac{1}{0.013}\frac{\pi D^2}{4}\left(\frac{d}{4}\right)^{2/3} 0.00167^{1/2}$$

D = 0.78 m

V = Q/A = 1.04 m/sec

Now, v/V = 1.12

Now, v/V = 1.12

Therefore v = 1.12 x 1.04 = 1.17 m/sec

This velocity is less than limiting velocity hence, OK Check for minimum velocity

Now q_{min} = 0.14/3 = 0.047 m^3 /sec

$q_{min}/Q = 0.047/0.5 = 0.09$

From proportional chart, for q/Q = 0.09,

d/D = 0.23 and v/V = 0.65

Therefore, the velocity at minimum flow = 0.65 x 1.04 = 0.68 m/sec

This velocity is greater than self-cleansing velocity,

Hence OK

d_{min} = 0.23 x 0.78 = 0.18 m

Comment: If the velocity at minimum flow is not satisfactory, increase the slope or try with reduction in depth of flow at maximum discharge or reduction in diameter of the sewer.

Laying of Sewer Pipes

- Sewers are generally laid starting from their outfall ends towards their starting points. With this advantage of utilization of the tail sewers even during the initial periods of its construction is possible.

- It is common practice, to first locate the points where manholes are required to be constructed as per drawing, i.e., L-section of sewer, and then laying the sewer pipe straight between the two manholes.

- The central line of the sewer is marked on the ground and an offset line is also marked parallel to the central line at suitable distance, about half the trench width plus 0.6 m. This line can be drawn by fixing the pegs at 15 m intervals and can be used for finding out center line of the sewer simply by offsetting.

- The trench of suitable width is excavated between the two manholes and the sewer is laid between them. Further excavation is then carried out for laying the pipes between the next consecutive manholes. Thus, the process is continued till the entire sewers are laid out.

- The width of the trench at the bottom is generally kept 15 cm more than the diameter of the sewer pipe, with minimum 60 cm width to facilitate joining of pipes.

- If the sewer pipes are not to be embedded in concrete, such as for firm grounds, then the bottom half portion of the trench is excavated to confirm the shape of the pipe itself. In ordinary or softer grounds, sewers are laid embedded in concrete.

- The trench is excavated up to a level of the bottom embedding concrete or up to the invert level of the sewer pipe plus pipe thickness if no embedding concrete is provided.

- The designed invert levels and desired slope as per the longitudinal section of the sewer should be precisely transferred to the trench bottom.

- After bedding concrete is laid in required alignment and levels. The sewer pipes are then lowered down into the trench either manually or with the help of machines for bigger pipe diameters.

- The sewer pipe lengths are usually laid from the lowest point with their sockets facing up the gradient, on desired bedding. Thus, the spigot end of new pipe can be easily inserted on the socket end of the already laid pipe.

Hydraulic Testing of Sewers

Test for Leakage or Water Test

The sewers are tested after giving sufficient time for the joints to set for no leakage.

For this sewer pipe sections are tested between the manholes to manhole under a test pressure of about 1.5 m water head.

To carry this, the downstream end of the sewer is plugged and water is filled in the manhole at upper end.

The depth of water in manhole is maintained at about 1.5 m.

The sewer line is inspected and the joints which leak are repaired.

Test for Straightness of alignment

This can be tested by placing a mirror at one end of the sewer line and a lamp at the other end.

If the pipe line is straight, full circle of light will be observed.

Backfilling the trench:

After the sewer line has been laid and tested, the trenches are back filled. The earth should be laid equally on either side with layer of 15 cm thickness. Each layer should be properly watered and rammed.

Sewer materials

Important Factors Considered for Selecting Material for Sewer

Resistance to corrosion

- Sewer carries wastewater that releases gases such as H_2S.

- This gas in contact with moisture can be converted into sulphuric 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 amount of suspended solids, part of which are inorganic solids such as sand or grit.
- These particles moving at high velocity can cause wear and tear of sewer pipe internally.
- This abrasion can reduce thickness of pipe and reduces hydraulic efficiency of the sewer by making the interior surface rough.

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.

Materials for Sewers

Asbestos Cement Sewers

- These are manufactured from a mixture of asbestos fibers, silica and cement.
- Asbestos fibers are thoroughly mixed with cement to act as reinforcement.
- 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 and the joints are flexible to permit 12^o deflection for curved laying.
- These pipes are used for vertical transport of water.

For example, transport of rainwater from roofs in multi-storeyed buildings, for transport of sewage to grounds, and for transport of less foul sullage i.e., wastewater from kitchen and bathroom.

Advantages

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

Disadvantages

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

Plain Cement Concrete or Reinforced Cement Concrete

- Plain cement concrete (1: 1.5: 3) pipes are available up to 0.45 m diameter and reinforcement cement pipes are available up to 1.8 m diameter.
- These pipes can be cast in situ or precast pipes.
- Precast pipes are better in quality than the cast in situ pipes.
- The reinforcement in these pipes can be different such as single cage reinforced pipes, used for internal pressure less than 0.8 m; double cage reinforced pipes used for both internal and external pressure greater than 0.8 m.
- Elliptical cage reinforced pipes used for larger diameter sewers subjected to external pressure; and Hume pipes with steel shells coated with concrete from inside and outside.

- Nominal longitudinal reinforcement of 0.25% is provided in these pipes.

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

- These pipes can get corroded and pitted by the action of H_2SO_4.
- The carrying capacity of the pipe reduces with time because of corrosion.
- The pipes are susceptible to erosion by sewage containing silt and grit.

The concrete sewers can be protected internally by vitrified clay linings. With protection lining they are used for almost all the branch and main sewers. Only high alumina cement concrete should be used when pipes are exposed to corrosive liquid like sewage.

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

- 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

- 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.

Brick Sewers

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

Cast Iron Sewers

- These pipes are stronger and capable to withstand greater tensile, compressive, as well as bending stresses.
- However, these are costly.
- Cast iron pipes are used for outfall sewers, rising mains of pumping stations, and inverted siphons, where pipes are running under pressure.
- These are also suitable for sewers under heavy traffic load, such as sewers below railways and highways.
- They are used for carried over piers in case of low lying areas.
- They form 100% leak proof sewer line to avoid groundwater contamination.
- They are less resistant to corrosion; hence, generally lined from inside with cement concrete, coal tar paint, epoxy, etc.
- These are joined together by bell and spigot joint.
- IS:1536-1989 and IS:1537-1976 provides the specifications for spun and vertically cast pipes, respectively.

Steel Pipes

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

Ductile Iron Pipes

- Ductile iron pipes can also be used for conveying the sewers.
- They demonstrate higher capacity to withstand water hammer.
- The specifications for DI pipes are provided in IS: 12288-1987.
- The predominant wall material is ductile iron, a spheroidized graphite cast iron.
- Internally these pipes are coated with cement mortar lining or any other polyethylene or poly wrap or plastic bagging/ sleeve lining to inhibit corrosion from the wastewater being conveyed, and various types of external coating are used to inhibit corrosion from the environment.
- Ductile iron has proven to be a better pipe material than cast iron but they are costly.
- Ductile iron is still believed to be stronger and more fracture resistant material. However, like most ferrous materials it is susceptible to corrosion.
- A typical life expectancy of thicker walled pipe could be up to **75 years**, however with the current thinner walled ductile pipe the life could be about 20 years in highly corrosive soils without a corrosion control program like cathodic protection.

Plastic sewers (PVC pipes)

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

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 (IS:4984-1987).
- These are commonly used for conveyance of industrial wastewater.
- They offer all the advantages offered by PVC pipes.
- PVC pipes offer very little flexibility and normally considered rigid; whereas, HDPE pipes are flexible hence best suited for laying in hilly and uneven terrain.

- Flexibility allows simple handling and installation of HDPE pipes.
- Because of low density, these pipes are very light in weight. Due to light in weight, they are easy for handling, this reduces transportation and installation cost.
- HDPE pipes are non-corrosive and offer very smooth inside surface due to which pressure losses are minimal and also this material resist scale formation.

