CE3303 WATER SUPPLY AND WASTE WATER ENGINEERING

UNIT I - WATER SUPPLY

OBJECTIVES of a water Supply System.

(i) To Supply safe and unpolluted water to consumers

(ii) To Supply water in adequate quantity.

(iii) To make water easily available to consumers.

Components of a water Supply system.

(i) Collection.

Surface water and ground water Sources.

(Perennial rivers, dams, intake structures).

(ii) Transmission

Conveyance of water from the source to the treatment Plants.

(Pipelines / Conduits, Canals, aqueducts, pumps, etc.)

(iii) Purification.

To remove physical, Chemical and biological impurities from water and make it safe for Consumption - water treatment plant.

(filter beds, softening units etc).

(iv) Distribution.

To distribute treated purified water to the Consumers under pressure

(Elevated Reservoirs, Pipelines, Pumps, etc).

Surface Sources of water supply.

1. Natural Ponds and Lakes.
2. Streams and Rivers.
3. Impounding Reservoirs.

1) Natural Ponds and Lakes.

→ Natural large-sized depression formed on earth surface, when filled with water is called a pond or Lake

→ Surface run-off from nearby Catchment area drains water into lakes.

→ Sometimes, small springs also drain underground water into ponds and lakes.

Quality.

→ good quality.
→ There is no need of much purification.
→ Self purification of water occurs in lakes due to:

* Sedimentation of suspended matter
* Bleaching of colour.
* Removal of bacteria etc.

→ Larger and older lakes are more purer.

→ As lakes are still and standing waters, it contribute to growth of algae and weeds, imparting bad smell, taste, colour to waters

Intake of water.

Intakes are the structures built in Surface water sources (Such as rivers, lakes, reservoirs, etc).

Different Parts of an intakes are:

(i) **Entry Ports or Inlets or Penstocks:**

→ Provided at different elevations to ensure water flow during all seasons. i.e to take care of fluctuation during summer.

(ii) **Screens:**

→ The entry ports are protected with screens to prevent entry of any debris or floating materials into the intakes.

(iii) **Intake well.**

→ It is built of masonry or concrete which may be rectangular or circular in shape.

(iv) **Conduits.**

→ They are the pipelines through which water is conveyed from the intake well to the nearby treatment plant.

(v) **Gate valves and control room:**

→ The water flow is regulated by gate valves provided on top at the control tower.

(vi) **Foot Bridge.**

→ A Foot bridge is provided on top of the intake tower for access.

Factors governing the location of site for intakes

The site chosen for intakes should be preferably.

(i) Near the treatment plant (To reduce the cost of pipelines)

(ii) At the purer zone of the surface source (To reduce the water treatment cost).

(iii) At the upstream side of source.

(iv) Not near any waste water or sewage disposal points

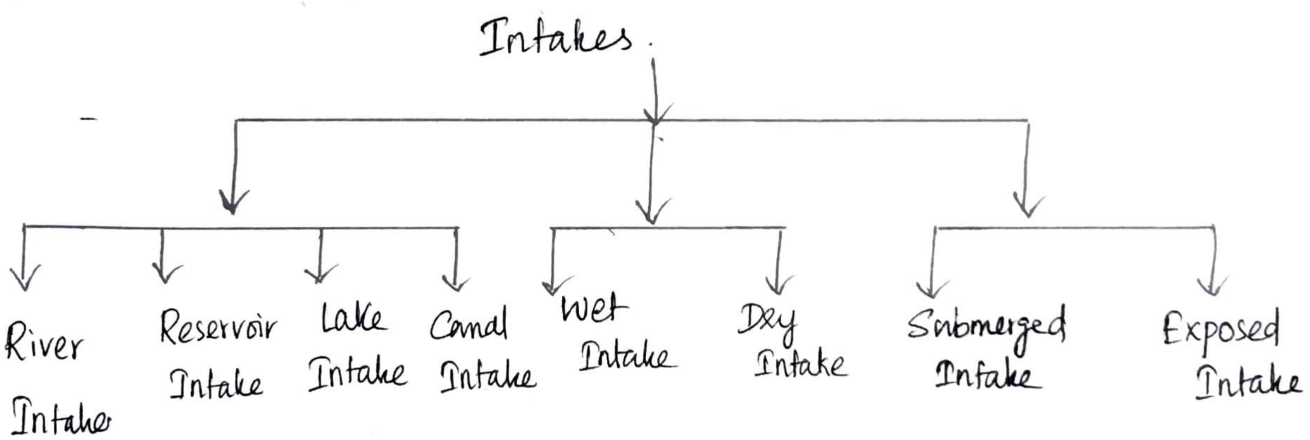
(v) Provide greater withdrawal of water including expansions in future

(vi) Provide water even during dry seasons.

(vii) Not near any navigation channel.

(viii) Should not get flooded.

TYPES OF INTAKES.



Pumping and Gravity Schemes

Pumps are used for the following Purposes

1. To lift raw water from the source of supply (lake, reservoir, river, well)
2. To lift treated water to overhead tanks and reservoir.
3. To deliver treated water to consumer's taps at reasonable pressure
4. To boost the water line pressure.
5. To supply water under pressure for fire hydrants.
6. For miscellaneous operations at water treatment plants such as:
   (i) Backwashing of filters.
   (ii) Pumping of Chemicals.
   (iii) Dewatering of tanks, basins, sumps etc.

TYPES OF PUMPS.

Based on Mechanical Principle of Operation.

(i) Displacement Pumps.
(ii) Centrifugal Pumps.
(iii) Air lift Pumps.
(iv) Miscellaneous pumps.

Based on Type of Power required.

(i) Steam engine pumps.

(ii) Diesel engine pumps.

(iii) Electrically driven pumps.

Based on Types of service called for.

(i) Low lift pumps.

(ii) High lift Pumps.

(iii) Deep well pumps.

(iv) Booster Pumps.

Water Demand.

Types.

1. Domestic water demand (Residential)

2. Industrial Water demand

3. Institutional and Commercial water demand.

4. Demand for Public uses.

5. Fire demand.

6. Water required to compensate losses in wastes and thefts.

1. Domestic Water Demand:

→ The water required in residential buildings for drinking, Cooking, bathing, gardening, flushing etc.

→ The domestic water demand is 50 to 60% of the total water consumption.

→ The demand may vary according to the living conditions of Consumers (LIG/MIG/HIG)

LIG – Low Income Group
MIG – Middle Income group
HIG – High Income group.

Minimum water consumption for Indian Cities.

Description	Amount of water in lpcd.
Bathing	55
Washing Clothes	20
Flushing of W.C	30
Washing House	10
Cooking	5
Drinking	5
Total	135 lpcd

2. Industrial Water Demand.

→ Represents the water demand of industries (existing & future)

→ The demand varies according to the number and type of industries in the city.

→ The average per capita consumption for industrial needs is 50 lpcd

→ In Industrial cities, the per capita water requirement is 450 lpcd.

→ Water demand of certain industries are

a) Automobile - 40 litre per vehicle produced

b) leather - 40 kilo litre per tonne produced

c) Textile - 80-140 litre per tonne produced.

3. Institutional and Commercial water demand.

→ Water requirement of Institutions such as Hotels, Hospitals, schools, colleges, offices, Railway stations, Factories etc.

→ The water demand depends on the nature of city and number of commercial establishments.

→ On an average, the per capita demand is 20 lpcd.

Water for Institutional Needs.

Institution	Water requirement (lpcd).
Offices	45 to 90
Schools	45 to 90
Hotels	135 to 180
Hostels	180
Hospitals	450
Railway station	70.

4. Demand for Public or Civic use.

→ The quantity of water required for public utility purposes such as watering of public parks, gardening, washing and sprinkling on roads, public fountains etc.

→ It accounts to 5% of the total water consumption i.e. 10 lpcd

5. Fire Demand.

→ In thickly populated and industrial areas, fire outbreaks may cause serious damages.

→ The quantity of water required for fire fighting is called fire demand and it is stored in storage reservoirs

→ The minimum water pressure available in fire hydrants should be 100 to 150 kN/m² (10 to 15 m of water head)

→ For cities having population > 50,000, water required for fire fighting in kilo litre.

$= 100\sqrt{P}$, Where, P = Population in thousands.

6. Water required to compensate losses (thefts / wastes).

(i) Leakage / overflow from service reservoirs.
(ii) Leakage from main/service pipe connections.
(iii) Leakage / losses on consumer's premises (unmetered)
(iv) Leakage from public taps.
(v) Defective pipe joints.
(vi) Cracked pipes
(vii) Loose valves / Fittings
(viii) Unauthorised water connections
(ix) Damaged meter

PER CAPITA DEMAND.

The Per Capita Demand (q) in litres per day per head (Annual average daily consumption per person)

$$= \frac{\text{Total yearly water requirement of city in litres}}{365 \times \text{Design Population}}$$

Factors Affecting Per Capita Demand.

1) Size of City / Type of Community - The fluctuations in demand depends upon the size of City.

- → Large city - fluctuations are less and demand is more
- → Small City - demand is less
- → Residential community - More fluctuations in demand.
- → Industrial Community - Fluctuation is less.

2) Standard of living / habits of people.

- → Higher the standard of living - demand for water is more

3) Climatic Conditions.

- → Hot Climate - Usage of water will increase (bathing, lawn sprinkling etc)
- → Cold Climate - water is wasted to prevent freezing of pipes.

4) Quality of water

- → Good quality water - usage is more
- → Poor quality water - Usage is less

5) Pressure in the supply.

- → High Pressure - increased usage
- → Low Pressure - decreased usage.

6. System of Supply

→ Water supply may be Continuous (24hrs) or intermittent.

→ Intermittent supply reduces the demand.

7. Sewerage.

→ Flushing system increases water demand.

8. Policy of metering

→ Use of water decreases when the supplies are metered

9. Water rates

→ Increase in water rates reduces the Consumption

10. Age of Community.

→ Older communities use less water. Developing new Communities require large quantity of water for construction works.

11. Lawn sprinkling.

→ Enforcement of lawn sprinkling regulations can reduce peak demands.

SOURCES OF WATER SUPPLY.

- Surface water Sources
  1. Natural Ponds & Lakes
  2. Streams & Rivers
  3. Impounding Reservoirs
- Ground water Sources.
  1. Springs
  2. Wells
  3. Infiltration Galleries.

Surface Water Sources:

1. Natural Ponds and Lakes:

- Natural Large-sized depression formed on earth surface, when filled with water is called a pond or Lake.
- Surface runoff from nearby catchment area drains water into lakes.
- Sometimes, small springs also drain underground water into ponds and lakes.

Quality of water

- Good quality
- There is no need of much purification.
- Self purification of water occurs in Lakes due to.
  * Sedimentation of suspended matter.
  * Bleaching of colour
  * Removal of bacteria, etc.
- Larger and older lakes are more purer.
- As lakes are still and standing waters, it contribute to growth of Algae and weeds, imparting bad smell, taste colour to waters.

Quantity of water:

- Small quantity of water
- The quantity depends on, catchment area, Annual rainfall, Geological formation
- Cannot be used as a principal source of water supply.
- Useful for small towns & hilly areas only.
- When no other sources are available, lakes may be used for water supply.

Ex: Water supply to Bombay city is from lakes

2. Streams And Rivers:

Streams:

- As the quantity of water is less, it is not suitable for water supply schemes.
- They are useful for small villages and hilly areas.
- Large perennial streams may be used as sources of water by providing storage reservoirs.

Rivers:

- Most important source of water for public water supply.
- Rivers may be perennial or non-perennial.
- In Perennial rivers, water is available throughout the year.
- Perennial rivers can be used as a source for water supply
- Non-Perennial rivers can also be used as source of Public supply by constructing storage reservoirs, dams etc.

Quantity:

Good source of water supply to cities mostly located nearby the rivers.

Quality:

- Water quality is not reliable.
- River water has large amount of silt, sand and suspended matter.
- The disposal of sewage into river contaminates the waters.
- Proper treatment is required for river waters before supply to public.

3) Impounding Reservoirs / Storage Reservoirs:

- The Rivers or Streams when directly used for water supply schemes fail due to the following problems.
- During low flows (dry season), it cannot meet the demand of the consumers.
- During high flows, it leads to devasting floods.

Hence, it is necessary to build a barrier or dam or storage / Impounding reservoirs at the upstream of rivers to store the excess water (during low flows)

- An Impounding Reservoir is an artificial lake created by constuction of dam across a water course.
- The objective is to (impound) Store water for water supply schemes.

Parts of an Impounding Reservoir:

(i) Dam to hold back water

(ii) Spillway to discharge excess flow

(iii) Gate Valves to regulate water flow

Location of Impounding reservoir is selected based on the following factors.

(i) Existence of suitable dam site - Short and narrow dams

(ii) Quantity of water available should be sufficient to meet the demand throughout the year (Rainfall, runoff, Catchment area characteristics)

(iii) Distance and elevation of reservoir with reference to point of distribution.

(iv) Longer distance - Cost will be high
Higher elevation - Cost is low due to gravity flow. Pumping is not required.

(iv) Density and distribution of population over the Catchment area. If the population is less, the pollution of streams will be less.

(v) Existence of towns, highways, railyards, cultivable areas.

(vi) Geological conditions of storage basins.

→ Existence of calcareous bed rocks may cause hardness to water.

→ Existence of fissures may lead to water loss by percolation.

Selection of Dam Site:

The selection of a site for constructing dam is governed by following factors:

(i) Suitable foundation

(ii) Length of dam should be small with maximum storage volume. The river valley should be narrow with large upstream basin for reservoir.

(iii) Bed level of dam site should be higher than river basin.

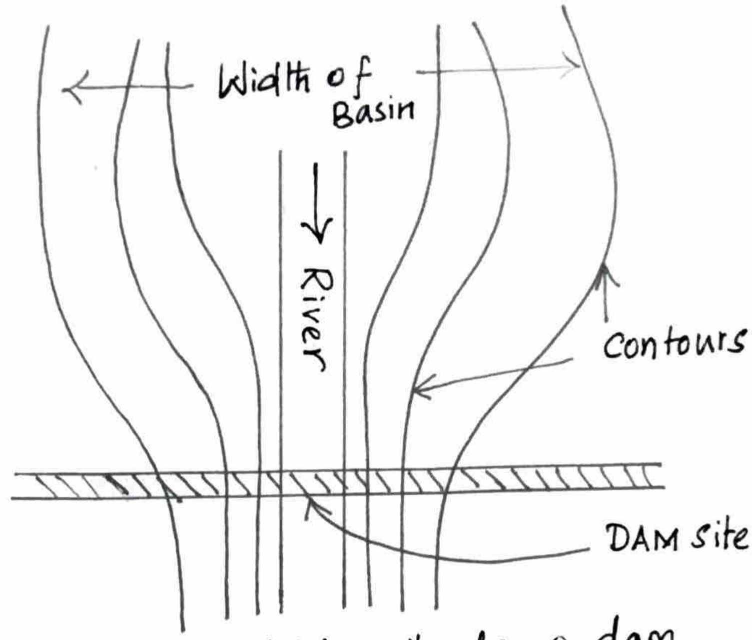
(iv) Construction materials should be locally available.

(v) Reservoir basin should be water tight

(vi) Land value should be low.

(vii) Accessible and well connected by roads, rails to towns and cities.

(viii) Labour easily available.



Contour map of a suitable site for a dam.

Storage Capacity of Reservoir:

→ It is determined from the contour maps of the area (Topographic Survey)

→ The contours of the area can be plotted as an Area-elevation curve. The integral of this curve is used to compute the elevation capacity or storage.

→ The volume of water that can be stored by the reservoir at a certain water surface elevation can be computed by summing up the increment between two elevations.

$$\Delta s = \Delta a + \Delta h$$

- Δs → Increment of storage
- Δa → Avg. area of two elevations
- Δh → Elevation difference.

→ In the absence of topographic maps, capacity can be determined using formulae.

$$\text{Volume} = h\left[\frac{A_1 + A_n}{2} + A_2 + A_3 + \ldots\ldots A_{n-1}\right] \quad \text{Trapezoidal formula}$$

(or)

$$= \left[(A_1 + A_n) + 4(A_2 + A_4 + \ldots) + 2(A_3 + A_5 + \ldots)\right] \quad \text{Prismoidal formulae}$$

Catchment yield = Annual inflow to the reservoir

Reservoir Yield = Amount of water drawn from the reservoir

Storage capacity = Inflow = Outflow.

Quality of Water in Impounding Reservoir.

- Good quality
- There is no need of much purification
- Self purification of water occurs in Impounding reservoir due to
  * Sedimentation of suspended matter.
  * Bleaching of Colour.
  * Removal of bacteria, etc.
- Impounding Reservoirs are more purer.
- As Impounding reservoirs are still and standing waters, it contribute to growth of Algae and weeds, imparting bad smell, taste, colour to waters.

Quantity of water in Impounding Reservoir.

- Sufficient quantity to meet the demand of water supply schemes.
- Used for other purposes also - Irrigation, fishing, recreation, hydropower generation.

GROUND WATER SOURCES.

The part of rainfall that percolates through soil pores, contributes to ground water and appears as springs, wells and infiltration galleries

Characteristics of Water table.

→ It follows the profile of ground surface.

→ It is not static, fluctuates, rises during wet season and falls in dry season.

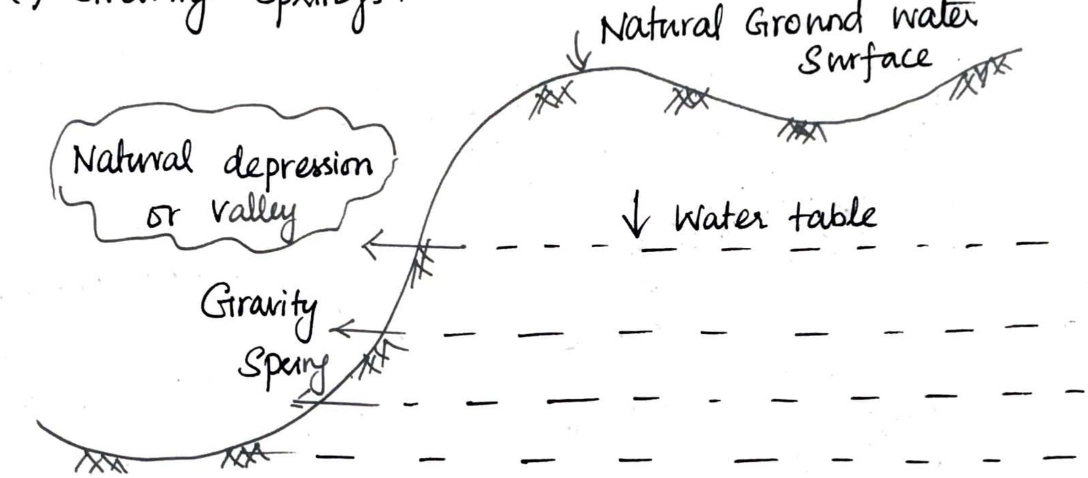
→ Where the water table level and ground level meets, springs or streams may appear.

1) Springs

Springs are outcrops of groundwater at foot of hills and river banks. The types are

(i) Gravity springs
(ii) Artesian springs
(iii) Surface springs.

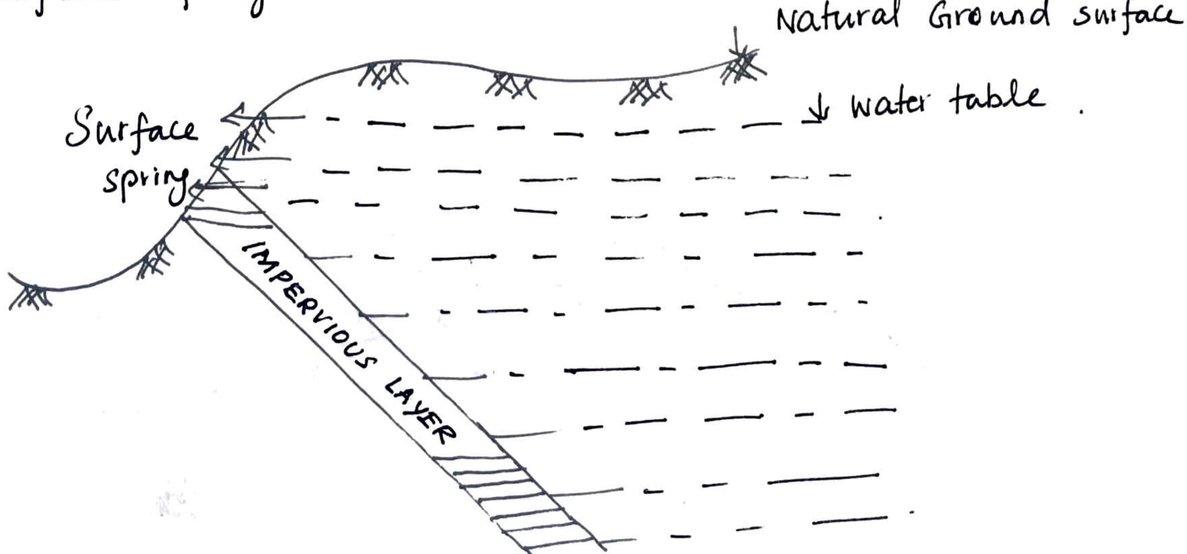
(i) Gravity Springs.



→ When the ground water table rises high and water overflows through sides of natural valley, a gravity spring is formed.

→ The flow fluctuates with the rise (or) fall of water table.

(ii) Surface Springs.

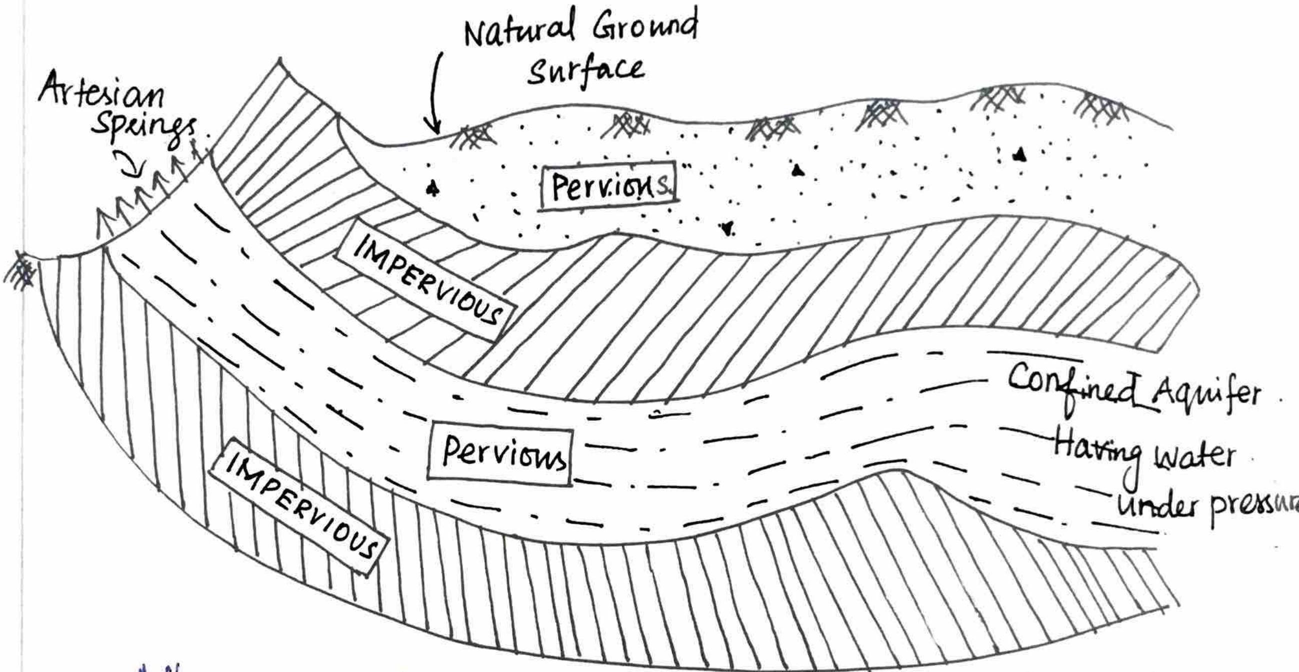


→ Surface Springs are formed when an impervious

Stratum Supporting underground Storage becomes inclined Causing the water table to rise up and get exposed to the ground surface

→ The quantity of water in these springs is uncertain

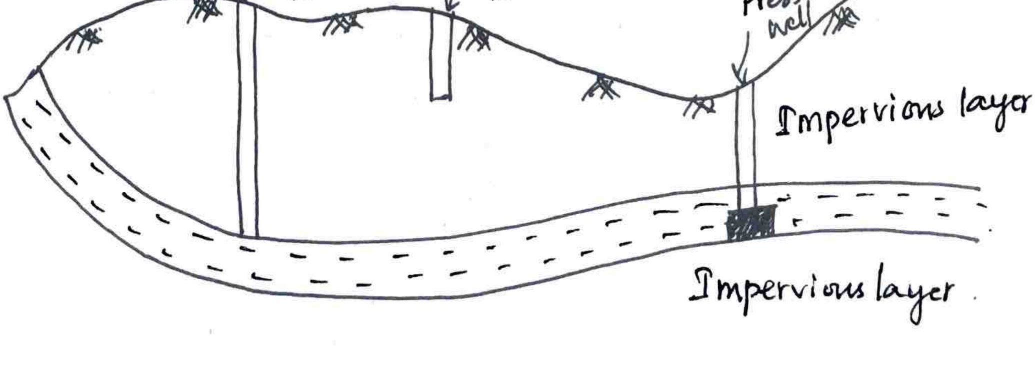
(iii) Artesian Springs.



→ When the water bearing Strata between two impervious Strata is under pressure, the water flows through weaker section which is called artesian springs.

2) Wells.

Well are vertical cylindrical openings from surface to a water bearing formation



Classification.

a) Based on the type of Aquifer tapped

(i) Shallow wells

Tapping of uppermost water Bearing strata

Draw backs

→ Large fluctuations in yield

→ Quality of water is poor.

(ii) Deep wells.

→ Tapping of deeper and larger aquifers

b) Based on the Condition of flow:

(i) Gravity well.

Water flows under gravity into the well under atmospheric pressure.

(ii) Pressure well.

→ Aquifer is confined between two impervious strata.

→ water flows under pressure greater than atmospheric pressure.

C) Based on type of Construction.

(i) Dug well or percolation well (open wells).

(ii) Sunk wells.

(iii) Driven wells.

(iv) Tube well.

(i) Dug well

- Shallow wells with masonry walls. The well sinks under masonry weight
- More masonry is added and excavation proceeds till the required height
- Cheap and easy construction.
- Useful for villages and small Towns.

Quality

- Water is easily contaminated.

Quantity

- Larger diameter increased the yield.

(ii) Tube wells

Constructed by drilling auger boring into ground using machinery.

Types:

Deep and shallow wells.

Methods of drilling:

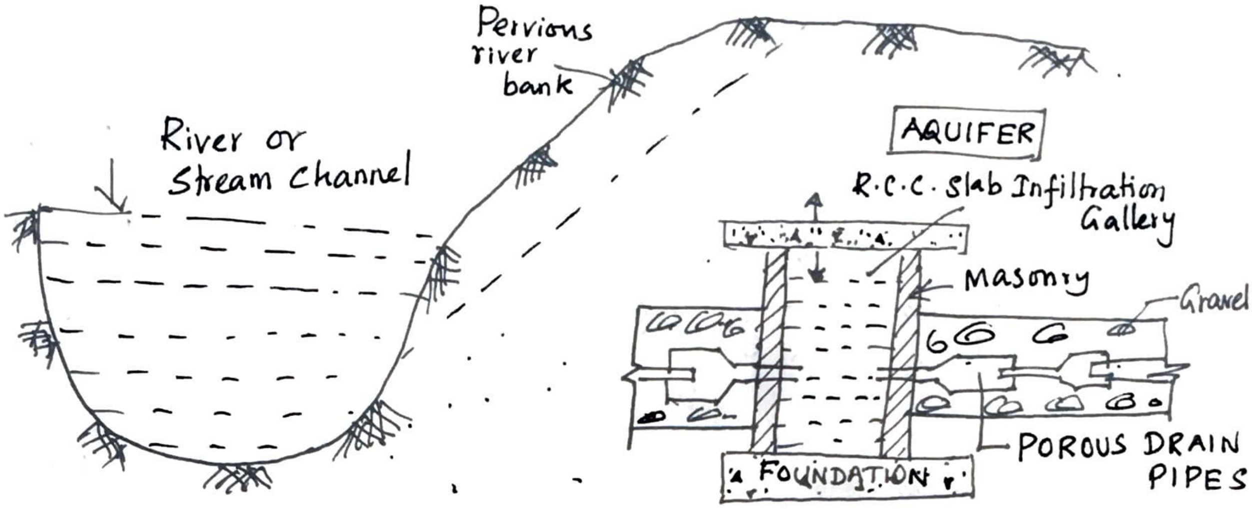
(a) Percussion drilling
(b) Core drilling
(c) Rotary drilling.

Storage capacity of ground water

Storage capacity depends on

(i) Porosity of soil (Percentage of voids to total volume).
(ii) Permeability of soil (ability of rock to pass water)

3) Infiltration Galleries:



→ These are horizontal tunnels/wells constructed at shallow depths along the river bank for tapping water.

→ An Infiltration gallery is constructed of masonry walls with roof slab and extracts water from aquifers by various porous lateral drain pipes.

→ The pipes are covered with gravel to prevent entry of sand and particles.

→ The galleries are laid at slope and water collected in them is taken to a sump well, from where it is pumped.

→ The discharge from infiltration gallery is computed by,

$$Q = KL\left[\frac{H^2-h^2}{2R}\right]$$

K - Permeability Coefficient of aquifer

L - Length of gallery

R - Radius of influence

H - Static water level

h - Depth on pumping equilibrium.

Factors Governing Selection of a Particular Source of Water.

- Quantity of available water sufficient to meet the demand throughout the year

- Quality of available water : Should be nontoxic, without any impurities and must be easily and economically treatable.

- Distance of Source of supply : Should be nearer to City, so that the cost of Pipe laying is less.

- Topography of intervening area

  The land between the source and the City (distribution area) should be even without any valleys or ridges to reduce Construction Cost.

- Elevation of source.

  The water source should be at higher elevation than the City to achieve gravity flow or to reduce the cost of pumping.

Comparison of Surface Sources and Ground water Sources.

Item	Surface water Sources	Ground water Sources
Form in which Available	Ponds, lakes, Streams, Rivers Artificial Storage or Impounding reservoirs.	Springs (Gravity, Artesian) Wells (shallow, deep, tube) Infiltration galleries Infiltration wells.
Quantity.	* Huge amount of water is available during rainy season. * Quantity of water is less during summer * For continuous, constant supplies, storage reservoirs are constructed to store the excess water during rains and supply it during dry periods * Useful for public water supply for big cities.	* The available yield is smaller * They are useful for towns and villages only * Cannot be relied for water supply to cities.
Quality	(a) River waters. * Contain huge amounts of suspended impurities (silt, sand, vegetable matter, dead animals, industrial wastes etc) * Rivers are highly polluted and unsafe. (b) Lakes. * Water from the reservoirs and lakes are clear and contain less suspended matter as it settles down in still waters * But lakes and reservoirs encourage weed and algae growth (organic impurities) * However, controlled algae growth increases oxygen in lake or reservoir waters due to photosynthetic process * The surface waters therefore require extensive treatment before supply to public.	* Ground water has lesser suspended matter. As water passes through soil pores, it undergoes natural filtration which reduces the suspended impurities * The ground water however, contains large amounts of dissolved salts minerals and gases. Thus the ground water is hard and salty * Unconfined water wells are liable to high bacterial contamination * Ground water requires lesser treatment and can be supplied to public with minimum treatments.

1.10.6. WATER-BORNE DISEASES

World Health Organization (WHO) has observed that 80% of communicable diseases are transmitted through water. The diseases like cholera, gastroenteritis, typhoid, amoeba, diarrhea, polio, hepatitis (Jaundice), Leptospirosis and Dracontiasis are caused by bacteria. Excess of fluorides presents in water (above 1.5 mg/litre) cause diseases like dental fluorosis, skeletal fluorosis. This is a permanent irresistible disease that weakens the bone structure. The patient becomes immobile and bedridden.

Excess of nitrates in water causes **Methaemoglobinaemia** or **Blue Baby Symptoms** in infants. It affects the hemoglobin in the blood and reduces its capacity to transport oxygen to the cells. Nitrates in water are caused by industrial effluents, agricultural runoff. Toxic ions of chromium, lead, arsenic and pesticides in water cause diseases affecting the kidney, liver and high blood pressure, paralysis, cancer etc. These toxic substances are due to industrial effluents reaching the surface and ground water sources.

1.11. WATER QUALITY STANDARDS

Following table gives the physical, chemical and bacteriological standards for water quality as suggested by the following agencies, as per the WHO recommendations.

Table 1.6. Water Quality Standards

S.No.	Characteristics in mg/l (1)	Acceptable (2)	Cause for rejection (3)
1	pH value	7.0 - 8.5	6.5 - 9.2
2	Total dissolved solids (mg/l)	500	1500
3	Total Hardness (as $CaCO_2$) in mg/l	200	600
4	Chlorides(mg/l)	200	1000
5	Sulphates (mg/l)	200	400
6	Fluorides (mg/l)	10	1.5
7	Nitrates (mg/l)	45	45
8	Calcium (mg/l)	75	200
9	Magnesium (mg/l)	30	150

(If there are 250 mg/l of sulphates, Mg content can be increased to a maximum of 125 mg/l with the reduction of sulphates at the rate of one unit per 2.5 units of sulphates)

S.No.	Characteristics in mg/l (1)	Acceptable (2)	Cause for rejection (3)
10	Iron (mg/l)	0.1	1.0
11	Manganese (mg/l)	0.05	0.1
12	Copper (mg/l)	0.05	1.5
13	Zinc (mg/l)	5.0	15.0
14	Phenolic compounds (mg/l)	0.001	0.002
15	Anonic detergents (mg/l)	0.2	1.0
16	Mineral oil Toxic Materials (mg/l)	Nil	Nil
17	Arsenic (mg/l)	0.05	0.05
18	Cadmium (mg/l)	0.01	0.01
19	Chromium (mg/l)	0.05	0.05
20	Cyanide (mg/l)	0.05	0.05
21	Lead (mg/l)	0.1	0.1
22	Selenium (mg/l)	0.01	0.01
23	Mercury (mg/l)	0.001	0.001
24	Poly-unclear aromatic hydrocarbons Radio Activity	0.2 hg/l	0.2 hg/l
25	Gross Alpha activity	3 pci/l	3 pci/l
26	Fross Beta activity when PCL-Pico curie unit	30 pci/l	30 pci/l

Dissolved Solids

The total permissible amount of solids in water is generally limited to 500 ppm. Sometimes the higher values of up to 1000 ppm may be permitted. When the dissolved solids exceed the limited value, it produces some **Psychological Effects** on human beings.

1.11.1. IMPURITIES PRESENT IN SURFACE SOURCES OF WATER

When completely or partially treated water is being discharged into the river at some upstream point of the river, its gets contaminated.

As the rainwater run through various soil surfaces, it dissolves some salts, sediments on the surface. In addition, to this, surface contains numerous physical, chemical and biological impurities which may cause harmful to health.

The various impurities present in the surface water are listed below.

1. Physical Impurities
   - (*a*) Turbidity causing agents
   - (*b*) Suspended Solids
   - (*c*) Floating matters like leaves etc.
2. Chemical Impurities
   - (*a*) Dissolved Solids
   - (*b*) Chlorides, Nitrates, Nitrites, Sulphates etc.
   - (*c*) Metals and other chemical substances
3. Biological Impurities
   - (*a*) Bacteria
   - (*b*) E-Coli etc.

UNIT-II WATER TREATMENT

OBJECTIVES

→ To remove objectionable colour of water

→ To remove unpleasant taste and odour.

→ To remove dissolved gases in water.

→ To remove suspended, colloidal and dissolved impurities in water.

→ To remove hardness of water

→ To reduce corrosiveness of water

→ To remove the disease producing micro organisms (pathogens) from water.

→ To make water suitable for domestic and industrial purposes.

UNIT OPERATIONS AND PROCESSES.

Unit Operations:

Treatment done by physical or mechanical methods are called as unit operations.

Eg: screening, Filtration, sedimentation, etc.

UNIT PROCESSES

Treatment done by employing Chemical or biological methods are Called as unit processes.

Eg: Coagulation, Chlorination etc.

Important Unit operations

1) Gas transfer : Aeration

2) Ion transfer
   - (i) Chemical Coagulation.
   - (ii) chemical Precipitation
   - (iii) Ion exchange
   - (iv) Adsorption.

3) Solute stabilization.
   - (i) chlorination
   - (ii) Liming.

4) Solids transfer.
   - (i) Straining
   - (ii) Sedimentation.
   - (iii) Floatation
   - (iv) Filtration.

5) Nutrient or Molecular transfer

6) Interfacial Contact.

7) Miscellaneous Operations:
   - (i) Disinfection
   - (ii) Desalination
   - (iii) Fluoridation.

8) Solids concentration & stabilization
   - (i) Thickening
   - (ii) centrifuging
   - (iii) Sludge digestion.

WATER TREATMENT PROCESSES.

1) Screening.

2) Aeration.

3) Sedimentation with or without coagulation.

   (a) Plain sedimentation

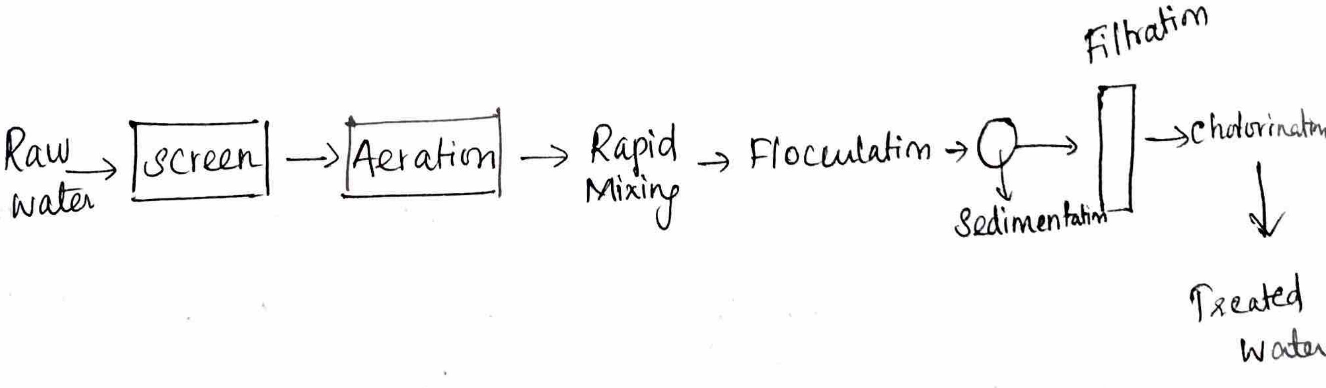
   (b) Sedimentation with coagulation.