Glass Fiber Reinforced Plastic Pipes

- This martial is widely used where corrosion resistant pipes are required.
- Glass fiber reinforced plastic (GRP) can be used as a lining material for conventional pipes to protect from internal or external corrosion.
- It is made from the composite matrix of glass fiber, polyester resin and fillers.
- These pipes have better strength, durability, high tensile strength, low density and high corrosion resistance.
- These are manufactured up to 2.4 m diameter and up to 18 m length (IS:12709-1989).
- Glass reinforced plastic pipes represent the ideal solution for transport of any kind of water, chemicals, effluent and sewage, because they combine the advantages of corrosion resistance with a mechanical strength which can be compared with the steel pipes.
- Light weight of pipes that allows for the use of light laying and transport means.
- Possibility of nesting of different diameters of pipe thus allowing additional saving in transport cost.
- Length of pipe is larger than other pipe materials.
- Easy installation procedures due to the kind of mechanical bell and spigot joint.
- Corrosion resistance material, hence no protections such as coating, painting or cathodic are then necessary.
- Smoothness of the internal wall that minimizes the head loss and avoids the formation of deposits.
- High mechanical resistance due to the glass reinforcement.
- Absolute impermeability of pipes and joints both from external to internal and vice versa.
- Very long life of the material.

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.

Shapes of Sewer Pipes

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

Other shapes used for sewers Standard Egg-shaped sewer

- New egg-shaped sewer
- Horse shoe shaped sewer
- Parabolic shaped sewer
- Semi-elliptical section
- Rectangular shape section
- U-shaped section
- Semi-circular shaped sewer
- Basket handled shape sewer

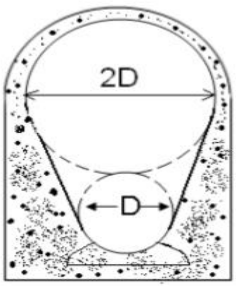
Standard egg-shaped sewers, also called as ovoid shaped sewer, and new or modified egg-shaped sewers are used in combined sewers.

These sewers can generate self-cleansing velocity during dry weather flow.

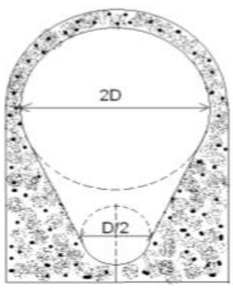
Horse shoe shaped sewers and semi-circular sections are used for large sewers with heavy discharge such as trunk and outfall sewers.

Rectangular or trapezoidal section is used for conveying storm water. U-shaped section is used for larger sewers and especially in open cuts.

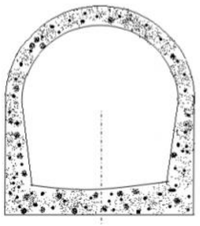
Other sections of the sewers have become absolute due to difficulty in construction on site and non-availability of these shapes readily in market.

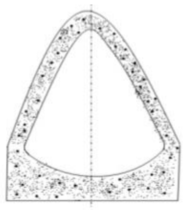


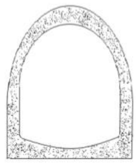
Standard egg shaped sewer

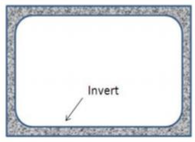


Modified egg shaped sewer

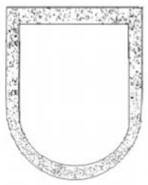


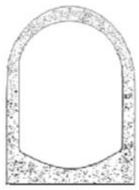


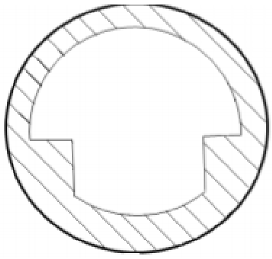




Horse shoe section Parabolic section Semi Elliptical section Rectangular section







U shaped section Semi circular section Basket handle section

Sewer appurtenances

Definition

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

These include:

(1) Manholes,

(2) Drop manholes,

(3) Lamp holes,

(4) Clean-outs,

(5) Street inlets called Gullies,

(6) Catch basins,

(7) Flushing Tanks,

(8) Grease & Oil traps,

(9) Inverted Siphons, and

(10) Storm Regulators.

1.Manholes

Definition

The manhole is masonry or R.C.C. chamber constructed at suitable intervals along the sewer lines, for providing access into them.

Thus, the manhole helps in inspection, cleaning and maintenance of sewer.

Location of Manholes

These are provided at every bend, junction, change of gradient or change of diameter of the sewer.

The sewer line between the two manholes is laid straight with even gradient.

For straight sewer line manholes are provided at regular interval depending upon the diameter of the sewer.

Spacing of manhole

The spacing of manhole is recommended in IS 1742-1960.

For sewer up to 0.3 m diameter or sewers which cannot be entered for cleaning or inspection the maximum spacing between the manholes recommended is 30 m, and 300 m spacing for pipe greater than 2.0 m diameter.(**Table1)**

A spacing allowance of 100 m per 1 m diameter of sewer is a general rule in case of very large sewers (CPHEEO, 1993).

The internal dimensions required for the manholes are provided in Table 2 (CPHEEO, 1993).

The minimum width of the manhole should not be less than internal diameter of the sewer pipe plus 150 mm benching on both the sides.

Spacing of Manholes –Table1

Pipe Diameter	Spacing
Small sewers	45m
0.9 to 1.5 m	90 to 150 m
1.5 to 2.0 m	150 to 200 m
Greater than 2.0 m	300 m

The minimum internal dimensions for manhole chambers- Table 2

Depth of sewer	Internal dimensions
0.9 m or less depth	0.90 m x 0.80 m
For depth between 0.9 m and 2.5 m	1.20 m x 0.90 m, 1.2 m dia. for circular
For depth above 2.5 m and up to 9.0 m	For circular chamber 1.5 m dia.
For depth above 9.0 m and up to 14.0 m	For circular chamber 1.8 m dia.

Classification of Manholes

Depending upon the depth the manholes can be classified as:

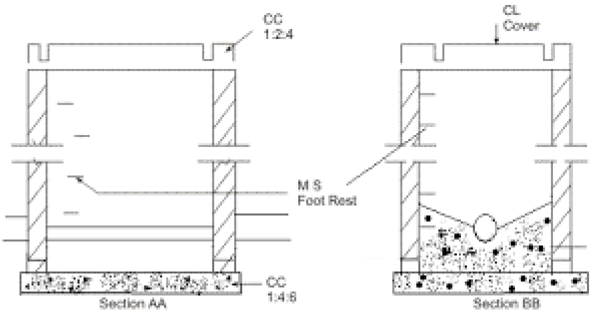
(a) Shallow Manholes,

(b) Normal Manholes, and

(c) Deep Manholes

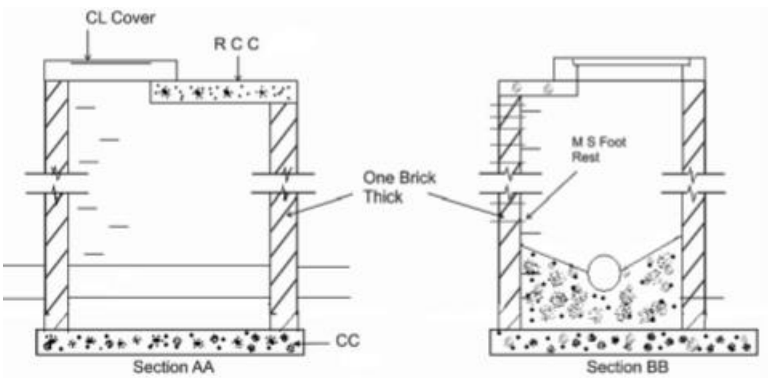
Shallow Manholes:

- Shallow manholes are those which are about 0.75 to 0.90 m in depth.
- These manholes are of rectangular shape with minimum internal size 0.9 m x 0.8 m.
- These are constructed at the beginning of branch sewers or on sewers laid at places which are not subjected to heavy traffic.
- These are also known as inspection chambers and are provided with light cast iron cover and frame at the top.