4) Filtration

5) Disinfection

6) Miscellaneous processes.

   ↳ water softening, desalination, removal of iron & manganese etc.



LAYOUT OF WATER TREATMENT PROCESS.

SCREENING

- Screening is the first unit operation in the water treatment
- It is used to remove the floating particles in water such as debris, dead animals, trees, branches, leaves, sand, silt, etc.
- screens serve as protective device for the subsequent treatment units.
- screens are of two types.
  (i) coarse screens
  (ii) Fine screens.

(i) Coarse screens.

→ It consists of parallel iron rods placed vertically or sloped, at 2 to 10cm c/c spacing. It removes large floating matter and organic solids.

(ii) Fine screens.

→ It consists of fine wire or perforated metal with openings less than 1 cm wide. It removes fine suspended solids. These screens get clogged and need frequent cleaning.

- The screens are kept inclined at 45° to 90° so as to increase the opening area to reduce the flow velocity for making the screening more effective.

- The velocity through the screens ~~exabl.~~ should be 0.8 to 1 m/s.

- The material collected on the screens called screenings are manually or mechanically removed by rakes.

→ Screens are also classified as (a) movable type. (b) Fixed type.

→ The fixed type of screens remain fixed both during operation and cleaning.

→ Whereas, the movable type screens can be taken out to facilitate cleaning.

SEDIMENTATION.

Sedimentation is the removal of suspended particles by gravitational settling. It is designed to reduce the velocity of flow of water, so as to permit suspended solids to settle by gravity.

Types of Sedimentation.

a) Plain Sedimentation.

The impurities are separated from water by natural forces - gravitation or natural aggregation of settling particles.

b) Sedimentation with Coagulation

- Clarification : Chemicals are added to hasten aggregation and settling of finely divided suspended matter and colloidal substances.

TYPES OF SETTLINGS

1) TYPE I - Sedimentation (Discrete settling)

2) TYPE II - Sedimentation (Hindered settling)

3) TYPE III - Sedimentation (Zone settling)

4) TYPE IV - Sedimentation (compression settling)

Problem 1.

The maximum daily demand at a water purification plant has been estimated as 12 million litres per day. Design the dimensions of a suitable sedimentation tank (fitted with mechanical sludge removal arrangements) for the raw supplies, assuming a detention period of 6 hrs and velocity of flow as 20 cm per minute.

Solution.

Quantity of water to be treated in 1 day (24 Hrs) $= 12 \times 10^6$ litres

Quantity of water to be treated during detention period of 6 hrs $= \left[\frac{12 \times 10^6}{24} \times 6\right]$ litres $= 3 \times 10^6$ litres

$\therefore$ The volume or Capacity of tank required $= 3000\ m^3$.

Velocity of flow $= 20$ cm/min $= 0.2$ m/min.

Length of tank required = Velocity of flow × Detention period

[$\because$ Distance = Speed × Time]

$$\text{Depth} = \frac{\text{Volume}}{\text{Surface area}} = \frac{\text{Volume}}{L \times B}$$

$$= \frac{3000}{72 \times 11.6} = 3.6\,m$$

Assuming free board as 0.5m.

$\therefore$ Tank dimensions are $= 72m \times 11.6m \times (3.6+0.5)m$.

$= 72m \times 11.6m \times 4.1m$.

Problem 2.

Two million litres of water per day is passing through a sedimentation tank which is 6m wide, 15m long and having a water depth of 3m. (a) Find detention time (b) What is the average flow velocity (c) If 60 ppm is the concentration of suspended solids present in turbid raw water, how much dry solids will be deposited in the tank per day, Assuming 70% removal in the basin and average specific gravity of the deposit as 2 (d) Compute the overflow rate.

Solution.

Capacity of tank $= LBH = 15 \times 6 \times 3 = 270\,m^3$.

Discharge through tank $Q = 2\,MLD$

$= 2 \times 10^6\,l/d = 2 \times 10^3\,m^3/d$

$Q = 8.33\,m^3/hr$.

$= 0.2\ m/min \times (6 \times 60)\ min$

$= 72\ m.$

Cross sectional area of the tank required

$$= \frac{\text{Capacity of tank}}{\text{Length of tank}} = \frac{3000\ m^3}{72\ m} = 41.7\ m^2$$

Assuming depth of water in the tank as 4 m.

$\therefore$ Width of the tank required $= \frac{41.7}{4} = 10.5\ m$.

Assuming free board of 0.5 m.

Overall depth $= 0.5 + 4.0 = 4.5\ m$.

Hence, the dimensions of the rectangular sedimentation tank are.

$L \times B \times H = 72\ m \times 10.5\ m \times 4.5\ m$.

Note:: Alternatively, instead of assuming depth, assume Overflow rate as 600 litres/hr/m².

$$\text{Overflow rate} = \frac{\text{Discharge}}{\text{Surface Area}} = \frac{Q}{BL}$$

$$\frac{Q}{BL} = 600\ l/hr/m^2.$$

Where, $Q = \frac{12 \times 10^6}{24}\ lit/hr = 0.5 \times 10^6\ lit/hr.$

$$\text{Surface area} = BL = \frac{Q}{600} = \frac{0.5 \times 10^6}{600} = 833\ m^2.$$

$$B = \frac{833}{72} = 11.6\ m \quad (\because L = 72\ m).$$

(a) Detention time.

$$= \frac{\text{Capacity of tank}}{\text{Discharge}}$$

$$= \frac{LBH}{Q} = \frac{270}{83.33} \frac{m^3}{m^3/hr}$$

$$= 3.24 \text{ hrs } (3 \text{ to } 4 \text{ hrs})$$

(b) Average flow velocity -

$$= \frac{\text{Discharge}}{\text{Cross-sectional Area}} = \frac{Q}{BH}$$

$$= \frac{83.33}{6 \times 3} \frac{m^3/hr.}{m^2} = 4.63 \, m/hr$$

$$= 7.72 \, cm/minute.$$

(c) Quantity of suspended solids entering the tank per day.

$$= 2 \times 10^6 \times \frac{60}{10^6} \text{ litres} = 120 \text{ litres} = 0.12 \, m^3.$$

Specific gravity of particle = 2 (given)

then density = $2000 \, kg/m^3$.

∴ Mass of suspended solids deposited (with 70% removal) per day.

$$= 0.12 \times 0.7 \times 2000 = 168 \, kg$$

(d) Overflow rate = Discharge per unit plan area.

$$= \frac{Q}{B \cdot L} = \frac{83.33 \times 10^3}{6 \times 15} \frac{l/hr.}{m^2}$$

$$= 926 \text{ litres}/hr/m^2.$$

Sedimentation with Coagulation : Clarification.

Flash mixer → Flocculator → Sedimentation tank

(rapid mixing of Chemicals in water) (Slow mixing Causing particles to agglomerate and form floc) (settling of flocs)

(i) Addition of measured quantities of chemicals (coagulants) to water and thorough mixing is done in a Flash mixer.

(ii) Formation of precipitate which coagulates and forms floc which happens in a flocculator.

(iii) Settling of flocs in a sedimentation tank.

Coagulation - is the first stage which refers to the formation of precipitate and destabilisation of charged colloidal particles.

Flocculation - is the second stage which refers to the slow mixing technique promoting agglomeration of stabilised particles.

Factors affecting coagulation:

1) Type of coagulant.
2) Quantity or dose of coagulant.
3) Characteristics of water.
   * Type and quantity of suspended matter

* Temperature of water.

* pH of water.

4) Time and method of mixing - short period of violent agitation (chemical mixing) followed by gentle stirring (floc formation).

COMMON COAGULANTS.

1) Alum or Aluminium Sulphate.

2) Chlorinated copperas.

3) Ferrous Sulphate and lime.

4) Magnesium Carbonate.

5) Polyelectrolytes.

6) Sodium aluminate.

Problem 3.

Design a coagulation-cum-sedimentation tank with continuous flow for a population of 60,000 persons with a daily per capita water allowance of 120 litres. Make suitable assumptions where needed.

Solution:

1) Design of settling tank.

Average daily consumption = population x per capita demand

$= 60000 \times 120 = 7.2 \times 10^6$ litres

Maximum daily demand $= 1.8 \times$ Average daily demand.

$= 1.8 \times (7.2 \times 10^6)$

$= 12.96 \times 10^6$ litres

Assuming detention time of 4 hours (between 2 to 4 hours)

Capacity or volume of Tank = Discharge x Detention Time.

$$\text{Volume} = \frac{12.96 \times 10^6}{24} \times 4$$

$= 2.16 \times 10^6$ litres

$= 2.16 \times 10^3\ m^3$

Assuming, surface overflow rate as 1000 Litres/hr/m^2.

(between 1000 to 1250 l/hr/m^2)

$$Q = 12.96 \times 10^6\ l/d = 540 \times 10^3\ l/hr$$

$$SOR = \frac{Q}{\text{Surface Area}} = \frac{Q}{B \cdot L} = 1000\ l/hr/m^2$$

$$\frac{540 \times 10^3}{B \cdot L} = 1000$$

$$B \cdot L = 540 m^2$$

Assuming width of tank as 12m.

$12 \times L = 540 m^2$

$L = 45m$

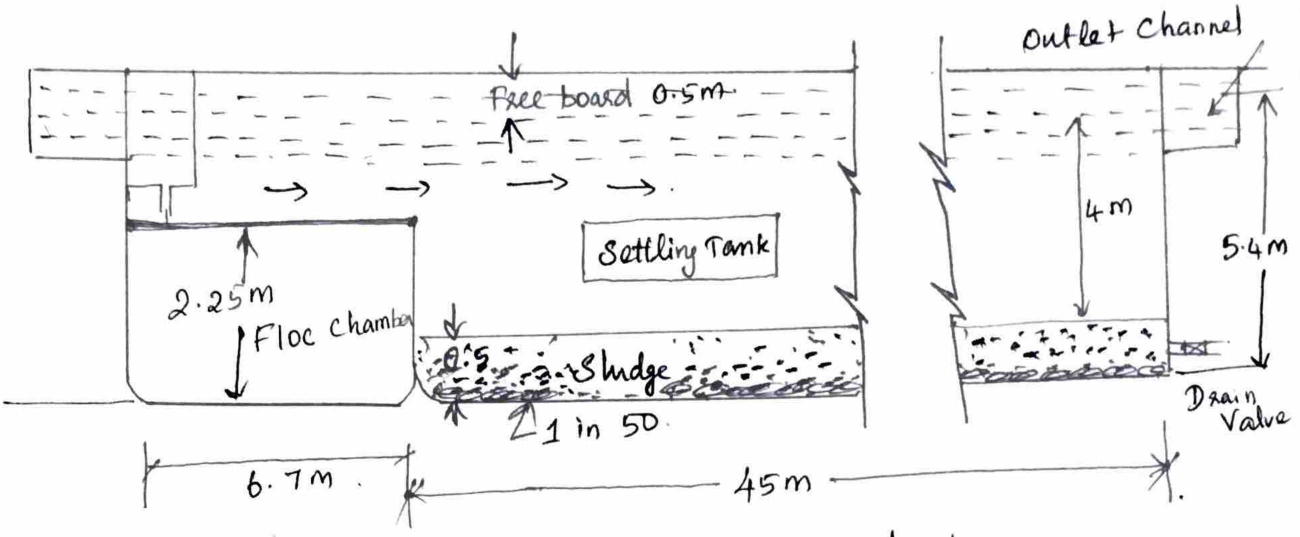
Volume $= L \times B \times H = 2.16 \times 10^3\ m^3$

$= 45 \times 12 \times H = 2.16 \times 10^3$

$H = 4m$.

Extra depth for sludge storage (1 in 50 slope) $= \frac{45}{50} = 0.9m$

Assume Free Board $= 0.5m$.



Coagulation cum Sedimentation tank

Overall depth = water depth + Sludge storage + free board

= 4m + 0.9m + 0.5m

= 5.4 m.

Provide settling tank of dimensions 45m × 12m × 4m.

2. Design of the floc chamber.

Depth of floc chamber $= \frac{1}{2} \times$ depth of settling tank

$= \frac{1}{2} \times 4.5 = 2.25$ m.

Assuming period of flocculation (detention period) as 20 minutes between (15 to 40 mins)

Volume or Capacity of chamber = Q × Detention time

$= \frac{12.96 \times 10^3}{24 \times 60} \times 20 = 180 m^3$

Area required $= \frac{\text{Volume}}{\text{depth}} = \frac{180}{2.25} = 80 m^2$

using same width = 12 m,

Length of flocculation Chamber $= \frac{80}{12} = 6.67$m

The dimensions of Floc Chamber are = 6.7m × 12 m × 2.25m.

Plate and Tube settlers

→ Have been developed as an alternative to shallow basins and are used in conjunction with both existing and specially designed sedimentation basins.

→ They are used to enhance the settling characteristics of sedimentation basins.

→ The shape, hydraulic radii, angle of inclination, and length of the plate and tube settlers will vary according to the particular installation.

→ To be self cleaning, plate or tube settlers are usually set an angle between 45° and 60° above the horizontal.

Advantages of tube settlers are:

* Solids removal efficiency will be higher leading to clarified water turbidity as less than 10 NTU
* Hence the load on the filter will be less.
* Treatment plant capacity of the existing water treatment plant could be increased by 50 to 60%

Advantages of Plate settlers are:

* Compact design
* No moving parts
* Simple installation
* Ease of access
* Sludge handling benefits
* Flexible System

Disadvantages of Tube settlers / plate settlers are

* Algae growth in tubes and plates may cause maintenance and odour problems.
* Easy to clean in Lamella but not in tubular module
* Careful attention is necessary to avoid turbulence and uneven flow.

PULSATOR CLARIFIER.

Components.

Vacuum chamber, Vacuum pump and Vent valve

1) Raw water distribution channel and perforated distribution pipes.
2) Lamellar plates / Tubes for Clarification.
3) Clarified water collection laterals & Channel.
4) Sludge collection and Concentrator schematic and view of pulsator clarifier.

Filtration

The process of passing the water through the beds of granular materials (filters) is known as filtration.

Purpose of filtration.

(i) To remove very fine suspended and colloidal particles that do not settle in the sedimentation process.

(ii) To remove dissolved impurities in water

(iii) To remove pathogenic bacteria from water

(iv) To remove colour, Odour, turbidity in water.

Types of filters.

(i) slow sand filters.
(ii) Rapid sand filters.
(iii) Pressure filter.

Theory of filtration:

During filtration, the following actions takes place

(i) Mechanical straining
(ii) Sedimentation.
(iii) Biological action
(iv) Electrolytic action.

DESIGN OF RAPID SAND FILTERS

1) Design a set of rapid gravity filters for treating water required for a population of 50,000; the rate of supply being 180 litres per day per person. The filters are rated to work 5000 litres per hour per sq.m. Assume whatever data are necessary.

Solution.

Average demand = Population × per Capita demand.

= 50,000 × 180 = 9×10^6 l/d.

Maximum demand = 1.8 × Avg. daily demand.

= $1.8 \times 9 \times 10^6$ l/d

= 16.2×10^6 l/d.

Water demand per hour = $\frac{16.2 \times 10^6}{24}$ l/hr.

= 0.675×10^6 l/hr.

Rate of filtration = 5000 l/hr/sq.m (given)

Area of filter beds required = $\frac{\text{Water demand}}{\text{Rate of filtration}} = \frac{0.675 \times 10^6 \text{ l/hr}}{5000 \text{ l/hr/m}^2}$

= 135 m^2.

Since two units are designed,

Area of each unit = $\frac{135}{2} = 67.5 \text{ m}^2$.

Assuming, $\frac{L}{B} = 1.5$

$L \times B = 67.5$

$(1.5B)B = 67.5$

$B = 6.75$ m

$L = 1.5 \times 6.75 = 10$ m.

∴ Hence two units of size 10 m × 6.75 m are provided with one additional unit as stand-by.

2) Design a rapid sand filter for 4 MLD of supply with all its principal Components.

Solution:

Water required per day = 4 million litres.

Assuming 4% of filtered water is used for backwashing

Total filter water required per day $= 1.04 \times 4\,ML = 4.16\,MLD$

Assuming 0.5 hr (30 min) is lost in backwashing every day.

Filtered water required per hour $= \frac{4.16}{23.5}$ ML/hr ($\because$ operation time is 23.5 hrs)

$= 0.177$ ML/hr.

Assuming rate of filteration = 5000 l/hr/sq.m.

Area of filter required $= \frac{0.177 \times 10^6}{5000} \frac{l/hr}{l/hr/m^2} = 35.4\,m^2$

Assuming that 2 units are provided.

Area of each unit $= \frac{35.4}{2} = 17.7\,m^2$.

Assuming $L/B = 1.5$

Area $= L \times B = 17.7\,m^2$

$(1.5B)B = 17.7$

$B = 3.43\,m / L = 1.5 \times 3.43 = 5.14\,m$.

Hence, adopt 2 filter units with dimensions

$5.2\,m \times 3.4\,m$.

DESIGN OF SLOW SAND FILTER

Design six slow sand filter beds from the following data:

Population to be served - 50000 persons

Per capita demand - 150 litres / head / day.

Rate of filtration - 180 litres / hr. / sq.m.

Length of each bed - Twice the breadth

Assume maximum demand as 1.8 times the average daily demand

Also assume that one unit, out of six, will be kept as stand-by.

Solution:

Average daily demand = population × per capita demand

$= 50000 \times 150$ litres/day.

$= 7.5 \times 10^6$ litres/day.

Maximum daily demand = 1.8 × Average daily demand.

$= 1.8 \times 7.5 \times 10^6$

$= 13.5 \times 10^6$ litres/day

Rate of filtration = 180 litres/hr/sq.m

$= 180 \times 24$ litres/day/sq.m

Total Surface area of filters required

$$= \frac{\text{Max. daily demand}}{\text{Rate of filtration per day}}$$

$$= \frac{13.5 \times 10^6}{180 \times 24} \text{ sqm} = 3125 \text{ m}^2$$

6 units are used with 1 unit as standby, Hence Consider only 5 units for filtration.

Area of each filter unit $= \frac{3125}{5} = 625 \text{ m}^2$

$$\text{Area} = 625 \text{ m}^2$$

$$L \times B = 625$$

$$L = 2B$$

$$(2B)\,B = 625$$

$$B^2 = 312.5$$

$$B = 17.7 \simeq 18 \text{ m}$$

Now, $L = 2B = 2 \times 18 = 36$ m.

Hence, use 6 filter units with one unit as standby, each unit of size 36 m x 18 m arranged in series with 3 units on either side.

Design of Under-drainage System.

Total area of perforations = 0.2% of total filter area

(Assuming 13mm dia)

$$= \frac{0.2}{100} \times (5.2 \times 3.4)$$

$$= 0.035\ m^2.$$

Total area of laterals = 2 x total area of perforations

$$= 2 \times 0.035 = 0.070\ m^2.$$

Area of manifold = 2x area of laterals

$$= 2 \times 0.07 = 0.14\ m^2.$$

Diameter of manifold (circular pipe) $= \frac{\pi}{4} d^2 = 0.14 m^2$

$$d = \sqrt{\frac{0.14 \times 4}{\pi}} = 0.42 m.$$

Use 45cm dia manifold pipe laid lengthwise along the centre of filter bottom.

Laterals are laid perpendicular to manifold width-wise at spacing of 15cm.

$$\text{No. of laterals} = \frac{\text{Length of filter.}}{\text{Spacing of laterals}} = \frac{5.2m \times 100}{15cm}$$

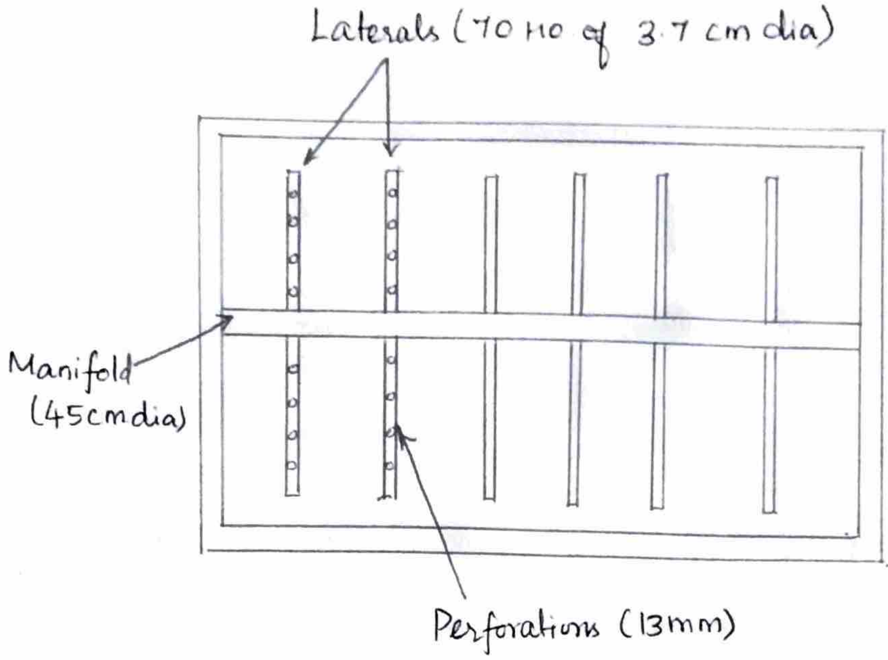
$$= 34.6 \simeq 35.$$

35 laterals on either side, hence total 70 laterals

$$\text{Lateral length} = \frac{\text{Width} - \text{Manifold diameter}}{2}$$

$$= \frac{3.4 - 0.45}{2}$$

$$= 1.475 m.$$



Under drainage system

Adopt 13 mm perforations in laterals

Total Area of perforation = $0.035 m^2 = 350 cm^2$

$$N \times \frac{\pi}{4}(1.3)^2 = 350$$

Where, N = total number of perforation in all the 70 laterals

$$N = \frac{350 \times 4}{\pi \times (1.3)^2} = 264.$$

No. of perforations in each lateral.

$$= \frac{264}{70} = 3.8 \text{ say } 4.$$

Area of perforations per lateral.

$$= 4 \times \frac{\pi}{4} \times (1.3)^2 = 5.3 cm^2$$

Area of each lateral = 2 x Area of perforations.

$$= 2 \times 5.3 = 10.6 cm^2.$$

Dia of each lateral = $\sqrt{10.6 \times \frac{4}{\pi}} = 3.7 cm.$

Hence, use 70 laterals each of 3.7 cm dia at 15cm c/c each having 4 perforations of 13mm size, with 45cm dia manifold.

Design of wash water trough

Assume spacing of wash water troughs between 1.5 to 2m

$$\text{No. of troughs} = \frac{\text{Length of filter}}{\text{spacing of wash water troughs}} = \frac{5.2}{1.75} = 3 \text{ nos}$$

Assume rate of washing = 0.45 m/minute.

$$\text{Wash water discharge} = \frac{0.45 \times 5.2 \times 3.4}{60} \text{ m}^3/\text{s}$$

$$= 0.133 \text{ m}^3/\text{s}$$

$$\text{Discharge in each trough} = \frac{0.133}{3} = 0.044 \text{ m}^3/\text{s}.$$

$$Q = 1.376 \cdot b \cdot y^{3/2}$$

Q = discharge m^3/s.

b = width = 0.2 m (assumed)

y = depth in m.

$$0.044 = 1.376 \times 0.2 \times y^{3/2}$$

$$y^{3/2} = \frac{0.044}{1.376 \times 0.2} = 0.16$$

$$y = 0.3\text{ m} = 30\text{ cm}$$

Keeping 5 cm free board, adopt depth of trough = 30+5 = 35 cm

Hence, 3 No. wash water troughs of size 35 cm x 20 cm may be used.

Comparison between Slow and Rapid Sand Filters

Sl.NO	Item	Slow Sand Filter	Rapid Sand Filter
1.	Rate of filtration	100 to 200 litres per hour per m^2	3000 to 6000 litres per hour per m^2
2.	Size of bed	Requires large area	Requires small area
3.	Coagulation	Not required	Essential.
4.	Filter media or Sand	Effective size : 0.2 to 0.35mm uniformity Co.eff : 2 to 3 Depth : 105cm	Effective size : 0.35 to 0.6mm uniformity co.efficient : 1.2 to 1.7 Depth : 75cm
5.	Base material or gravel	Size : 3 to 65mm Depth : 30 to 75cm	Size : 3 to 40mm Depth : 60 to 90cm.
6.	Underdrainage system	Perforated pipe laterals discharging into main drain	Perforated laterals with mains or wheeler system or Leopald or Wagner System
7.	Method of clearing	Scrapping of top layer to 15mm to 25mm	Backwashing with or without compressed air.
8.	Period of Cleaning	1 to 2 months	2 to 3 days.
9.	Efficiency	Very efficient in bacteria removal but less efficient in removal of colour and turbidity.	Less efficient in bacteria removal, more efficient in removal of colour and turbidity.
10.	Economy	High initial cost	Cheap and economical.
11.	Flexibility	Not flexible	flexible
12.	Skilled Supervision	Not essential	Essential

Iron and Manganese Removal.

→ Generally found together in well water or anaerobic reservoir waters.

→ When exposed to air, these reduced forms slowly transform to insoluble visible oxidized ferric iron and manganic manganese.

→ The reddish tinge in water is due to the presence of iron and brownish tinge is due to manganese.

→ When their concentration exceed 0.3 mg/l they become Objectionable due to the following reasons.

(i) Cause discolouration of clothes.

(ii) Cause incrustation of water pipes

(iii) Cause unpleasant taste and odour

(iv) Cause troubles in various manufacturing processes

(v) Promotes growth of bacteria in water mains.

(vi) Sulphate iron cause acidity and corrosive action on iron and brass.

① <u>Iron and Manganese without combination with Organic Matter.</u>

* Aeration → coagulation → Sedimentation → filtration

* The different methods.

(a) Cascade aerators.

(b) Spray nozzles.

(c) Trickling beds.

(d) Diffused aeration

The following reaction takes place:

$$4\,Fe + O_2 + 10\,H_2O = 4\,Fe(OH)_3 \downarrow + 8H.$$

Manganese removal requires a pH adjustment upto 9.4 to 9.6.

(2) Iron and Manganese bound with Organic matter

* It is difficult to break the bond between them to cause their removal.

* The bond is broken by adding lime, and thereby increasing the pH of water to 8.5 to 9 so that iron and manganese can be precipitated.

* Alternatively, the aerated water is allowed to trickle over contact beds of coke, gravel, crushed pyrolusite followed by sedimentation and filtration.

* If organic acids are present, aeration, dosage with lime, sedimentation and filtration are effective.

(3) Manganese Zeolite:

* This method is adopted when water does not contain large amount of iron or manganese.

* Manganese zeolite is a natural green sand, coated with manganese dioxide.

* After the zeolite becomes exhausted, it is regenerated by backwashing with potassium permanganate.

WATER SOFTENING.

* The reduction or removal of hardness from water is called water softening.

* Hard water causes the following problems:

→ It causes more consumption of soap in laundry work.

→ It causes modification of colours and affects the dyeing industries.

→ It causes serious difficulties in the manufacturing process such as paper making, ice manufacture Rayon industry etc.

→ It causes choking and clogging of plumbing fixtures.

→ It causes scale formation in boilers and hot water heating system.

→ It makes the food tasteless, tough or rubbery.

Classification	Total hardness as mg/l (ppm) of $CaCO_3$.
1. Soft water.	50
2. Moderately hard water	50 – 150
3. Hard water	150 – 300
4. Very hard water	300.

Objectives of water Softening are:

(i) To reduce the soap consumption of water

(ii) Improve the food taste.

(iii) To reduce the maintenance of plumbing fixtures.

(iv) Prevent scaling of boilers.

(v) Improves the efficiency of manufacturing and dying processes.

(vi) Improves the efficiency of filtration etc.

Types of Hardness

- Temporary Hardness (or) Carbonate hardness
- Permanent hardness (or) Non-Carbonate hardness.

Temporary / Carbonate Hardness.

→ It is caused by the carbonates and bicarbonates of Calcium and magnesium.

→ Temporary hardness can be easily removed by boiling or adding lime.

Permanent / Non-Carbonate Hardness.

→ It is caused by the sulphates, chlorides, nitrates of Calcium and magnesium.

METHODS OF REMOVING TEMPORARY HARDNESS

1) Boiling   2) Addition of Lime.

1) Boiling.

→ Calcium Carbonate is not readily soluble in water

→ When the water is boiled, CO_2 is released, leading to precipitation of $CaCO_3$.

$$Ca(HCO_3)_2 + Heat \rightarrow CaCO_3 \downarrow + CO_2 \uparrow + H_2O$$

Calcium Bicarbonate (soluble) → Calcium carbonate (Insoluble)

→ This method cannot be used for $MgCO_3$ since it is soluble in water.

Limitation.

→ Boiling does not remove temporary hardness caused by magnesium.

→ Boiling is unfeasible and uneconomical for public water supplies.

2) Addition of lime.

Lime (CaO), generally hydrated lime $[Ca(OH)_2]$ is added to the water. The following reactions take place.

$$MgCO_3 + Ca(OH)_2 \rightarrow Mg(OH)_2 \downarrow + CaCO_3 \downarrow$$

Magnesium carbonate (soluble); Hydrated lime; Magnesium Hydroxid (insoluble); Calcium carbonate (insoluble.

$$Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3 \downarrow + 2H_2O$$

The calcium carbonate and magnesium hydroxide are precipitated which can be removed in the sedimentation tank

METHODS OF REMOVING PERMANENT HARDNESS

1) Lime - soda process.
2) Base - Exchange process / zeolite process.
3) Demineralisation process.

1) Lime - Soda Process.

→ In this process, lime [$Ca(OH)_2$] and soda ash [Na_2CO_3] are added to hard water.

→ Which react with calcium and magnesium salts, to form insoluble precipitates of calcium carbonate and magnesium hydroxide.

→ These precipitates can be sedimented out in a sedimentation tank.

→ The chemical reactions are.

$$Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3 \downarrow + 2H_2O.$$

$$Mg(HCO_3)_2 + Ca(OH)_2 \rightarrow Ca(HCO_3)_2 \downarrow + Mg(OH)_2 \downarrow.$$

$$CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 \downarrow + 2NaCl.$$

→ This process removes,
i) Carbonate hardness
ii) Non-Carbonate hardness
iii) Removes free dissolved CO_2.

Equipments required for this process

(i) Mixing tank

(ii) Flocculation.

(iii) Sedimentation.

Advantages.

→ Economical

→ Easily combined with other water treatment methods.

→ Increases pH of water and thus reduces corrosion of pipes

→ Increases pH which kills the pathogens.

→ Reduces mineral content of water

→ Removes iron and manganese to some extent.

Disadvantages.

→ Large quantity of sludge requires proper disposal

→ Careful operation and skilled supervision is required.

→ Recarbonation of water is required.

→ Zero hardness cannot be achieved.

2) Zeolite or Base-Exchange or Cation-Exchange Process

→ General formula.

$$Na_2OAl_2O_3\,x \cdot SiO_2\,y \cdot H_2O.$$

$x = 2$ or more & y = varies.

→ Zeolites have the property of exchanging their cations

→ A zeolite softener resembles a sand filter in which the filtering media is zeolite.

Advantages.

→ Zero hardness can be achieved.

→ Plant is compact, automatic, easy to operate

→ No sludge is formed

→ RMO (Running, maintenance & Operation) Cost is less

→ Removes iron and manganese from water

Disadvantages.

→ Not suitable for treating turbid waters

→ Costly

3) Demineralisation Process.

→ It means removal of minerals from the water

→ Mineral free water.

→ Suitable for industrial purposes.

a) Cation-exchange Process.

→ Similar to zeolite method and hydrogen ions are exchanged.

$$CaCl_3 + H_2R \rightarrow CaR + 2HCl$$

(H_2R: Fresh resin; CaR: exhausted resin)

b) Anion-exchange Process

$$ROH + HCl \rightarrow RCl + HOH$$

(ROH: Fresh resin; RCl: Exhausted resin; HOH: water)

(i) Bleaching Powder.

→ It is a chlorinated lime containing about 33% of available chlorine.

$$Ca(OCl)_2 + H_2O \rightarrow 2HOCl + Ca(OH)_2$$

(ii) Chloramines :-

→ In this process ammonia is added to water just before the chlorine is applied.

→ Ammonia may be used in the form of gas or liquid or ammonium sulphate or ammonium chloride.

(iii) Free chlorine:

→ Chlorine is generally applied in gaseous form or in liquid form.

→ Gaseous chlorine is a greenish-yellow poisonous substance

→ The chlorine dose depends upon: organic matter present in water, pH of water, amount of carbon dioxide present in water, temperature and time of contact.

(iv) Chlorine Dioxide:

* The chlorine dioxide gas is unstable.
* It is harmless in aqueous solution.

$$2NaClO_2 + Cl_2 \rightarrow 2NaCl + 2ClO_2$$

Forms of Chlorination:

(i) Plain chlorination

(ii) Pre-chlorination

(iii) Post-Chlorination.

(iv) Double or multiple chlorination.

(v) Break point Chlorination.

(vi) Super chlorination.

(vii) Dechlorination.

DISINFECTION

The filtered water from the slow or Rapid sand filters normally contains some harmful pathogenic (disease causing) bacteria. These bacteria must be killed in order to make the water safe for drinking. The process of killing these harmful bacteria is called disinfection and the chemicals used in this process are called disinfectants.

Minor Methods of Disinfection.

1) Boiling of water (Sterilization).

* Most effective method
* Not feasible for large scale public water supplies.

2) Treatment with excess lime:

* Excess lime added increases the pH of water to greater than 9.5, when E-coli present in water will die.
* The bacterial removal efficiency is upto 99 to 100%.
* The dosage of lime is between 10 to 20 ppm of Calcium Oxide.

3) Treatment with ozone :-

$$3O_2 \rightarrow 2O_3 \rightarrow O_2 + O$$

* Ozone removes the colour, taste and odour from water
* It is very costly.

4) Treatment with iodine and bromine:

* kills the pathogenic bacteria.
* The dosage is 8ppm and contact period is 5 minutes
* Not used for treating large scale public supplies.
* Useful for small water supplies.

5) Treatment with ultra-Violet rays:

* Effectives in killing both the active bacteria as well as spores.
* This method is costly

6) Treatment with potassium permanganate:

* common method in rural areas.
* Dosage is 1 to 2 mg/L with contact period of 4 to 6 hours.

7) Treatment with silver, Called Electro-katadyn process:

* Contact time varies from 10 to 60 minutes
* Since, silver is costly, This method is suitable for small installations.

Chlorination.

* Chlorine is universally adopted for disinfecting public water supplies.
* It is Cheap, reliable, easy to handle, easily measurable and capable of providing effects for long periods.
* only disadvantage is that when used in excess, it imparts bitter and bad taste to the water.

$$Cl_2 + H_2O \rightarrow HOCl + HCl.$$

$$HOCl \rightarrow H^+ + OCl^-$$

Various forms in which chlorine can be applied:-

* Liquid chlorine or chlorine gas.
* Hypochlorites or bleaching powder.
* Chlorine tablets
* Chloramines i.e: mixture of ammonia and chlorine.
* Chlorine dioxide.

Problem 1) Design a zeolite - softener for an industry, using the following data:

(i) Quantity of soft water required per hour = 25,000 litre

(ii) Hardness present in raw water as $CaCO_3$ = 400ppm.

(iii) Hardness to be obtained in the treated supplies = 50ppm.

(iv) Ion exchange Capacity of zeolite = 10 kg of hardness per Cu.m of zeolite.

(v) Salt required for regeneration of exhausted zeolite = 50kg per cum of zeolite.

Also assume that the industry works for 2 Shifts of 8 hours each per day. Make suitable assumption wherever needed.

Solution:

* Quantity of soft water required per shift of 8hrs

$= 25000\ l/hr \times 8\ hr = 2,00,000$ litres.

* Hardness removal is upto 50 ppm out of total hardness of 400 ppm

* Percentage removal desired $= \frac{350}{400} \times 100 = 87.5\%$

∴ The quantity of water to be treated per Shift

$= 2 \times 10^5 \times 0.875 = 1.75 \times 10^5$ litres.

The amount of hardness to be removed per shift.

= Quantity of water treated per shift in litres × hardness in mg/l.

$= 1.75 \times 10^5 \times 400\ mg/l.$

$= 70 \times 10^6 \, mg = 70 \, kg.$

$\therefore$ The quantity of zeolite resin required

$$= \frac{\text{Hardness to be removed in kg}}{\text{Ion-exchange Capacity of resin in kg/Cu.m}}$$

$$= \frac{70 \, kg}{10 \, kg/Cu.m} = 7 \, Cu.m$$

Assume number of units as 6 with one unit as standby

Volume of one unit $= \frac{7 \, Cu.m}{5} = 1.4 \, Cu.m.$

Provide 6 (5+1 Stand by) units with volume 1.4 Cu.m.

i.e of area $= 1 m^2$ and depth $= 1.4$ m.

Regeneration:

In 8 hrs of shift time, assume regeneration process will take one hour and the useful operation time as 7 hours.

The quantity of salt required for regeneration.

$= 50 \, kg/Cum$ of zeolite

$= 50 \, kg/Cum \times 7 \, Cum$

$= 350 \, kg.$

using 10% brine solution (10 kg salt dissolved in water to make 100 kg solution)

$= \frac{350 \times 100}{10} = 3500 \, kg$ of water solution

$= \frac{3500 \, kg}{1000 \, kg/m^3} = 3.5 \, Cum.$

∴ Provide two tanks of 1·75 cu·m capacity each

Assume the diameter of tank as 1·2 m then the depth required.

$$= \frac{1 \cdot 75}{\frac{\pi}{4}(1 \cdot 2)^2} = 1 \cdot 55 m.$$

Using free board = 0.15, Overall depth = 1·55+0·15=1·7m

Overall tank size will be = 1·2m dia x 1·7m depth.

<u>Check for Contact Period</u>.

$$\text{Flow rate over zeolite bed} = \frac{\text{Volume of water treated per shift}}{\text{Operation hours of zeolite}}$$

$$= \frac{1 \cdot 75 \times 10^5}{7} \frac{\text{litres}}{\text{hr}} = 25000 \text{ litres/hr}.$$

$$\text{Rate of filtration} = \frac{\text{Flow rate of water over zeolite bed.}}{\text{Surface area of zeolite.}}$$

$$= \frac{25000}{5 \times 1} \frac{\text{litres/hr}}{m^2} = 5000 \ l/m^2/hr.$$

$$= \frac{5000}{60} = 83 \cdot 3 \ l/m^2/min. = 0 \cdot 083 m/min$$

$> 0 \cdot 3 m/min$

It is less than 0·3m/min Hence ok.