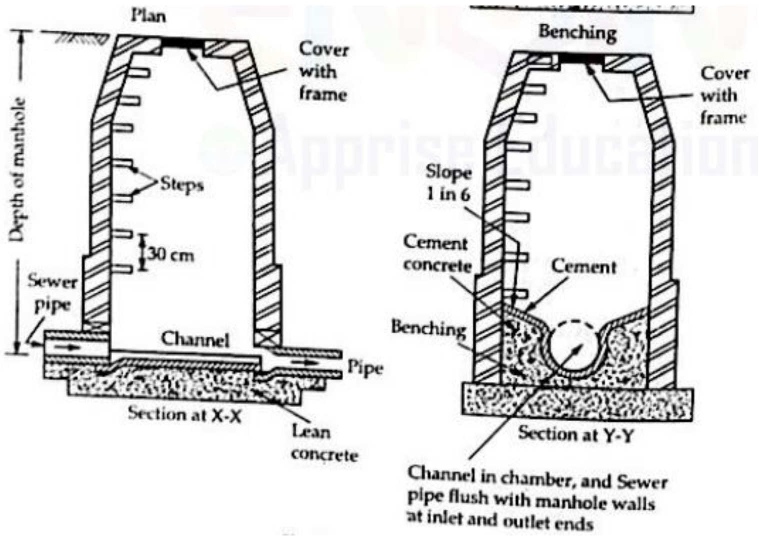
Normal Manholes:

- Normal manholes (or medium manholes) are those which have depth more than 0.9 m and up to 2 m.
- These manholes may be of square or rectangular shape with minimum internal size 1 m x 1 m or 1.2 m x 0.9 m, or of circular shape with minimum internal diameter 0.9 m.
- The section of square or rectangular manholes is not changed with depth.
- The circular manholes are of uniform section in lower portion and slanting in top portion so as to narrow down the top opening equal to internal diameter of manhole cover.
- These manholes are provided with heavy cast iron cover and frame at the top.



Deep Manholes:

- Deep manholes are those having depth more than 2 m.
- These manholes are mostly circular in shape.
- Depending upon the depth of manhole, the diameter of manhole changes.
- The circular manholes are of uniform section in lower portion and slanting in top portion so as to narrow down the top opening equal to internal diameter of manhole cover.
- However, for depths above 2.0 m and up to 2.5 m, manholes may be of rectangular shape with minimum internal size 1.2 m x 0.9 m.
- The size of rectangular manholes is reduced in the upper portion to reduce the size of manhole cover.
- The reduction in size is achieved by providing an offset constructed of either R.C.C. slab or brick arch.
- The rectangular manholes with arch type offset are also known as arch type manholes.
- The arch type manholes may be constructed for depths of 2.5 m and above with minimum internal size 1.4 m x 0.9 m.
- Deep manholes are provided with steps on one of the vertical wails to enable the workers to go down up to the bottom.
- These manholes are also provided with heavy cast iron cover and frame at the top.



Component Parts of a Manhole:

A typical manhole consists of the following component parts:

(i) Access shaft

(ii) Working chamber

(iii) Base and side walls

(iv)Bottom or invert

(v) Steps or ladder

(vi)Cover and frame.

i) Access Shaft

- The upper portion of a deep manhole is known as access shaft.
- It is a vertical passage which provides access to the working chamber of the manhole from the manhole cover.
- The minimum size of access shaft is about 0.75 m x 0.60 for rectangular manholes and about 0.70 m diameter for circular manholes.
- For rectangular manholes built of brickwork the access shaft is corbelled inwards on three sides to reduce its size to that of the opening in the cover frame, and to provide easy access on the fourth side to step irons or ladder.
- Alternatively, the access shaft may be covered by a reinforced cement concrete slab of suitable dimensions with an opening for manhole cover and frame.
- For circular manholes the access shaft is usually made slanting inwards so as to narrow down the top opening equal to internal diameter of manhole cover.

(ii) Working Chamber

- The lower portion of a manhole is known as working chamber which provides working space to carry out cleaning and inspection of sewer line.
- The minimum size of working chamber for deep rectangular manholes is 1.2 m x 0.9 m with larger dimension being in the direction of flow.
- For deep circular manholes the minimum diameter of the working chamber is 1.2 m.
- The height of working chamber should preferably be not less than 1.8 m.
- The size of working chamber of a manhole is usually larger than that of its access shaft and hence the working chamber is constructed by enlarging the access shaft at

its bottom by providing an offset constructed of R.C.C slab or brick arch or by corbelling.

(iii) Base and Side Walls

- A bed, generally of plain cement concrete, is provided at the base to support the side walls of the manhole and to prevent the entry of groundwater.
- The minimum thickness of concrete bed is 15 cm for manholes of depth up to 0.8 m, 23 cm for manholes of depth above 0.8 m and up to 2.1 m and 30 cm for manholes of depth more than 2.1 m.
- The concrete bed may be provided with adequate reinforcement if necessary to withstand excessive uplift pressure.
- The side walls of manholes are made of brick or stone masonry or reinforced cement concrete. The brick walls are very common.
- The minimum thickness of brick walls is 20 cm (or one brick) for manholes of depths up to 1.5 m and 30 cm (or one and a half brick) for manholes of depths more than 1.5 m.

The following thumb rule may be used for determining the thickness of brick walls-

$$t = 10 + 4d$$

Where

t = thickness of wall in cm. and

d = depth of manhole in m.

- The inside and outside of brick work is plastered with cement mortar 1:3 (1 cement and 3 coarse sand) and inside finished smooth with a coat of neat cement.
- The thickness of reinforced cement concrete (R.C.C.) walls will be much less as compared to that of brick walls and can be designed by the usual methods of structural analysis.
- However, R.C.C. walls are costly and hence these are adopted only under special circumstances.

(iv)Bottom or Invert

- At the bottom of the manhole a semi-circular or U-shaped channel of cement concrete of diameter equal to that of sewer is constructed.
- Above the horizontal diameter the sides of this channel are extended vertically, nearly up to the crown of the sewer and then their top edge is suitably rounded off and made to slope towards the channel to form benching.
- The slope provided for benching varies from 1 in 10 to 1 in 6.

- The benching enables the floor of the chamber to be drained of backed up sewage.
- The bottom of the channel lies in line with the invert of the sewer line.
- When two or more sewers enter a manhole at the same level at the bottom of the manhole, in addition to main channel branch channels are similarly constructed with respect to the benching.
- At the junction with the main channel the branch channels are provided with easy curves.
- Where the sewers entering and leaving a manhole are of different diameters, the entering and leaving sewers are placed with their crowns at the same level and necessary slope is given in the invert of the manhole chamber.
- This is done to prevent backflow in the smaller sewer when the larger sewer is flowing full. In exceptional cases and where unavoidable, the crown of entering sewer may be fixed at lower level but in such cases to the peak flow- level of the two sewers is kept the same.

(v) Steps or Ladder

- In order to facilitate entry and exit of workers steps or rungs are provided in all manholes of depth more than 0.8 m.
- The steps are made of cast iron and these are placed staggered at a horizontal centre to centre distance of 38 cm and a vertical centre to centre distance of 30 cm.
- The top step is placed 45 cm below the manhole cover and the lowest step not more than 30 cm above the benching.
- The width of the step is usually 15 cm. However, if steps are made of double width staggering is not required.
- The steps are firmly embedded in the wall so that they do not overturn.
- In very deep manholes it is desirable to provide a ladder instead of steps.
- The ladder gives a high sense of security to the workers.

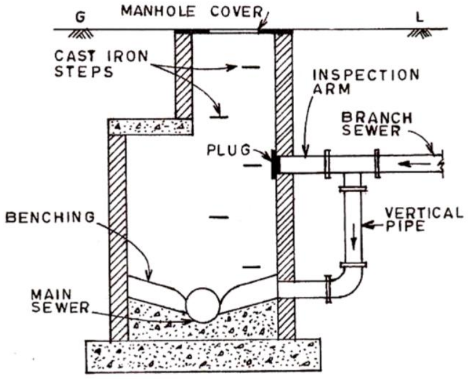
(vi) Cover and Frame

- The opening at the top of a manhole is provided with a cover set in a frame.
- Mostly the openings are of circular shape and hence the manhole covers of circular shape are most commonly used.

- The size of manhole covers is such that there is a clear opening of at least 56 cm in diameter for manholes of depth more than 0.9 m.
- Both cover and frame are of cast iron. The frame supporting the cover is generally 20 to 25 cm high and its base is 10 to 12 cm wide.
- The weight of cover and frame varies from 90 to 270 kg.
- The light type is adopted where light traffic load is to be borne and heavy type is adopted where heavy traffic load is to be borne.
- The frame is firmly embedded in cement concrete on the top of masonry and the cover rests in the groove provided inside the frame.
- The top of manhole cover should be properly adjusted in relation to the road surface.
- It should be in the plane of the pavement so that it does not interfere with the traffic.
- The top surface of manhole cover is provided with small projections or bosses to make it rough so that.it does not become slippery.