Contact period (i.e Average time of travel through the bed)

$$= \frac{\text{Depth}}{\text{rate of filtration}} = \frac{1 \cdot 4 m}{0 \cdot 083 m/min}$$

$$= 16 \cdot 9 \text{ minutes} > 7 \cdot 5 \text{ minutes}$$

Hence design is OK.

Requirements of Good Distribution System

1. It should be capable of supplying water at all the intended places within the city with the reasonably sufficient pressure head.
2. It should be capable of supplying requisite amount of water for fire fighting
3. It should be cheap with the least capital construction cost
4. It should be simple and easy to operate and repair thereby keeping the RMO cost and troubles to the minimum.
5. It should be safe against any future pollution of water.
6. It should be safe as not cause the failure of the pipe lines by bursting etc.
7. It should be fairly water tight as to keep the losses due to leakage to the minimum

Layouts of Distribution Networks

1. Dead end system
2. Grid iron system
3. Ring system
4. Radial system

Gravitational Distribution System

- In this system, the water from high levelled source is distributed to the consumer at lower levels by the action of gravity without any pumping.
- For proper functioning of this system the difference of head available between the source and localities must be sufficient enough as to maintain the adequate pressure level.
- The gravitational system is designed so as to leave only minimum permitted available head to the consumer.

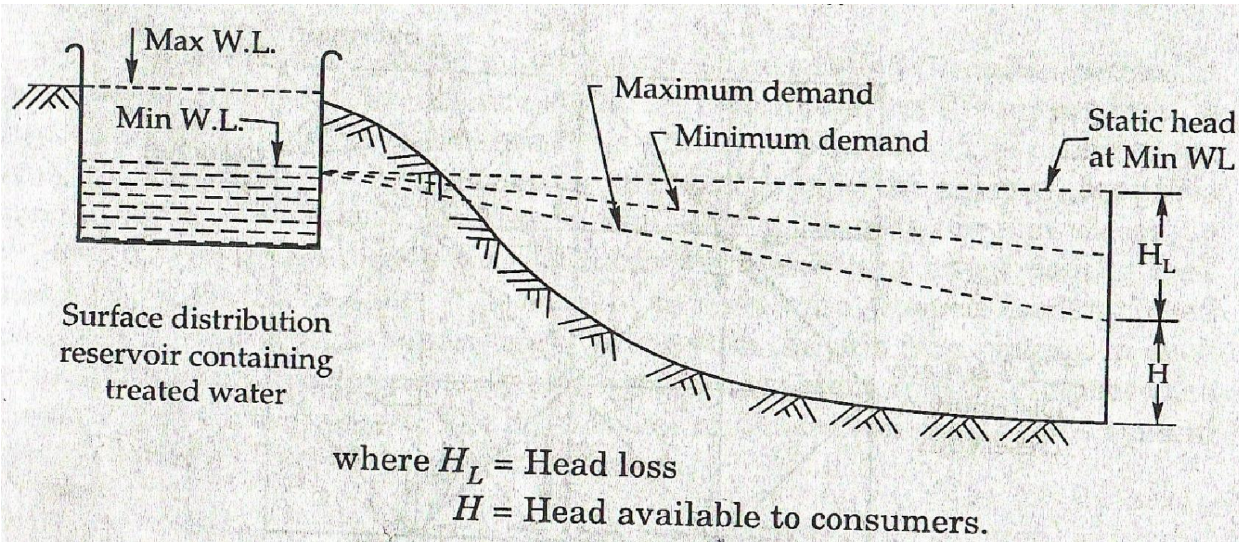


Fig. 10.6. Gravitational distribution system.

PUMPING SYSTEM

- In this system the treated water is directly pumped into the distribution main without storing it anywhere .
- For this reason this system is also sometimes called pumping without storage system.
- High lift pumps are required in this system which have to operate at variable speeds so as to meet variable demand of water.
- If the power supply fails there will be complete stoppage of water supply and if by chance fire breaks out such a time it will bring disaster.
- This method is generally not used.

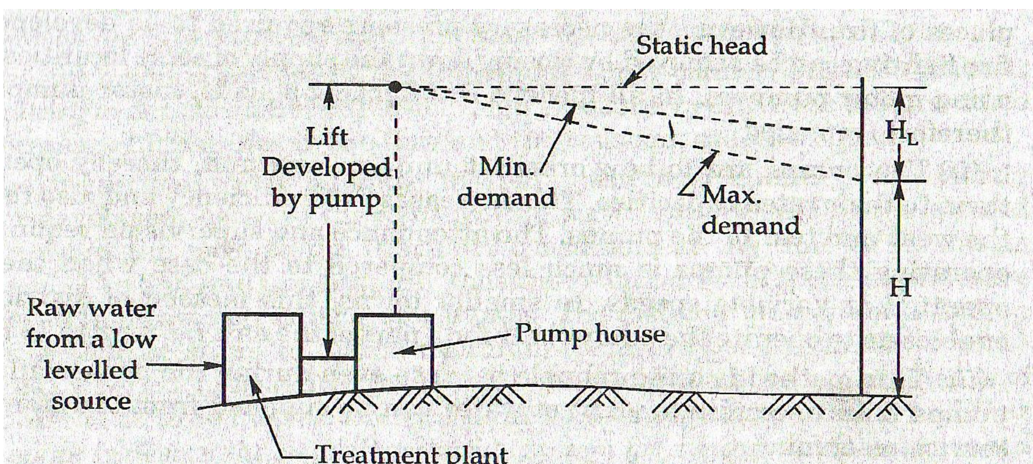
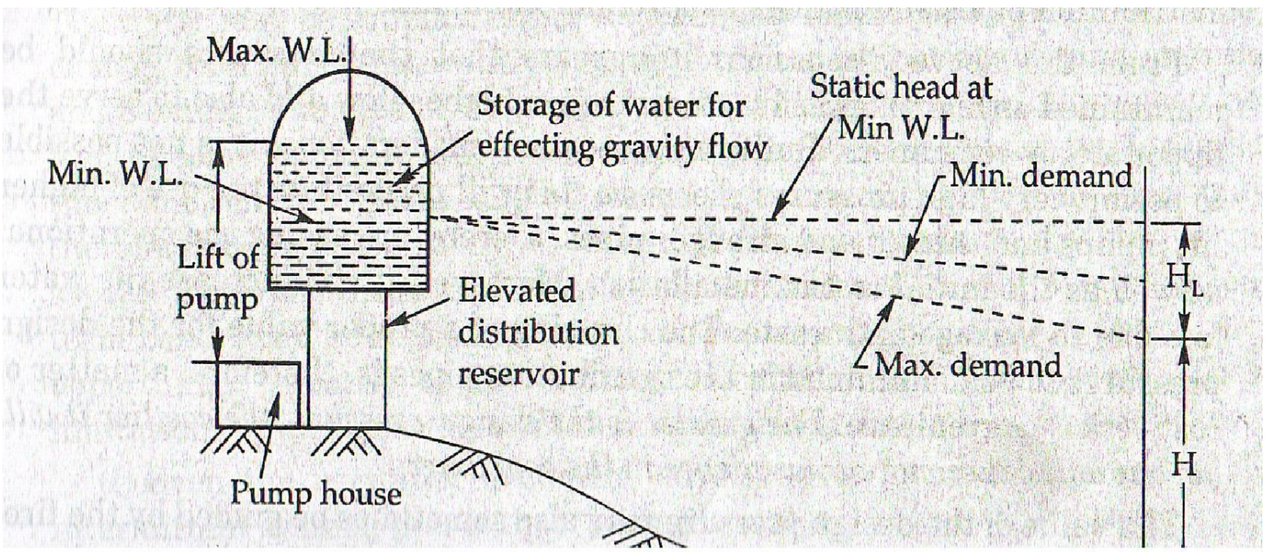


Fig. 10.7. Pumping system for water distribution.

COMBINED GRAVITY AND PUMPING SYSTEM

- In this system the treated water is pumped at a constant rate and stored in a elevated distribution reservoir from where it distributed to the consumer by the action of gravity.
- Sometimes the entire water is first of all pumped in tp the distribution reservoir and many a times it is pumped into the distribution main and reservoir simultaneously.
- This method thus combines the pumping and gravity flow and is sometimes called pumping with storage system.



Advantages

1. The balancing reserved water of the distribution system can be supplied to the places of fire.
2. The pumps are to be worked at uniform rate and thereby operating them to their rated capacities.
3. This method is quite reliable because even during the fire failure or pump failure , certain amount of water can be supplied from the storage or service reservoir.
4. This system proves overall cheap efficient and reliable and hence adopted practically everywhere.

Systems of Supply

1. Intermittent Supply System
2. Continuous Supply System

Distribution Reservoir (or) Service Reservoir

- Distribution reservoirs also called service reservoirs, are the storage reservoir which store the treated water for supplying the water during the emergencies and also to help in absorbing the hourly fluctuations in the normal water demand .

Functions of service reservoirs

1. They absorbs the hourly fluctuations in the normal water demand .
2. They help in maintaining the constant pressure in the distribution system.
3. The pumping of water in shifts is made possible by them without affecting the supply.
4. Water stored in the reservoir can be supplied during emergencies
5. They lead to overall economy by reducing the size of pumps and pipes and treatment units etc.

TYPES OF SERVICE RESERVOIR

- Based on the elevation with respect to the ground they may be classified in to two types

1. Surface Reservoir
2. Elevated Reservoir

SURFACE RESERVOIR

- Surface reservoir are circular or rectangular tanks constructed at ground level or below the ground level .
- They are therefore called Ground reservoir.
- They are generally constructed at high points in the city.

- These types of reservoir generally divided in to two compartments so that one may be cleaned and repaired while the other in use.
- Ventilators are provided in the roof slab so as to obtain free circulation of air.
- The floor cement concrete will sloped towards the central washout pipes.

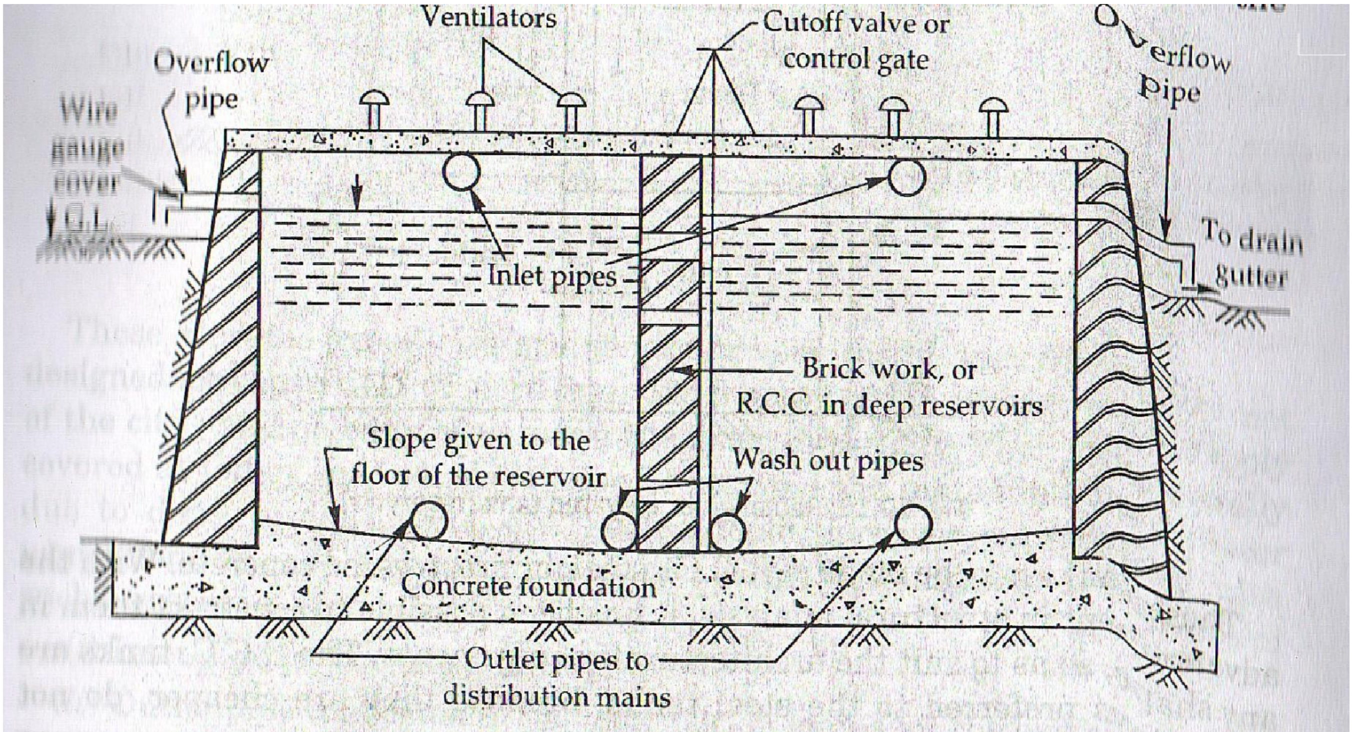


Fig. 10.9. Typical section of a ground reservoir.

ELEVATED RESERVOIR

- Elevated reservoirs are the rectangular, circular, or the elliptical overhead tanks erected at certain suitable elevation above the ground level and supported on towers.
- They are constructed where the pressure requirements necessitate considerable elevation above the ground surface and where the use of stand pipes becomes impracticable.
- They are constructed in areas where the combined gravity and pumping system for water distribution is adopted.
- Water is pumped in to this elevated tanks from the filter units and then supplied to the consumer.

Accessories of Service Reservoir

1. Inlet pipe for the entry of water
2. Outlet pipe connected to the distribution main
3. Overflow pipe discharging into the drain gutter and maintaining the constant head
4. A float gauge or an indicator for indicating the depth of water which can read from outside.
5. A wash out pipe for removing of water after cleaning the reservoir.
6. Automatic device to stop pumping when the tank is full
7. Ladders to reach the top of the reservoir and then up to the bottom of the reservoir for inspection.
8. Manholes for providing entry into the tank for inspection purposes.
9. Ventilators for fresh air circulation

STAND PIPE

- Stand pipes are a kind of elevated tanks without any erected towers for resting the tank body.
- They are thus tall cylindrical shells resting directly on the ground.
- The stand pipes may be 15 to 30 m high and 10 to 15 m in diameter.
- They may be made up of RCC or preferably of steel containing 0.2% copper.
- Because of their large heights , the hoop tension is developed at the portion is very high . RCC is difficult to withstand such a high pressure.

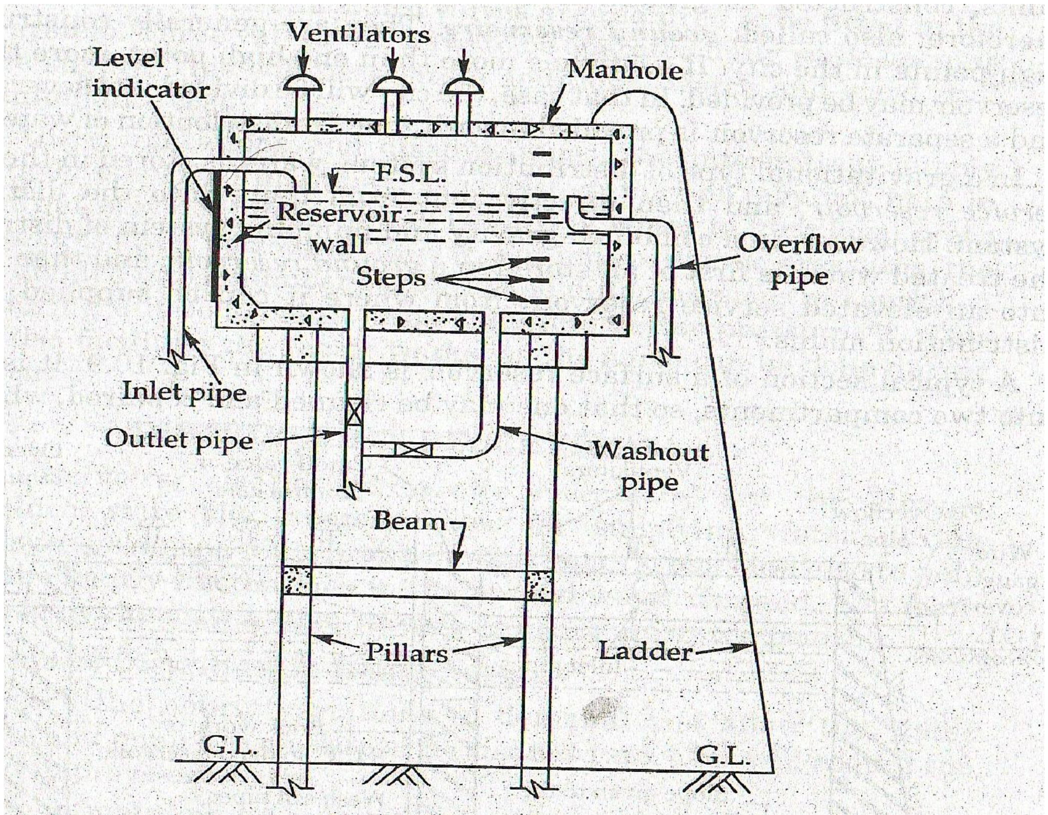
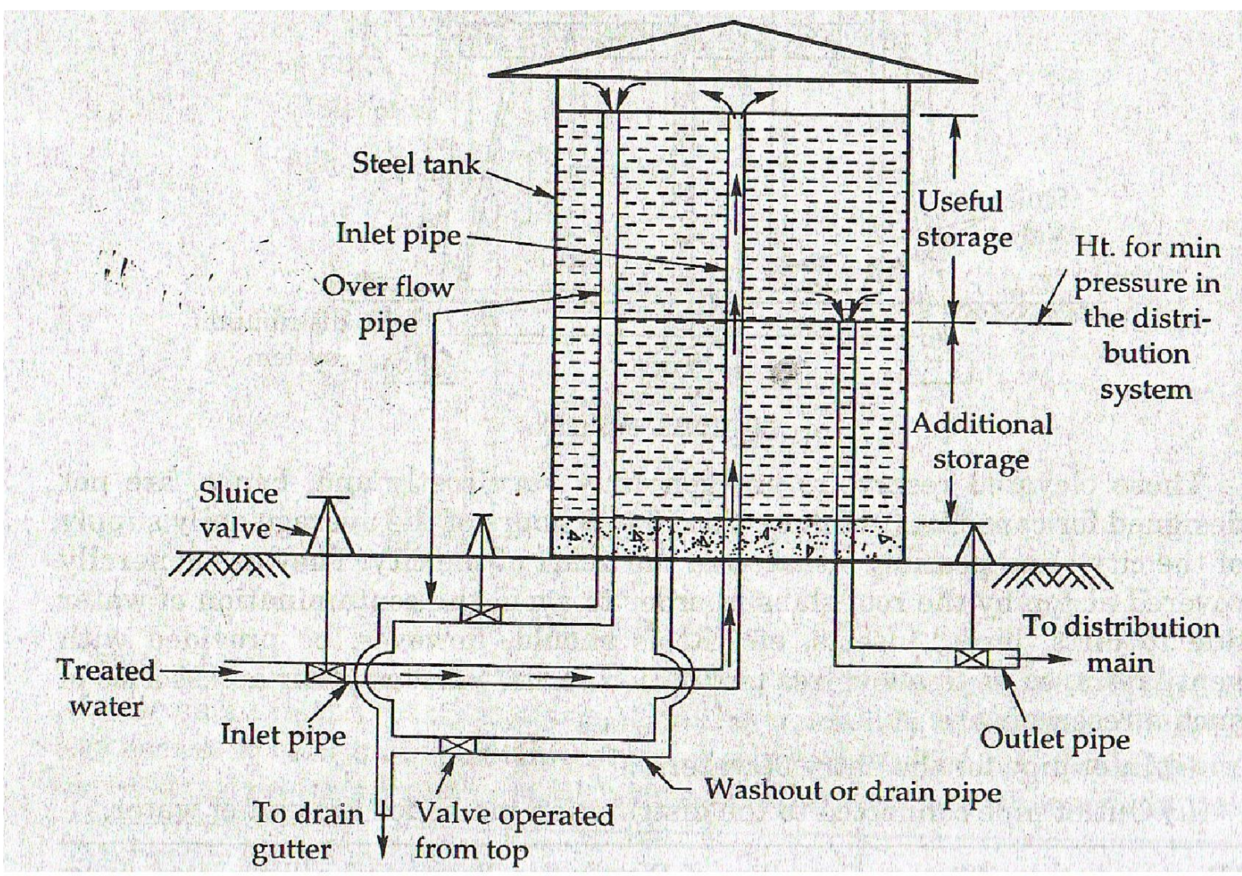


Fig. 10.10. Rectangular elevated tank (reservoir).

STAND PIPE



Storage capacity of Distribution Reservoir

- The total storage capacity of a storage reservoir is the summation of

1. Balancing Storage (or equalizing or operating storage)
2. Breakdown Storage
3. Fire Storage

Balancing Storage (or equalizing or operating storage)

- The main aim of a distribution reservoir is to meet the fluctuation in water demand with a constant rate of supply from the treatment plant.
- The quantity of water required to be stored in the reservoir for equalizing or balancing this variable demand against the constant supply is known as Balancing Storage or equalizing or operating storage .

LOCATION OF DISTRIBUTION RESERVOIR

1. They should be located in the heart of the city so as to command the maximum area all around.
2. They should be located at high elevations so that adequate pressure is maintained in the distribution system.
3. Based on the pumping station it can be located in two different ways.

    a) they can be placed between the pumping station and distribution area

    b) they can be placed at the farthest end of the distribution area.

LEAK DETECTION

1. By Direct observation
2. By using Sounding rod
3. By plotting Hydraulic gradient

4. By using waste detecting meter

DESIGN & ANALYSIS OF WATER DISTRIBUTION NETWORK

1. HARDY CROSS METHOD
2. EQUIVALENT PIPE METHOD
3. OTHER METHOD

WATER SUPPLY PLUMPING SYSTEM

- **Plumbing**
- Plumbing is the general term which indicates the practice materials and fixtures used in the installation or maintenance of all piping , and fixtures etc.
- **Plumbing water supply system.**
- The entire system of piping, fixtures and other appliance etc used in providing water supply and drainage facilities in a building is called plumbing water supply system.

THE HOUSE WATER CONNECTION

- To get water supply connection from municipalities
- It consists of the followings.

1. A ferrule
2. Goose neck
3. Service pipe
4. Stop cock
5. Water meter

WATER CONNECTIONS

A Ferrule

- A ferrule is a right angled sleeve made of brass or gun metal and is joined to a hole drilled in the water main to which it is screwed down with a plug.

Goose neck

- Goose neck is small sized curved pipe made up of a flexible material and is about 75 cm in length forming a flexible connection between the water main and the service pipe.

Service pipe

- It is a galvanized iron pipe of size less than 50 mm dia . It should be laid in under ground in a trench in which no sewage or drainage pipe is laid. The service pipe which supplies water to the building through the municipal mains is connected to the main through goose neck and ferrule.

Stop cock

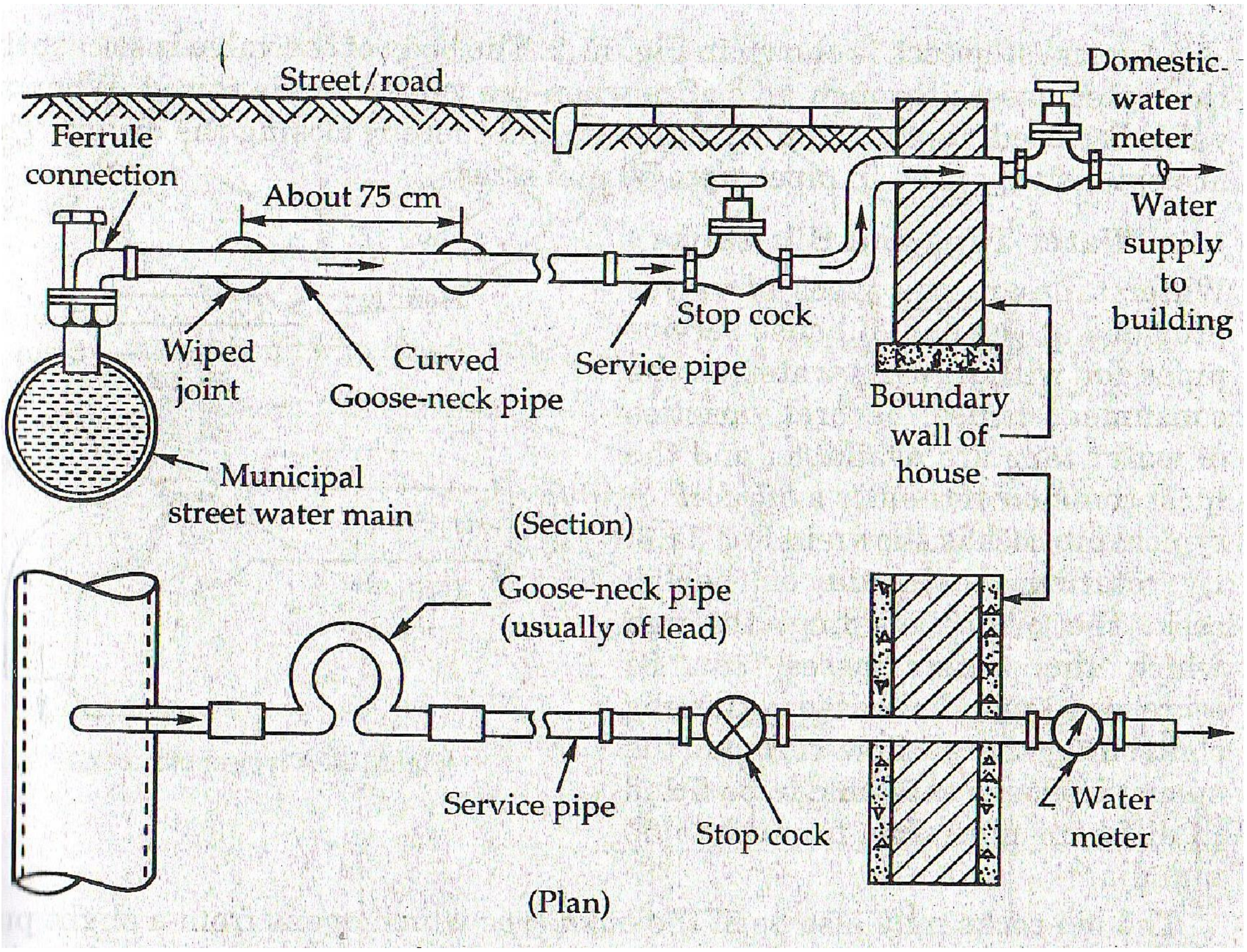
- The stop cock is provided before the water enters the water meter in the house. It is placed in a suitable masonry chamber with a removal cover and is fixed in the street close to the boundary wall in an accessible station.

Water meter

- It measures and records quantity of water consumed in the house.

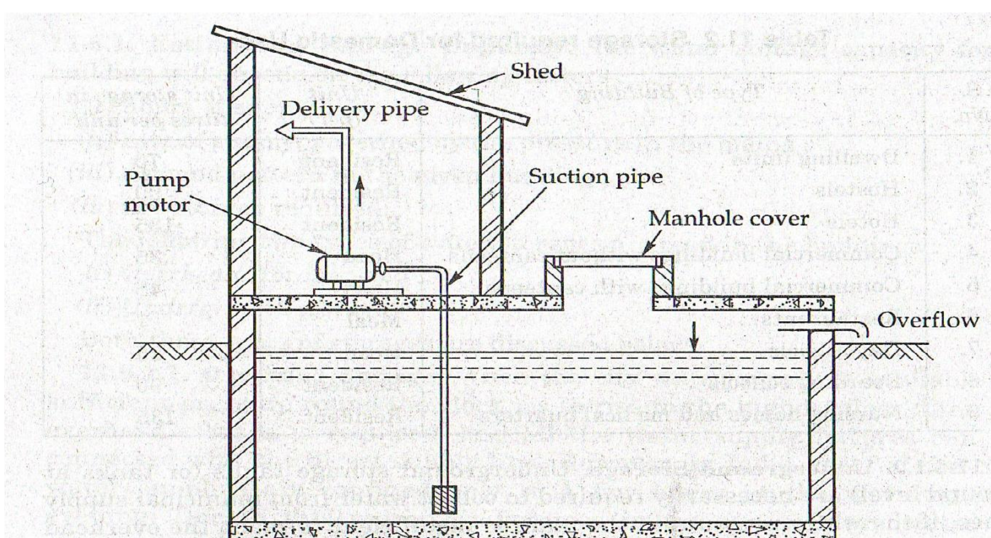
TYPES OF STORAGE IN BUILDINGS

1. OVER HEAD STORAGE
2. UNDER GROUND STORAGE

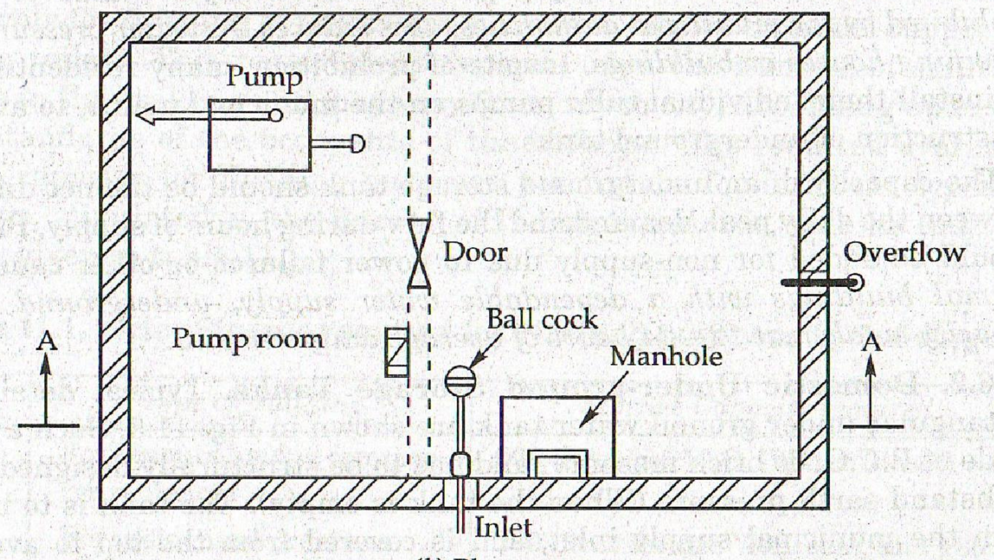


OVER HEAD STORAGE

1. R.C.C TANKS
2. G.I TANKS
3. HDPE TANKS



(a) Section A-A



(b) Plan

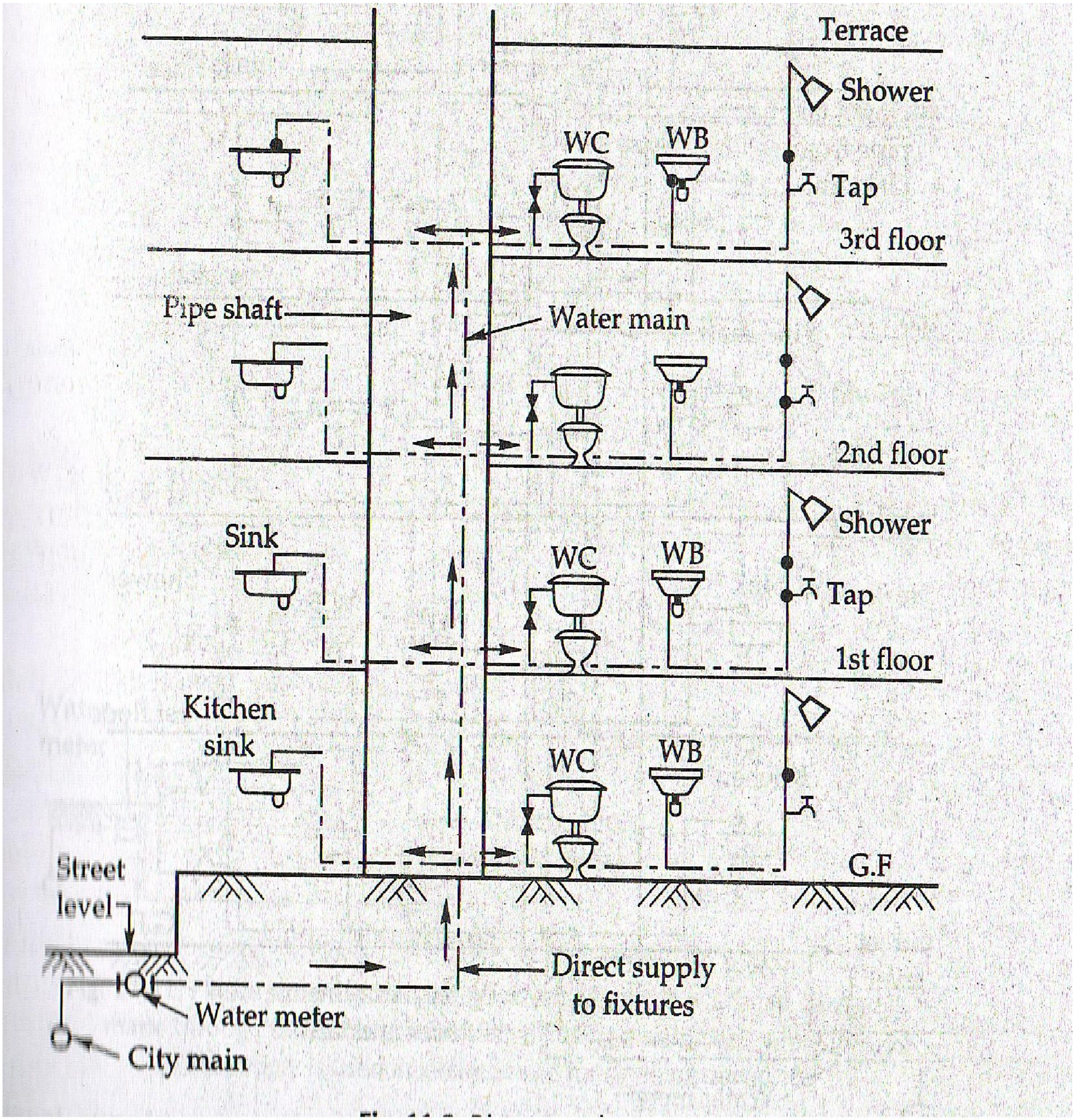
Fig. 11.5. A typical underground water storage tank.

REQUIREMENTS OF WATER STORAGE TANKS

1. The water storage tanks should be water tight and they should be constructed with non corrosive and non toxic materials.
2. The water storage tanks should be provided with the vent pipe for ventilation and prevention of negative pressure.
3. The water storage tanks should have an overflow pipe or warning pipe.
4. The water storage tanks should have a scour pipe with a plug at the bottom so that it can be emptied easily.
5. Under no circumstances should any overflow or scour pipe be directly connected to any drain or sewer.

WATER PIPING SYSTEM IN BUILDINGS

1. Piping system using Direct water supply
2. Piping system using Overhead Tanks
3. Piping system using Underground - Overhead Tanks
4. Pumped System



Terrace
Shower
WC
WB
Tap
3rd floor
Pipe shaft
Water main
2nd floor
Sink
Shower
WC
WB
Tap
1st floor
Kitchen sink
WC
WB
G.F
Street level
Direct supply to fixtures
Water meter
City main

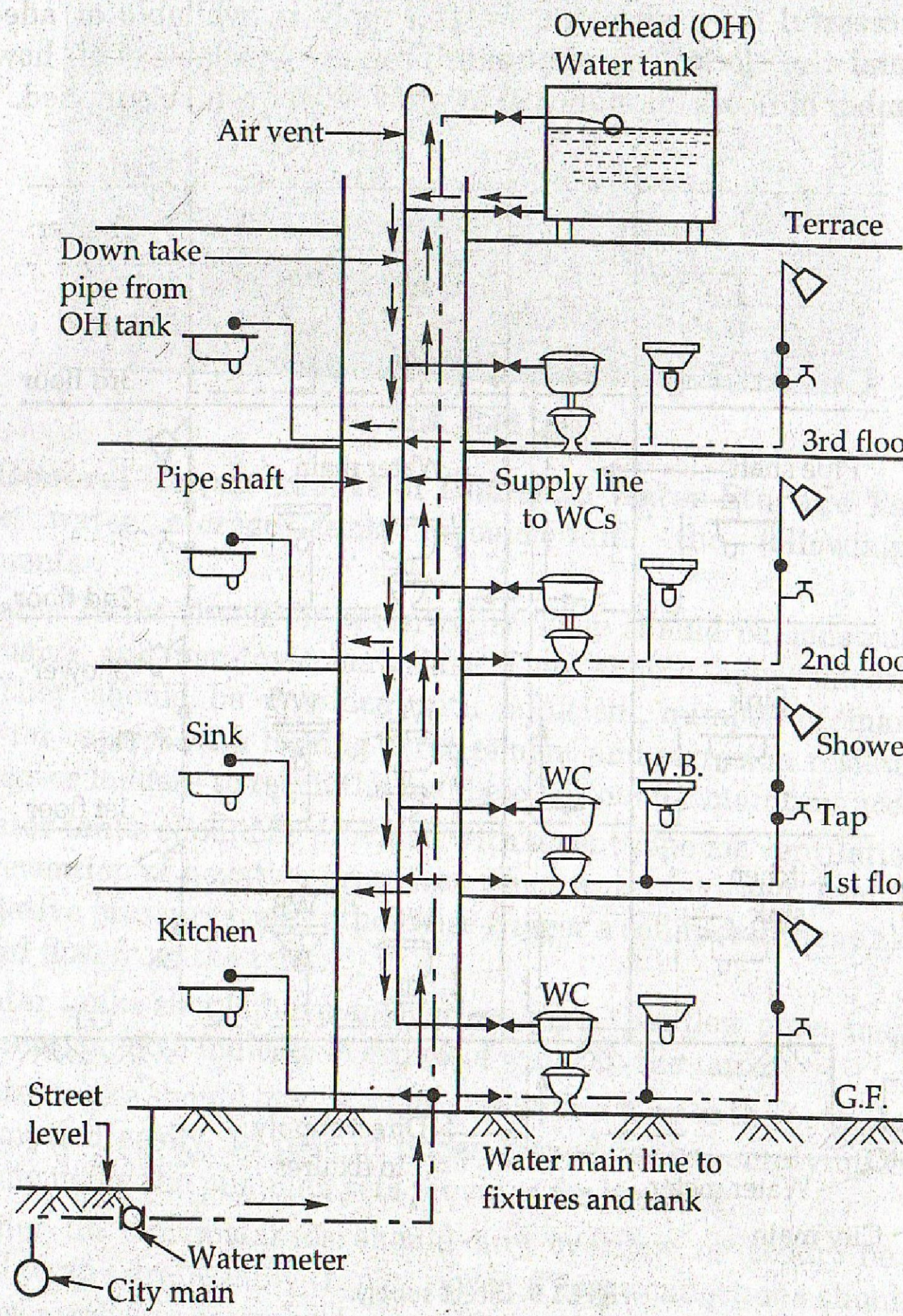


Fig. 11.10. Direct supply supplemented with an overhead tank supply.