2. Drop Manholes

- The manhole in which a vertical pipe is used is called a drop manhole, where as the one using an inclined pipe is called a ramp.
- The construction of a drop manhole in place of an ordinary manhole in case a high level branch sewer enters a low levelled main sewer, will thus given serve the following purposes:
- The steep gradients which otherwise would have to be given to the branch sewer will be avoided.
- The sewage trickling into the manhole from the directly placed branch sewer is likely to fall on persons working in the manhole. This is avoided in drop manhole.
- The branch sewer is joined to manhole through a vertical pipe.
- The sewage coking through the branch sewer dips in through the vertical pipe, and trickles over the main sewer channel, just above it.
- A plug is provided at the point where branch sewer, if taken straight intersects the wall of the manhole.
- The length of the branch sewer between the vertical pipe and the plug is known as inspection arm.



3. Lamp hole:

It's an opening or hole constructed in a sewer for purpose of lowering a lamp inside it.

The lamp holes are provided at places where.

Location of Lamp hole

i) A bend in the sewer is necessary.

ii) Construction of manhole is difficult.

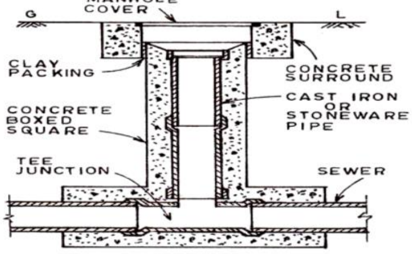
iii) The spacing of manholes is more than the usual.

Function of Lamp hole

- It is constructed when construction of manhole is difficult. In present practice use of lamp hole is avoided.
- This lamp hole can be used for flushing the sewer.
- If the top cover is perforated it will also help in ventilating sewer such lamp hole is known as fresh air inlet.

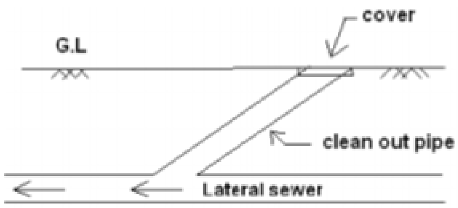
Construction of Lamp hole

- It consists of stoneware or concrete pipe which is connected to sewer line through a T-junction.
- The pipe is covered with concrete to make it suitable.
- A manhole cover is provided at the top to make up a load of traffic.



4. Clean -outs

- It is a pipe which is connected to the underground sewer.
- The other end of the clean-out pipe is brought up to ground level and a cover is placed at ground level.
- A clean-out is generally provided at the upper end of lateral sewers in place of manholes. During blockage of pipe, the cover is taken out and water is forced through the clean-out pipe to lateral sewers to remove obstacles in the sewer line.
- For large obstacles, flexible rod may be inserted through the clean-out pipe and moved forward and backward to remove such obstacle.



5. Street Inlets (Gullies)

An inlet is an opening on the road surface through which storm water is admitted and conveyed to the underground storm water sewer or combined sewer.

Location of street inlets

On the straight portion of a road, the inlets are located or placed along the roadside at an interval of 30 m to 60m.

They are also placed at road intersection points.

The inlets are placed in such a way that storm water is collected in a short period and the crosswalks are not flooded.

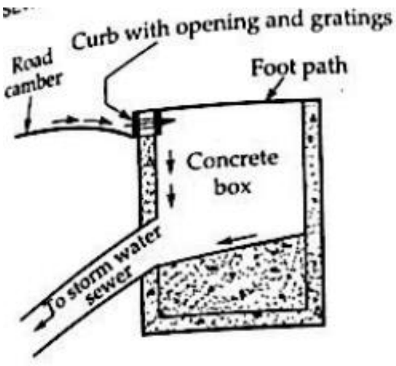
Function of street inlets

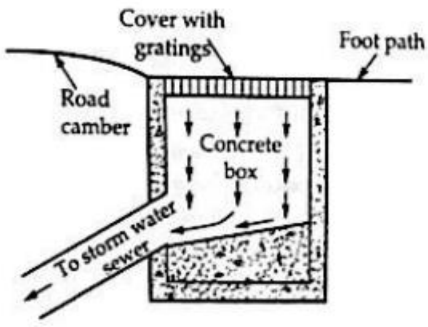
- Street inlet collects the storm water flowing along the streets and conveys it to the underground storm water sewer or combined sewer.
- Thus it prevents the accumulation of storm water on the road pavement.

Construction of street inlets

- A street inlet is a simple concrete box. It may have grating or openings in a vertical direction or in a horizontal direction.
- The former is known as vertical inlet or curb inlet and the later is known as a horizontal inlet.

* The inlets are connected to the nearby manholes by pipelines.





Vertical inlet or Curb inlet Horizontal inlet

Curb Inlet:

These are vertical opening in the road curbs through which storm water flow enters the storm water drains.

These are preferred where heavy traffic is anticipated.

Gutter Inlets: These are horizontal openings in the gutter which is covered by one or more grating through which storm water is admitted.

Combined Inlets: In this, the curb and gutter inlet both are provided to act as a single unit. The gutter inlet is normally placed right in front of the curb inlets.

6. Catch Basins

Catch basins are rectangular chamber provided along the sewer line to admit clear rainwater free from silt, grit, debris, etc into the sewers.

Location of the catch Basins

The catch basin is placed along roadsides below the street inlets.

Function of the catch Basins

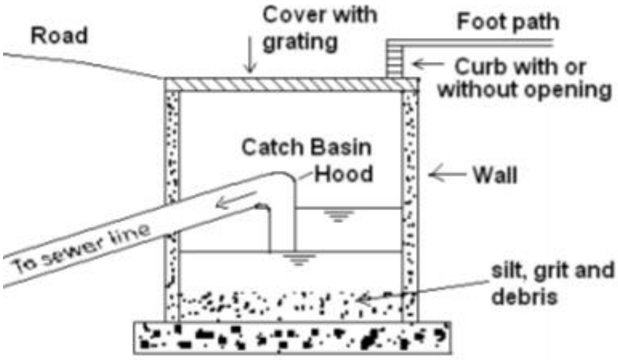
Catch basins are provided to stop the entry of heavy debris present in the storm water into the sewers.

However, their use is discouraged because of the nuisance due to mosquito breeding apart from posing substantial maintenance problems.

At the bottom of the basin space is provided for the accumulation of impurities.

Perforated cover is provided at the top of the basin to admit rain water into the basin.

A hood is provided to prevent escape of sewer gas.



7. Ventilating Shaft

The Ventilating Shaft or column is a device provided along the sewer line for the ventilation of sewer.

Location of Ventilating Shaft

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

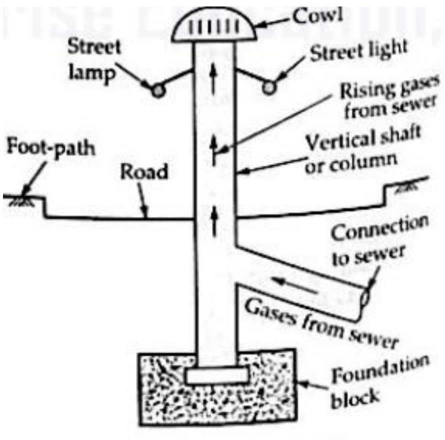
They are also provided at the upper end of every branch sewer and at every point where sewer diameter changes.

Function of Ventilating Shaft

- 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 airlocks in the sewage and thereby ensure the continuous flow of sewage inside the sewer.
- In modern sewerage system, provision of ventilators is not necessary due to elimination of intercepting traps in the house connections allowing ventilation.

Construction of Ventilating Shaft

- The ventilating shaft consists of a vertical shaft made by joining, cast iron or steel pipes.
- A foundation block is provided at the bottom end of the shaft to keep it in a vertical position.
- A cowl is provided at the top end to allow the escape of sewer gases.
- The shaft is connected to the sewer by an underground pipe.
- The height of the ventilating shaft should be more than the height of the



8. Inverted Siphons

When an obstruction is met by a sewer line, the sewer is constructed lower than the adjacent section to overcome the obstruction.