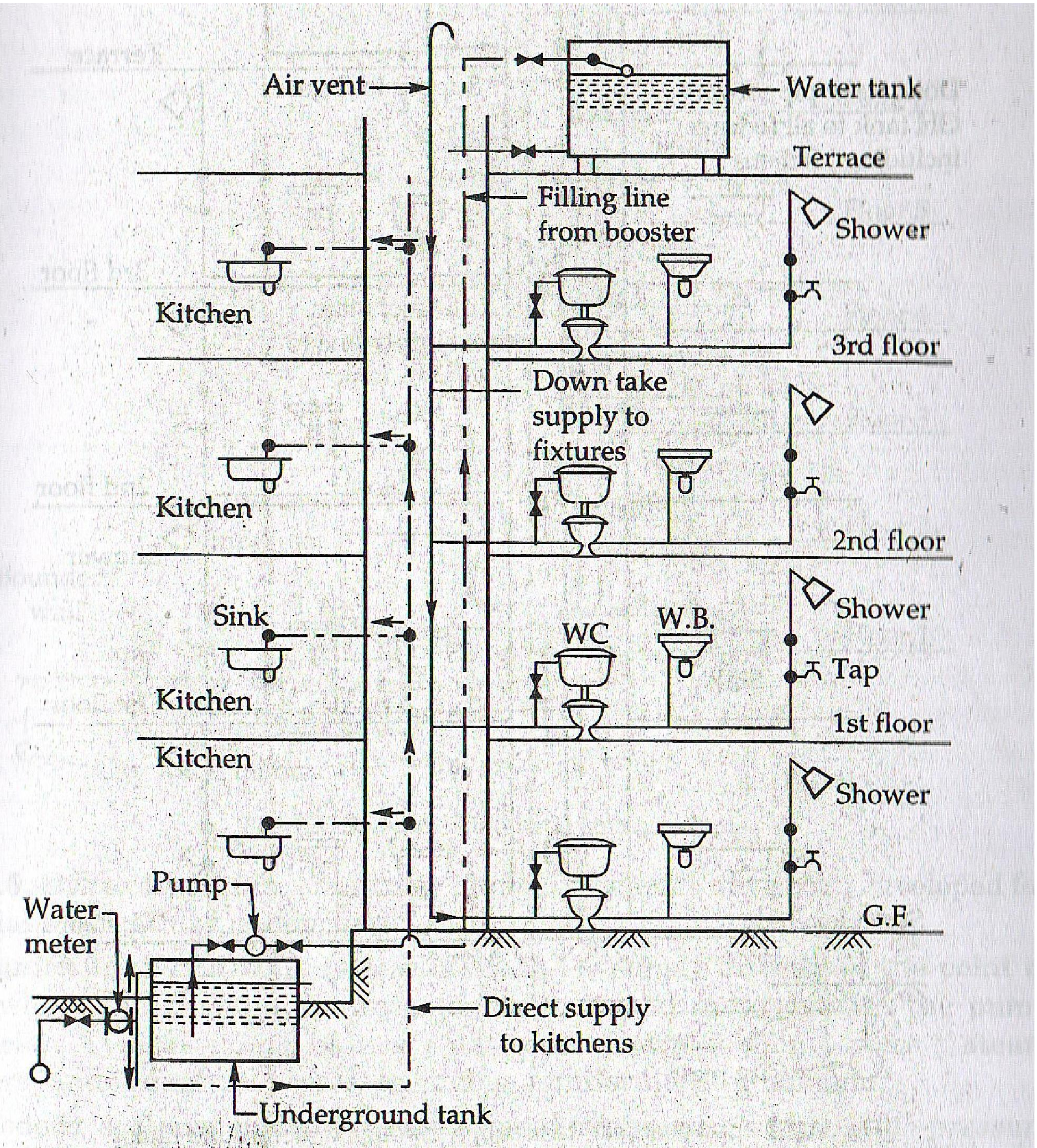


Fig. 11.11. Figure showing the piping system when the overhead storage is made through the underground tank by using a pump set, while the direct supply is used in kitchens and for drinking purposes.

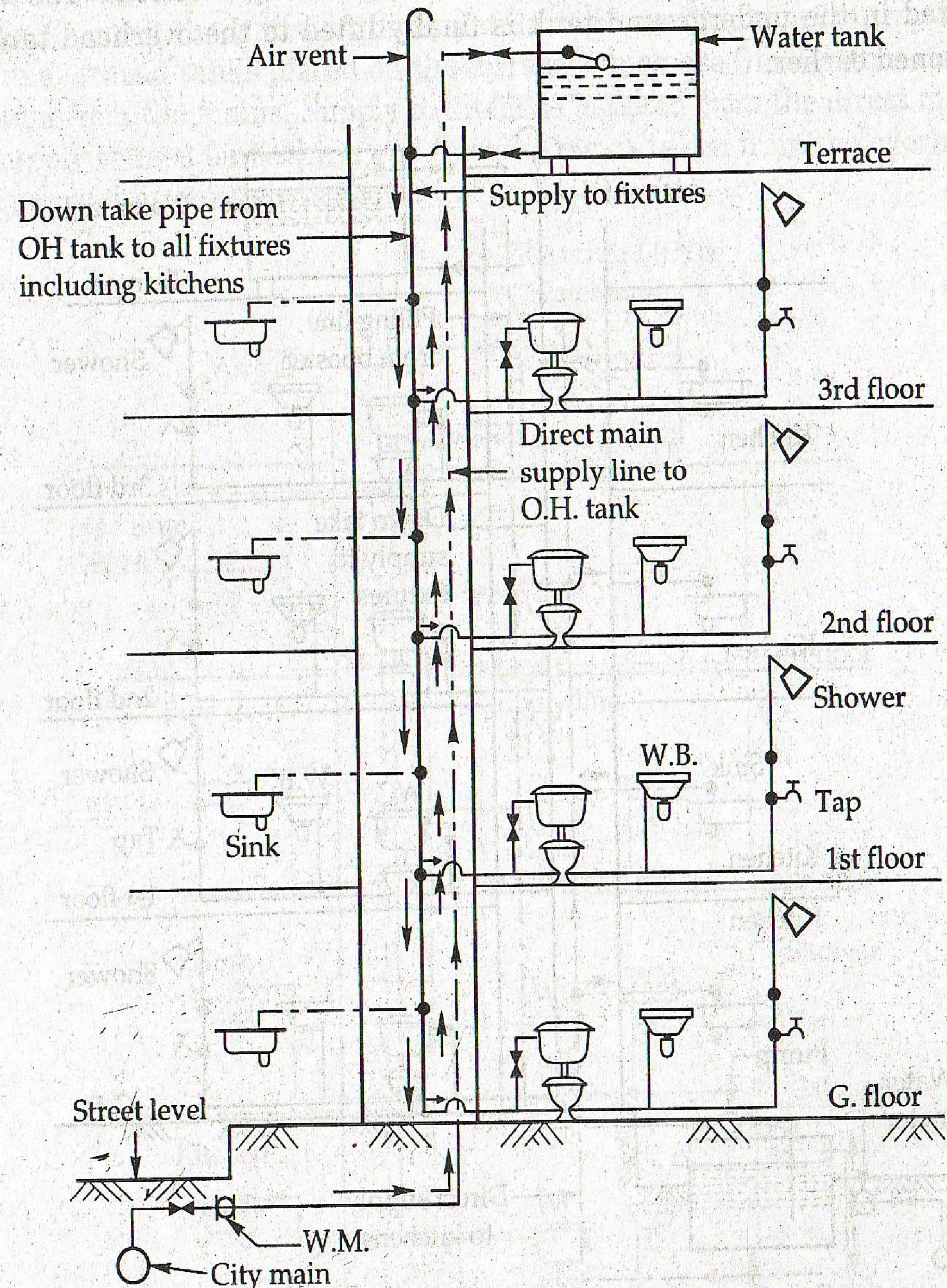


Fig. 11.12. Total overhead tank supply through underground tank.

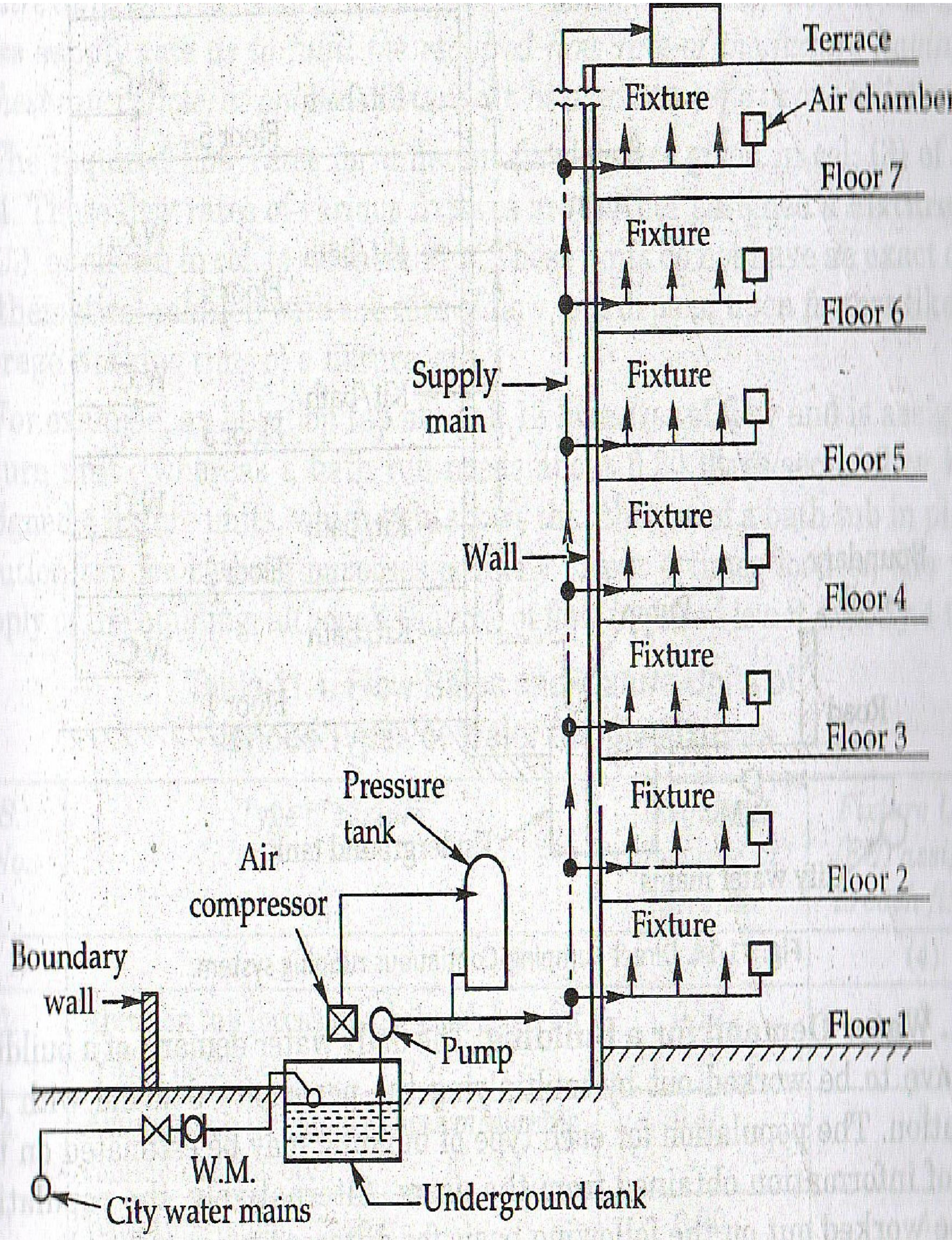


Fig. 11.13. Hydro-Pneumatic piping system.

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)

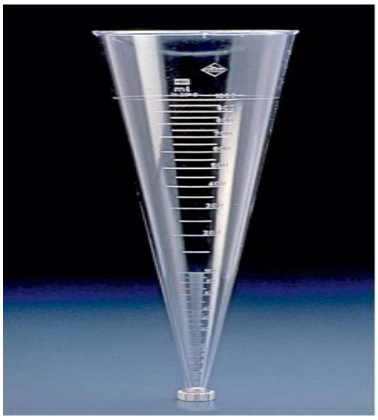
V- Volume of sample (L)

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))

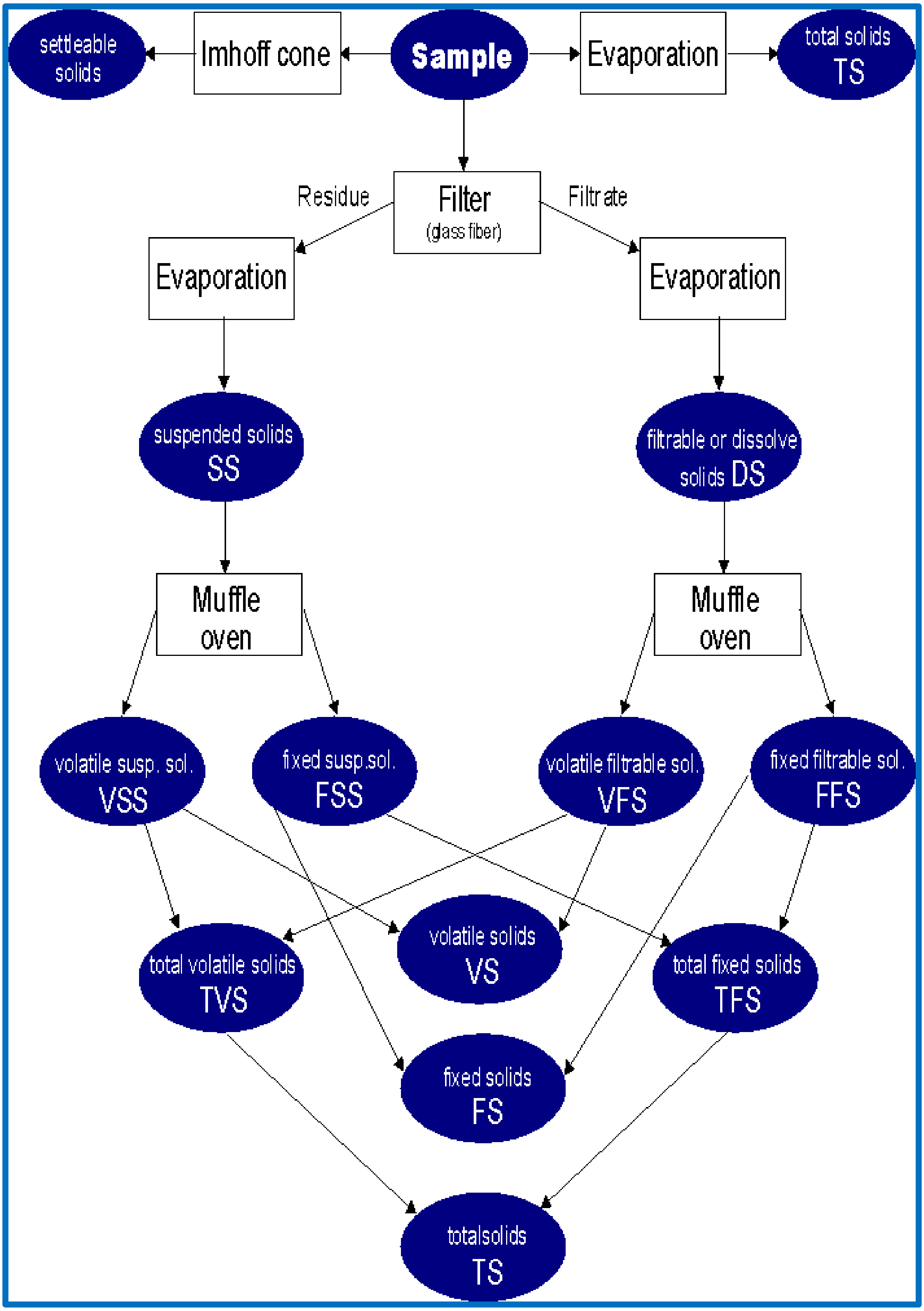
Fixed suspended solids (FSS)

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

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

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

3. Crimp and Burge's Formula

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

4. Hazen- Williams Formula

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

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

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

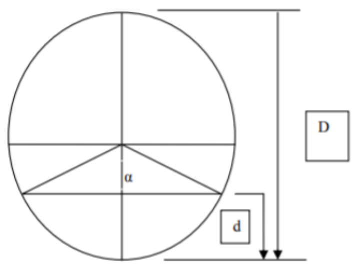
R = A/P Solving for half full sewer,

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

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

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

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

$d_{min} = 0.23 \times 0.78 = 0.18$ 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 H2SO4.
- 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

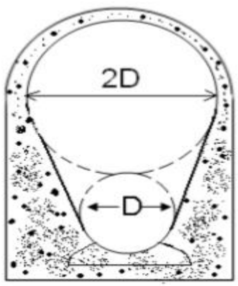
Standard egg-shaped sewers, also called as ovoid shaped sewer, and new or modified egg-shaped sewers are used in combined sewers.

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

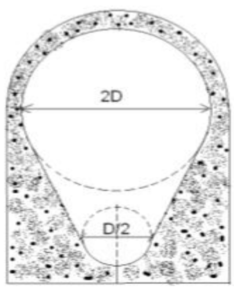
Horse shoe shaped sewers and semi-circular sections are used for large sewers with heavy discharge such as trunk and outfall sewers.

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

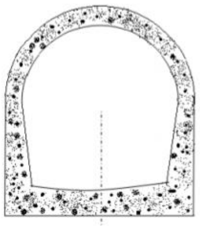
Other sections of the sewers have become absolute due to difficulty in construction on site and non-availability of these shapes readily in market.