Such a section of a sewer is termed as an inverted siphon or depressed sewer or a sag pipe. The sewage through such section flows under pressure.

Location of Inverted Siphons

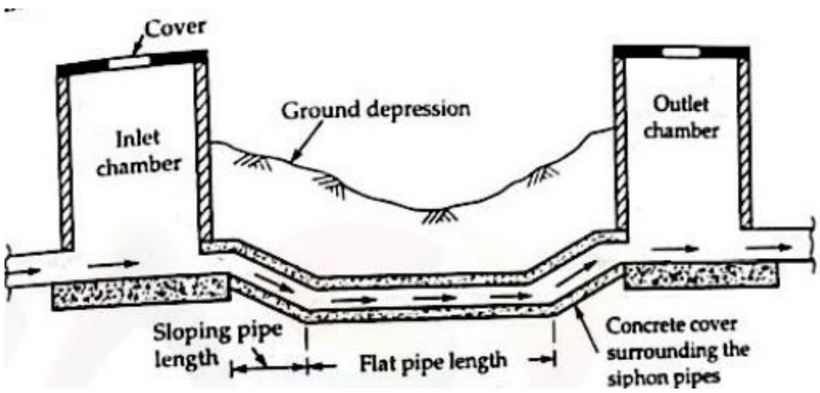
The inverted siphon is constructed at the place where a sewer pipe has to be dropped below the hydraulic gradient line for passing it beneath a valley, a road, a railway or any other obstruction.

Function of Inverted Siphons

The main purpose of the installation of inverted siphons is to carry the sewer line below the obstruction such as road, railway, stream, river, etc.

Construction of Inverted Siphons

- An inverted siphon usually consists of cast iron or concrete siphon tubes or pipes.
- The inverted siphon is constructed between inlet and outlet chambers.
- It is generally made up of two sloping pipe lengths joined by a flat pipe length.
- If the length of the siphon is more, a ventilating shaft should be provided in the siphon to prevent air locking.



9. Flushing tank

- The cleaning operation of a small sewer is generally done by flushing tanks.
- The flushing tank is a device that stores water temporarily and throws it into the sewer for the purpose of flushing and cleaning the sewer.

Location of Flushing tank

- It is installed at places where there are chances of blockage of sewer pipes.
- In case of sewer laid on flat topography not producing self-cleaning velocities or near the dead end points of the sewers, flushing tanks are installed.

Function of the Flushing tank

- It helps in flushing and cleaning of sewers.
- It is also used to store sewage temporarily at some places.

Types of Flushing tank

a) Hand operated flushing tank.

b) Automatic flushing tank.

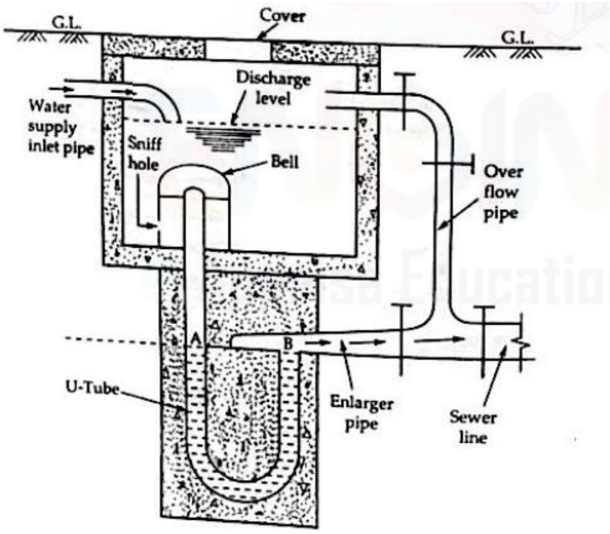
In a hand-operated flushing tank, the flushing and cleaning operation is carried out at suitable intervals by manual labour.

It is carried out by operating the sluice valve fitted at the outlet end and the inlet end of the manhole suitably.

An automatic flushing tank

- In automatic flushing tank, the flushing and cleaning operation is carried out automatically at regular intervals.
- In automatic flushing tank, the water is automatically released from the tank at required interval, which can be adjusted by the supply pipe tap, and flushes the sewer.
- It consists of a masonry or concrete chamber fitted with a tap for filling the tank with water.
- A U-tube with a bell cap at its one end connects the chamber with sewer.
- When the water level increases in the chamber, it also increases in the bell cap.
- As soon as it reaches a certain level, siphonic action takes place and the whole water of the chamber rushes to the sewer pipe and flushes it.

- The capacity of these tanks is usually 900-1400 litres and it is adjusted in such a way as to work twice or thrice a day depending on the quantity of deposits in the sewer and size of sewer.



10. Grease and oil traps

Grease and oil traps are those trap chambers which are constructed in a sewerage system to remove grease and oil from the sewage before it enters into the sewer line.

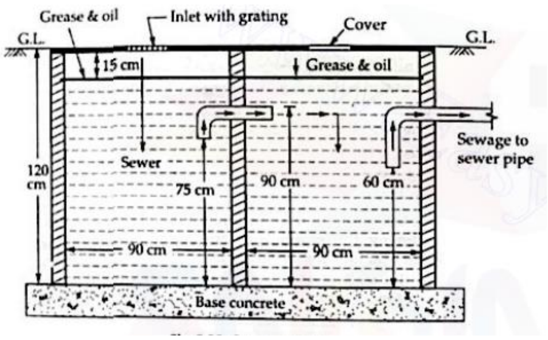
Such traps are located near the sources contributing grease and oil to the sewage.

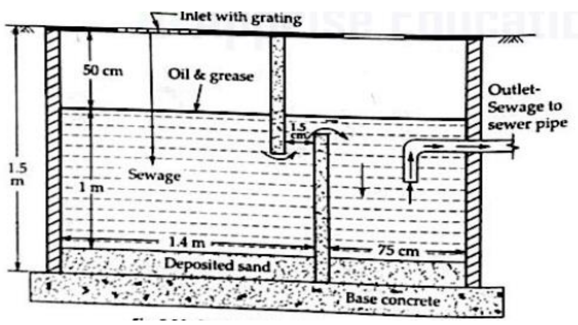
Necessities of Grease and oil traps

- It is essential to exclude grease and oil from sewage due to following reasons:
- If grease and oil are allowed to enter the sewer, they will stick to the inner surface of the sewer and will become hard, thus cause obstruction to flow and reduce the sewer capacity.
- The suspended matter which would have otherwise flown along with sewage will stick to the inner surface of the sewer due to sticky nature of grease and oil, thus further reduce the sewer capacity.
- The presence of grease and oil in sewage makes the sewage treatment difficult as they adversely affect the bio-chemical reactions.
- The presence of a layer of grease and oil on the surface of sewage does not allow oxygen to penetrate due to which aerobic bacteria will not survive and hence organic matter will not be decomposed. This will give rise to bad odours.
- The presence of grease and oil in sewage increases the possibility of explosion in the sewer line.

Working Principle

- The principle on which grease and oil traps work is very simple.
- The grease and oil being light in weight float on the surface of sewage.
- Hence, if outlet draws the sewage from lower level, grease and oil are excluded.
- Thus grease and oil trap is a chamber with outlet provided at a lower level near the bottom of the chamber and inlet provided at a higher level near the top of the chamber.
- However, in addition to grease and oil if it is desired to exclude sand, space should be kept at the bottom of the chamber for sand to be deposited.
- It consists of two chambers interconnected through a pipe.
- The inlet with grating is provided near the top of one of the chambers while the outlet is provided in the other chamber.
- The end of the outlet is located at a height of about 0.6 m above the bottom of the chamber and it is held submerged.
- The wastewater obtained from garages, particularly from floor drains and wash racks, contains grease, oil, sand and mud.
- To trap all these combined sand, grease and oil trap is provided which is shown in Fig.
- These traps should be cleaned at regular intervals for their proper functioning. If this precaution is not taken there will not be free flow of sewage.





11. Storm water regulator

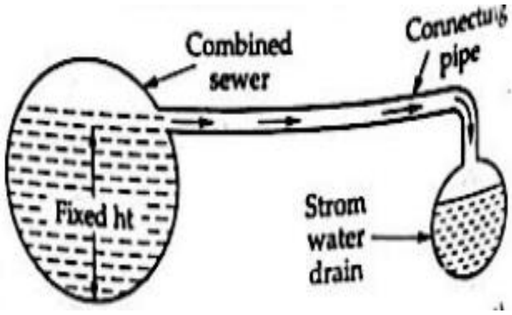
These are used for preventing overloading of sewers, pumping stations, treatment plants or disposal arrangement, by diverting the excess flow to relief sewer.

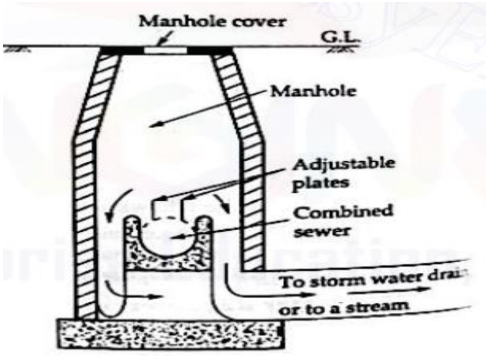
The overflow device may be side flow or leaping weirs according to the position of the weir, siphon spillways or float actuated gates and valves.

Side Flow Weir

It is constructed along one or both sides of the combined sewer and delivers the excess flow during storm period to relief sewers or natural drainage courses.

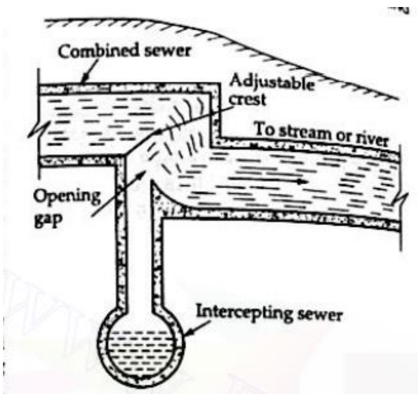
The crest of the weir is set at an elevation corresponding to the desired depth of flow in the sewer. The weir length must be sufficient long for effective regulation of the flow.





Leaping Weir

- The term leaping weir is used to indicate the gap or opening in the invert of a combined sewer.
- The leaping weir is formed by a gap in the invert of a sewer through which the dry weather flow falls and over which a portion of the entire storm leaps.
- This has an advantage of operating as regulator without involving moving parts.
- However, the disadvantage of this weir is that, the grit material gets concentrated in the lower flow channel.
- From practical consideration, it is desirable to have moving crests to make the opening adjustable.
- When discharge is small, the sewage falls directly into the intercepting sewer through the opening.
- But when the discharge exceeds a certain limit, the excess sewage leaps or jumps across the weir and it is carried to natural stream or river.



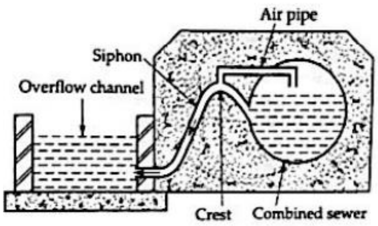
Float Actuated Gates and Valves

- The excess flow in the sewer can also be regulated by means of automatic mechanical regulators.

- These are actuated by the float according to the water level in the sump interconnected to the sewers.
- Since, moving part is involved in this, regular maintenance of this regulator is essential.

Siphon Spillway

- This arrangement of diverting excess sewage from the combined sewer is most effective because it works on the principle of siphon action and it operates automatically.
- The overflow channel is connected to the combined sewer through the siphon.
- An air pipe is provided at the crest level of siphon to activate the siphon when water will reach in the combined sewer at stipulated level.



Types of Pumps

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

- Radial-flow centrifugal pumps
- Axial-flow and mixed-flow centrifugal pumps
- Reciprocating pistons or plunger pumps
- Diaphragm pumps
- Rotary screw pumps
- Pneumatic ejectors
- Air-lift pumps

Other pumps and pumping devices are available, but their use in environmental engineering is infrequent.

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.

- A centrifugal pump consists of a revolving wheel called impeller which is enclosed in an air tight casing to which suction pipe and delivery pipe or rising main are connected.
- The clearance between the vanes of the impeller is kept large enough to allow any solid matter entering the pump to pass out with the liquid so that the pump does not get clogged. As such for handling sewage with large-size solids, the impellers are usually designed with fewer vanes.
- The pumps with fewer vanes in the impeller or having large clearance between the vanes are called non-clog pumps.
- However, pumps with fewer vanes in the impeller are less efficient.
- A spiral shaped casing called volute casing is provided around the impeller.
- At the inlet to the pump at the centre of the casing a suction pipe is connected, the lower end of which dips into the liquid in the tank or sump from which the liquid is to be pumped or lifted up.
- At the outlet of the pump a delivery pipe or rising main is connected which delivers the liquid to the required height.
- Just near the outlet of the pump on the delivery pipe or rising main a delivery valve is provided.
- A delivery valve is a sluice valve or gate valve which is provided in order to control the flow of liquid from the pump into the delivery pipe or rising main.
- The impeller is mounted on a shaft which may have its axis either horizontal or vertical.
- The shaft is coupled to an external source of energy (usually an electric motor) which imparts the required energy to the impeller thereby making it to rotate.
- When the impeller rotates in the casing full of liquid to be pumped, a forced vortex is produced which imparts a centrifugal head to the liquid and thus results in an increase of pressure throughout the liquid mass.
- At the centre of the impeller (which is commonly known as eye of the impeller) due to the centrifugal action a partial vacuum is created.

- This causes the liquid from the sump, which is at atmospheric pressure, to rush through the suction pipe to the eye of the impeller thereby replacing the liquid which is being discharged from the entire circumference of the impeller.
- The high pressure of the liquid leaving the impeller is utilized in lifting the liquid to the required height.
- Pumps for sewage pumping are generally of all cast iron construction.
- If the sewage is corrosive then the stainless steel construction may have to be adopted.
- Also, where the sewage would contain abrasive solids, the pumps constructed of abrasion-resistant material or with elastomer lining may be used.

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.

Types of Reciprocating pumps

(1) Ram type and

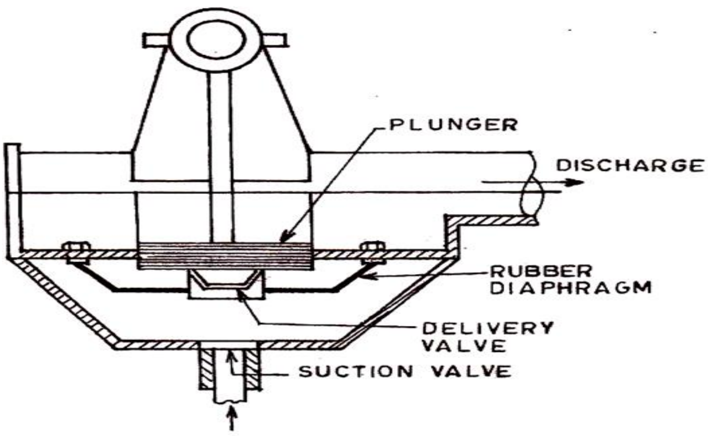
(2) Propeller type.

- In the propeller type reciprocating pump a multiple blade screw rotor or propeller moves vertically inside a pump-casing causing the sewage to be lifted.
- It draws liquid through inlet guide vanes and discharges through outlet guide vanes.
- Thus its action is somewhat similar to that of a ship's propeller.
- The axial-flow screw pump is an example of the propeller type reciprocating pump.

Diaphragm pump is a ram type reciprocating pump.

- A piston or plunger is attached to the centre of a circular rubber diaphragm, the outer edge of which is bolted to a flange on the pump.
- The flexibility of the diaphragm permits the up and down motion of the plunger thereby increasing or decreasing the capacity of the pump-casing.

- During upward movement of the plunger, liquid flows into the pump through the suction valve, while downward movement of the plunger closes the suction valve, and forces the liquid through the delivery valve (provided in the plunger) out to discharge.
- The diaphragm pump is simple, durable and needs no priming.
- However, after some use, the rubber diaphragm wears out needing replacement.



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-

(i) Where small quantity of sewage is to be lifted from cellar or basement of a building to a high level sewer;

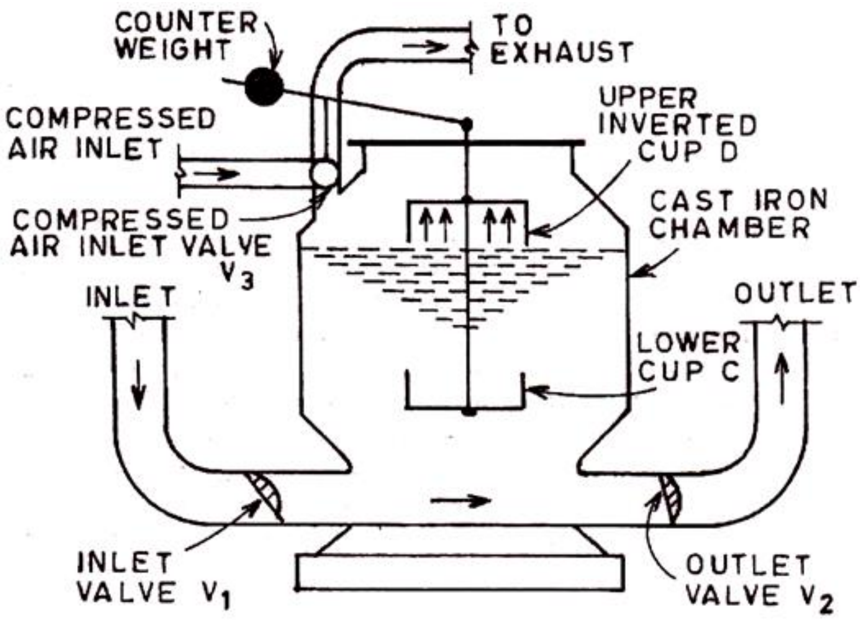
(ii) Where the quantity of sewage from a low lying area does not justify the construction of a pumping station; and

(iii) Where a centrifugal pump of small capacity is likely to clog.

Pneumatic ejectors use compressed air for lifting sewage.

- It consists of an air tight cast iron chamber with a spindle having two cups-upper cup D which is inverted and lower cup C.
- Two reflux valves (or check valves) V_1 and V_2 are provided at the inlet and the outlet points respectively.
- A compressed air inlet valve V_3, is provided which is operated by a lever arrangement with a counter weight.
- Compressed air is supplied through this valve at a pressure of about 0.15 N/mm2 (1.5 kg (f)/cm2). The air in the chamber can escape through the exhaust.

- The sewage flowing under gravity enters the chamber through the inlet valve K, and rises slowly in the chamber, the outlet valve V_2 and the compressed air inlet valve V_3 being closed at this stage.
- As the sewage level rises the air from the chamber escapes through the exhaust.
- When the sewage level reaches the rim of the upper inverted cup D the air inside this cup is entrapped.
- Further rise in the sewage level in the chamber makes the entrapped air to exert vertical pressure on the inner bottom surface of the upper inverted cup D. Due to this the cup D is lifted up and through the lever arrangement the compressed air inlet valve F3 gets opened and at the same time the exhaust gets closed.



- The air under pressure entering the chamber from valve V3 forces the sewage inside the chamber to flow through the outlet valve V2 into the outlet pipe which carries it to a high level sewer.
- At this stage when the outlet valve V2 and the compressed air inlet valve F3 are open, the inlet valve V1 is closed.
- The discharge of the sewage from the chamber continues till the sewage level in the chamber falls to such a point that the weight of the lower cup C and the sewage it contains causes the cup C to drop.
- The lower cup C and the upper inverted cup D being connected by one rod, when the cup C drops the cup D also drops and at the same time the compressed air inlet vale V3 gets closed and the exhaust gets opened.

- The sewage then starts entering the chamber through the inlet valve V1 as before and the process is repeated. The outlet valve V2 opens in one direction only and therefore the back flow of sewage from the high level sewer into the chamber of the ejector is prevented.
- Further while the ejector is discharging the inlet valve V1, remains closed and the incoming sewage is retained above the inlet valve or it is directed towards another ejector.
- To obtain nearly uniform rate of sewage flow, the ejectors are usually installed in pairs so that when one is filling the other is discharging.

The merits of pneumatic ejectors

- They have no clogging parts and they work silently with the compressed air easily supplied from a central station.
- These may be employed economically for a maximum lift of about 6 m or so.
- They also avoid the necessity of installing screens and underground suction wells.
- Their capacities are, however, small varying from 500 to 10 000 litres.

Demerit of pneumatic ejectors

They have very low efficiency seldom above 15 per cent except when working against low heads.

Plumbing systems for drainage

Drainage System

It is the arrangement provided in a house or building for collecting or conveying waste water through drain pipes, by gravity, to join either a public sewer or a domestic septic tank is termed as house drainage or building drainage.

Terminologies related to Drainage:

Wastewater

Water when used for different purpose like domestic commercial, industrial etc. receives impurities and become wastewater. Thus wastewater is used water and it has physical, chemical and biological impurities in it.

Sewage: The waste water coming from W.C. and containing human excreta is known as sewage.

Sullage: The wastewater coming from bathrooms and kitchens which does not contain faecal matter is known as sullage.

Plumbing/Drainage System:

It is entire system of pipe line for providing water supply to the building or it is a system of pipes for disposal of wastewater from the building.

Sewer: A pipe carrying sewage/ wastewater is called sewer.

Soil Pipe: It is pipe carrying sewage from W.C.

Vent Pipe: A vertical pipe that provides circulation of air to and from the Drainage system.

Stack: A general term used for any vertical line of soil, waste or vent piping

Cleanout: An access opening to allow cleanout of the pipe

Waste Pipe: It is a pipe carrying sullage from bathrooms, kitchens, sinks, wash basins, etc.

Sewerage System: A system of sewers of different types and sizes in a town collecting wastewater from the town and carrying it to the wastewater treatment plant.

Sanitary Sewer: A sewer pipe that carries only sewage.

Storm Sewer: A sewer pipe that carries storm water or other drainage (excluding sewage).

Building Sewer: Part of the drainage system from the building to the public, private, or individual sewer disposal system.

Sewer Main: A sewer pipe installed and maintained by public entity and on public property.

Components of Drainage system:

- Pipes
- Traps
- Sanitary Fittings
- Chambers

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.

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.

Classification of traps

Based on their shape

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.

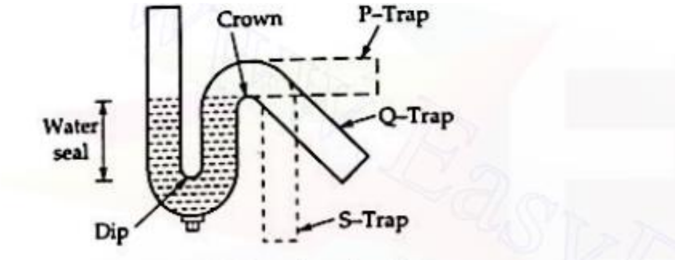
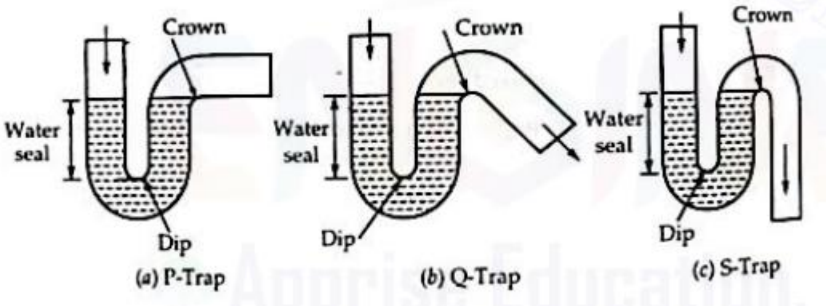


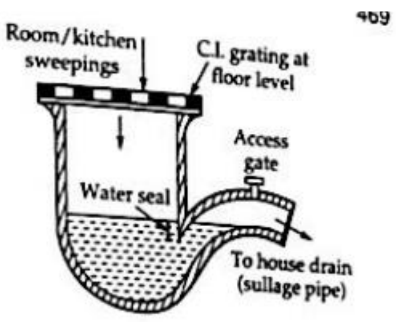
Fig. 13.1. P, Q and S Traps shown together.



Based on the Use

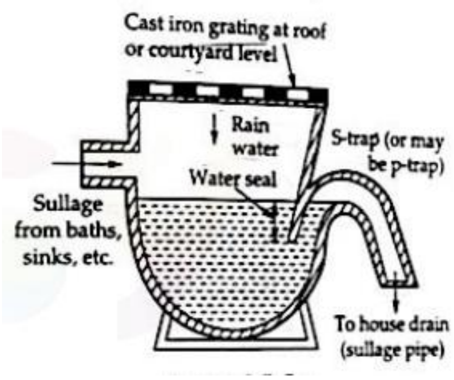
Floor Traps (Nahni Trap): This trap is generally used to admit sullage from the floors of rooms, bathrooms, kitchen etc. in to the sullage pipe.

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.

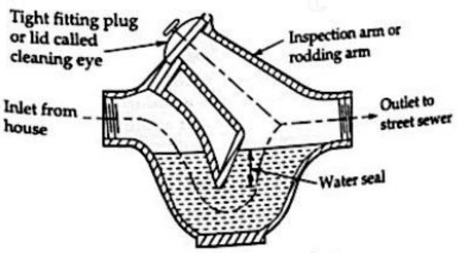


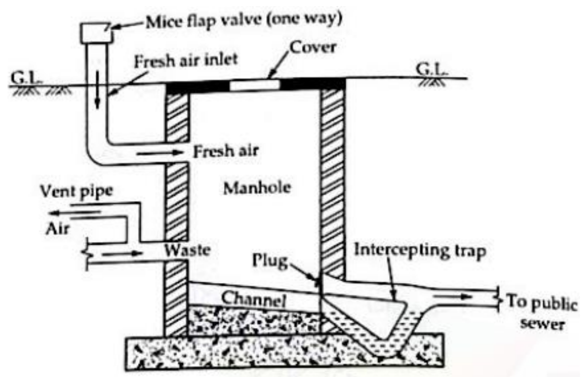
Intercepting Traps:

Intercepting traps 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.

This trap at such junction is often provided in a small manhole.

It's constructed just near the house, either outside the street or in a corner inside the house of boundary.





Four principle systems adopted in plumbing work in building

1. Two pipe system.

2. One pipe system.

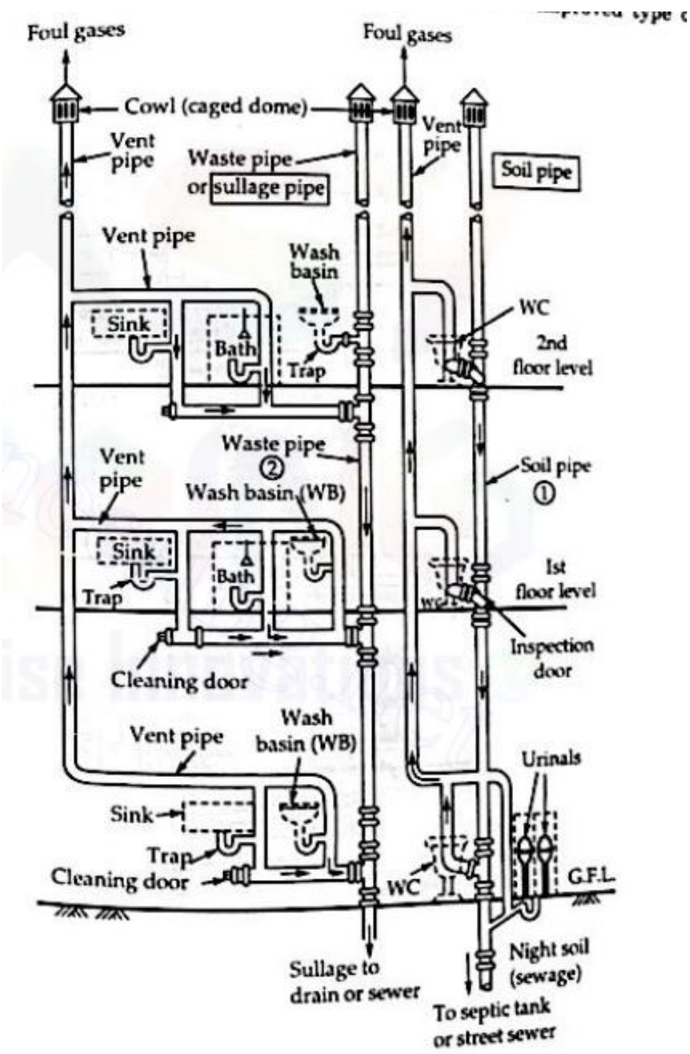
3. Single stack system

4. Partially ventilated single stack system.

1) **Two pipe system**

This is the best and most improved type of system of plumbing.

- In this system, two sets of vertical pipes are laid, i.e. one for draining night soil and other for draining sullage.
- The pipe of the first set carrying night soil is called soil pipes and the pipes of the second set carrying sullage from baths etc., are called sullage pipe or waste pipe
- The soil fixtures, such as latrines and urinals are thus all connected through branch pipes to the vertical pipe.
- Where the sludge fixtures such as baths, sinks, wash-basins, etc., are all connected through branch pipes to the vertical waste pipe.
- The soil pipe as well as the waste pipe is separately ventilated by providing separate vent pipe.

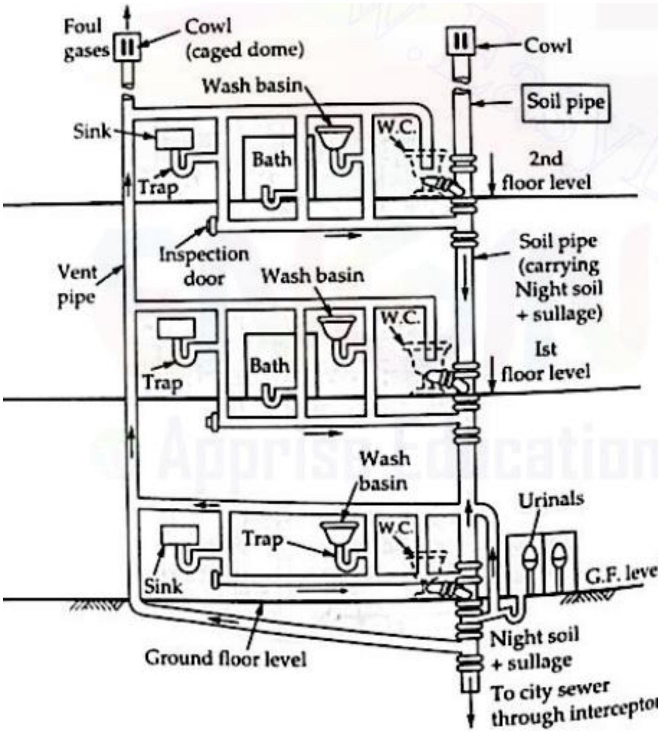


One pipe system:-

- In this system, instead of using two separate pipes(for carrying sullage and night soil, as it done in the above described two pipe system), only main vertical pipe is provided

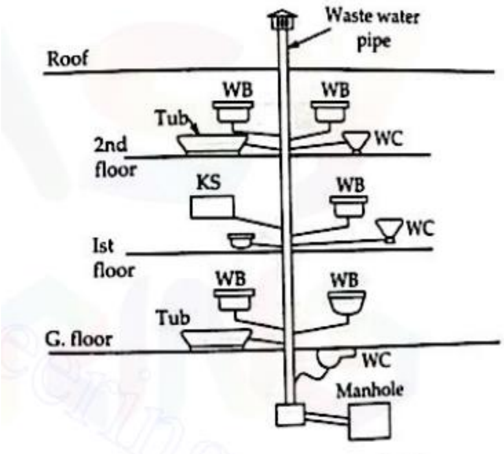
  which collects the night soil as well as the sullage water from their respective fixtures through the branch pipes.

- This main pipe is ventilated in itself by providing cowl at its top and in addition to this, a separate vent pipe is also provided.



Single Stack System

- This system is a single pipe system without providing any separate ventilation pipe.
- It uses only one pipe which carries the sewage as well as sullage, and is not provided with any separate vent pipe , except that it itself is extended up to about 2m higher than the roof level and provided with a cowl for removal of foul gases .



Partially ventilated single stack System

- This is an improved form of single stack system in the sense that in this system, the traps of water closets are separately ventilated by a separate vent pipe called relief vent pipe.

- This system uses two pipes as in single pipe system but the cost of branches is considerably reduced compared to single pipe system.