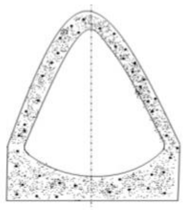
Standard egg shaped sewer



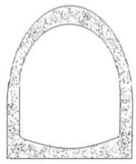
Modified egg shaped sewer



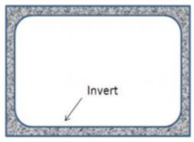
Horse shoe section



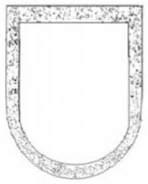
Parabolic section



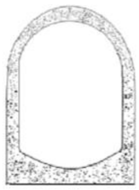
Semi Elliptical section



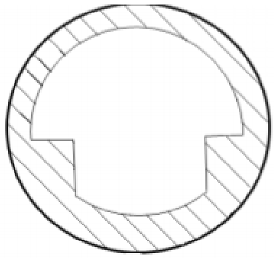
Rectangular section



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:

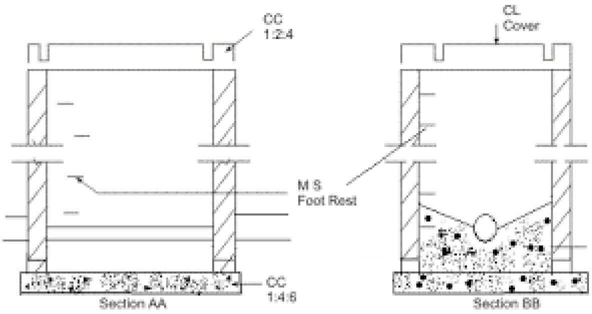
(a) Shallow Manholes,

(b) Normal Manholes, and

(c) Deep Manholes

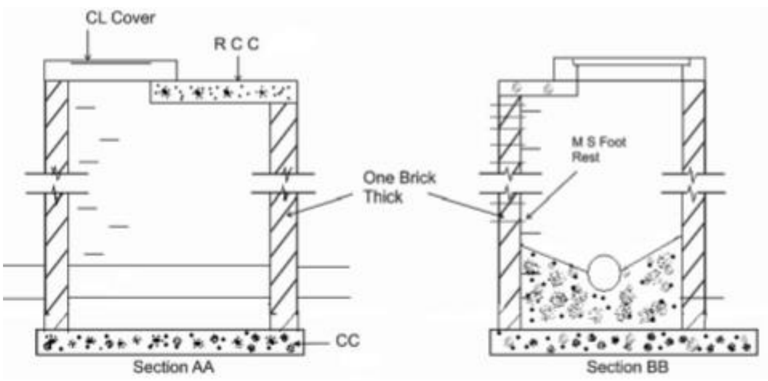
Shallow Manholes:

- 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.



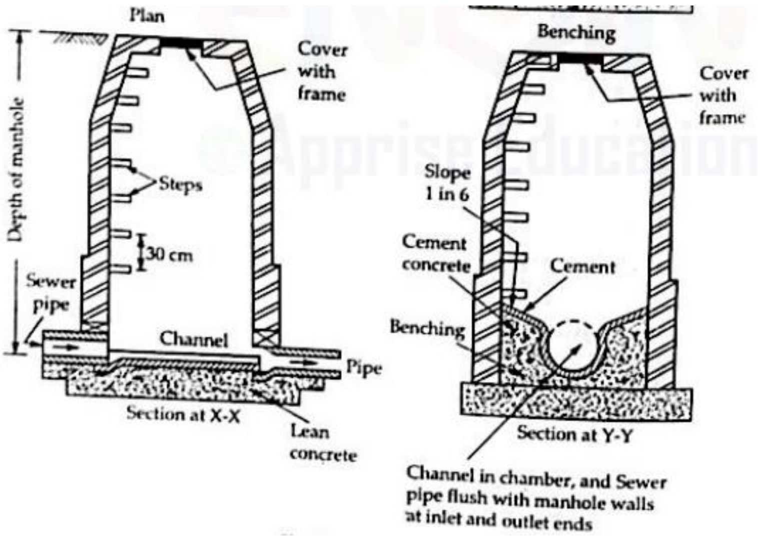
Normal Manholes:

- 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.

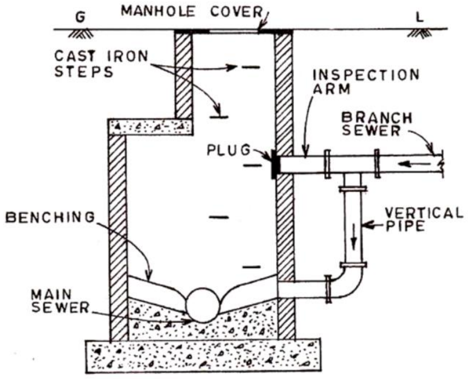
(vi) Cover and Frame

- 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.

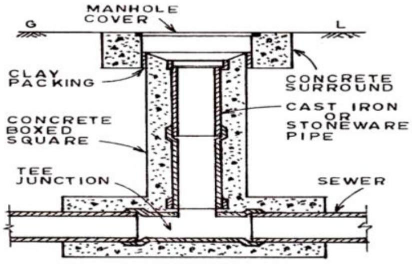
iii) The spacing of manholes is more than the usual.

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.

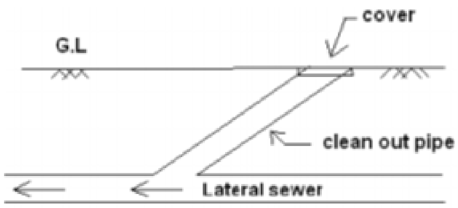
Construction of Lamp hole

- 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.

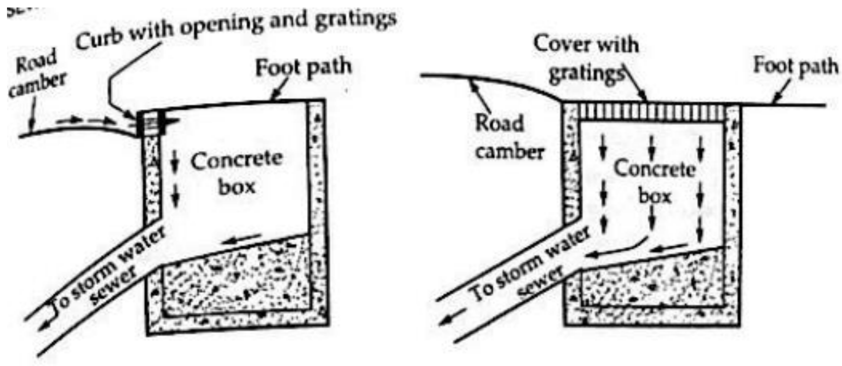
Function of street inlets

- 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

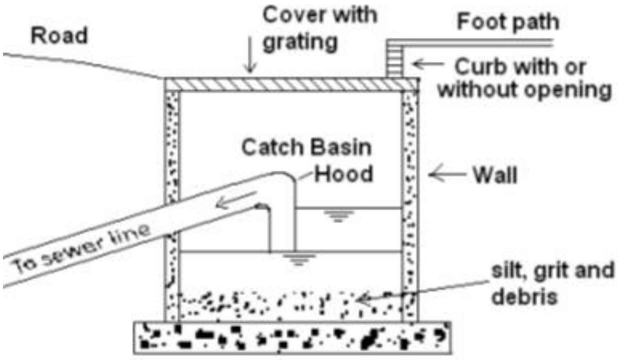
Catch basins are provided to stop the entry of heavy debris present in the storm water into the sewers.

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.

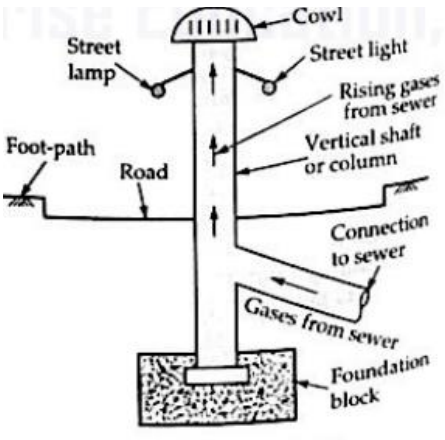
They are also provided at the upper end of every branch sewer and at every point where sewer diameter changes.

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

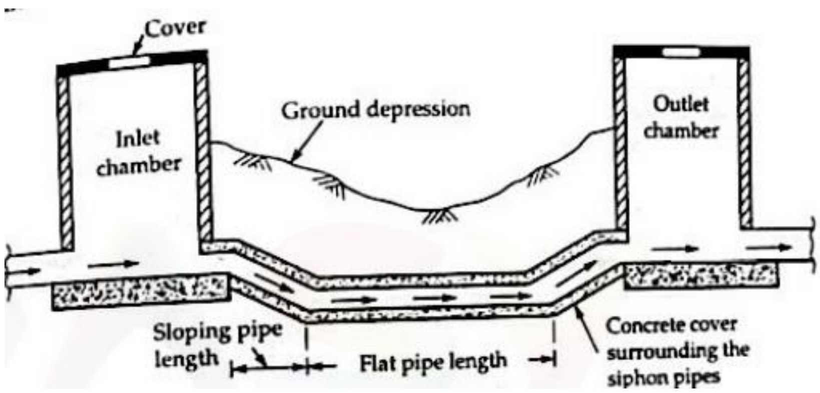
The inverted siphon is constructed at the place where a sewer pipe has to be dropped below the hydraulic gradient line for passing it beneath a valley, a road, a railway or any other obstruction.

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.

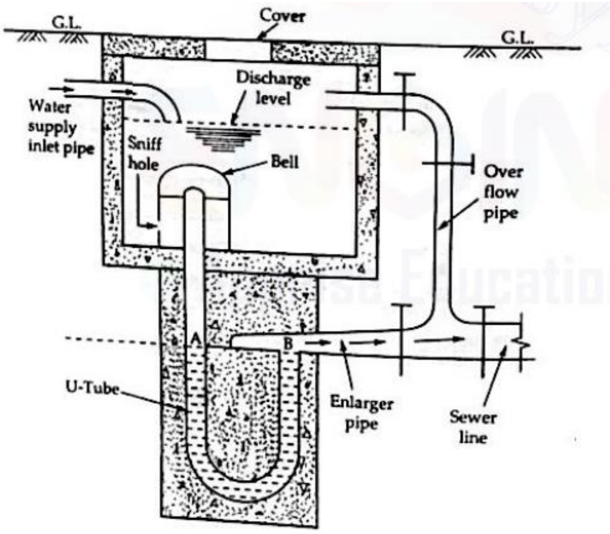
In a hand-operated flushing tank, the flushing and cleaning operation is carried out at suitable intervals by manual labour.

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.

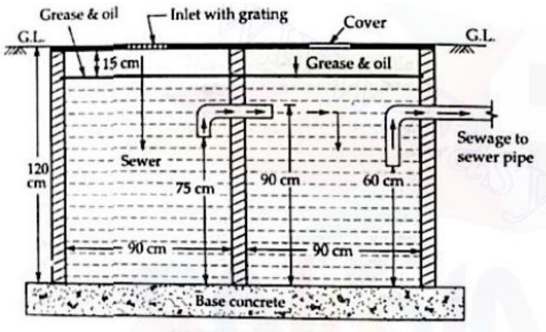
Such traps are located near the sources contributing grease and oil to the sewage.

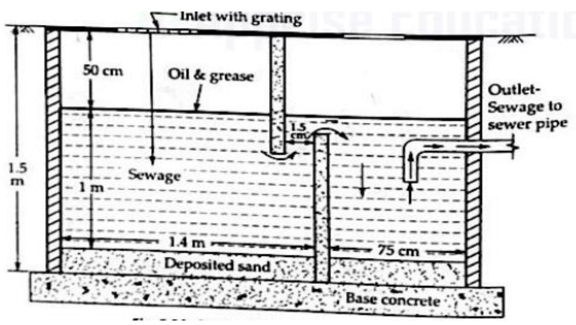
Necessities of Grease and oil traps

- 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

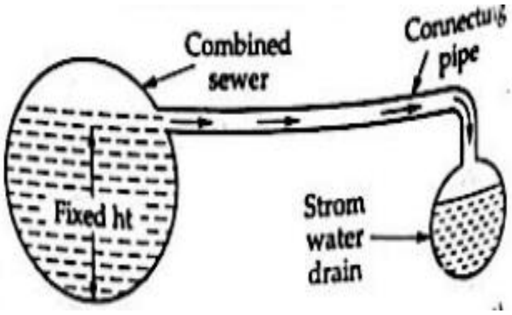
These are used for preventing overloading of sewers, pumping stations, treatment plants or disposal arrangement, by diverting the excess flow to relief sewer.

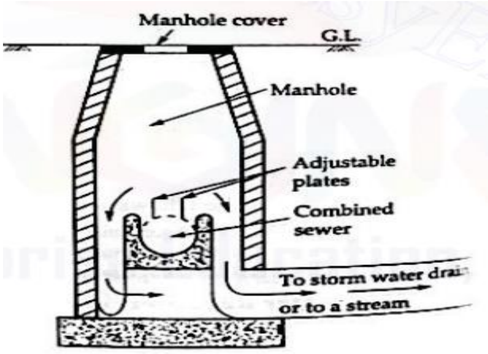
The overflow device may be side flow or leaping weirs according to the position of the weir, siphon spillways or float actuated gates and valves.

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.

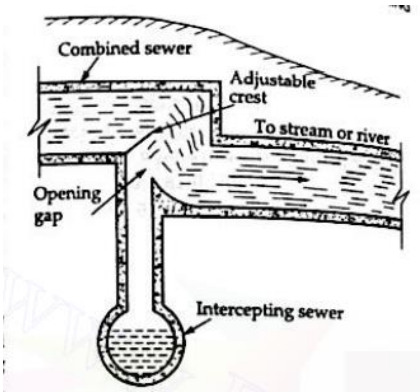
The crest of the weir is set at an elevation corresponding to the desired depth of flow in the sewer. The weir length must be sufficient long for effective regulation of the flow.





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.



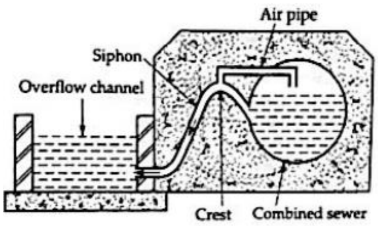
Float Actuated Gates and Valves

- 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

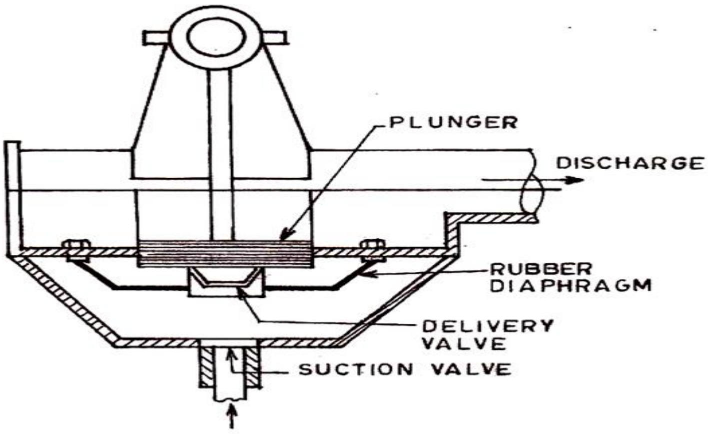
(2) Propeller type.

- 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;

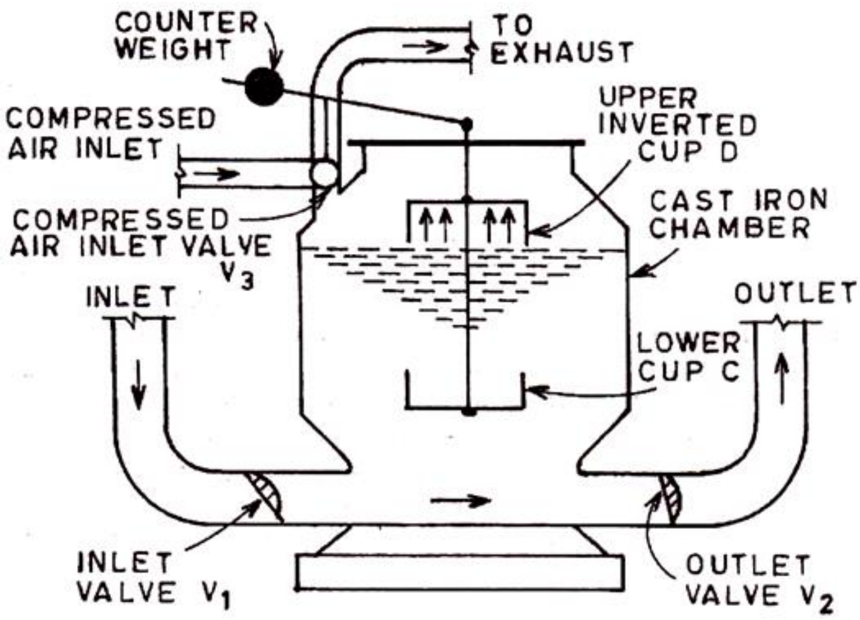
(ii) Where the quantity of sewage from a low lying area does not justify the construction of a pumping station; and

(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.

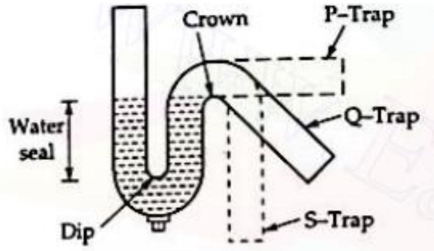
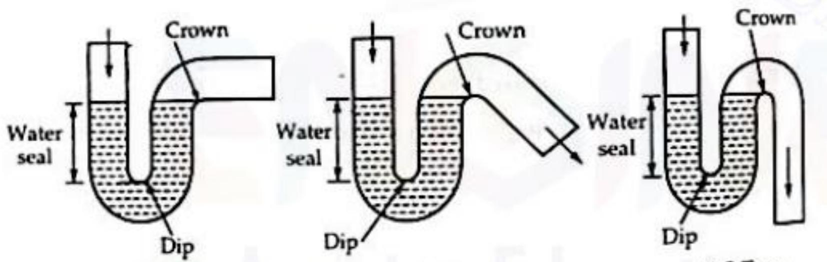


Fig. 13.1. P, Q and S Traps shown together.

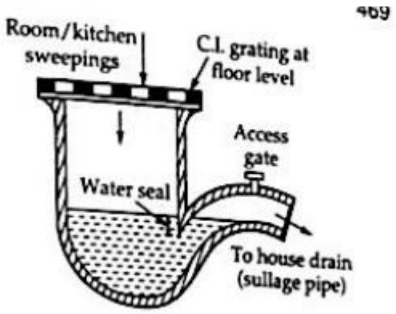


(a) P-Trap (b) Q-Trap (c) S-Trap

Based on the Use

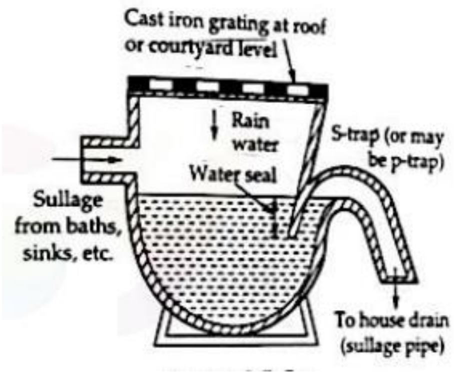
Floor Traps (Nahni Trap): This trap is generally used to admit sullage from the floors of rooms, bathrooms, kitchen etc. in to the sullage pipe.

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.

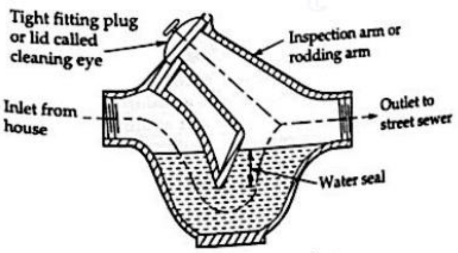


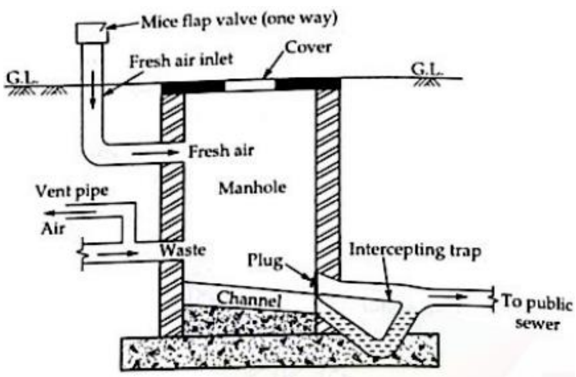
Intercepting Traps:

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.

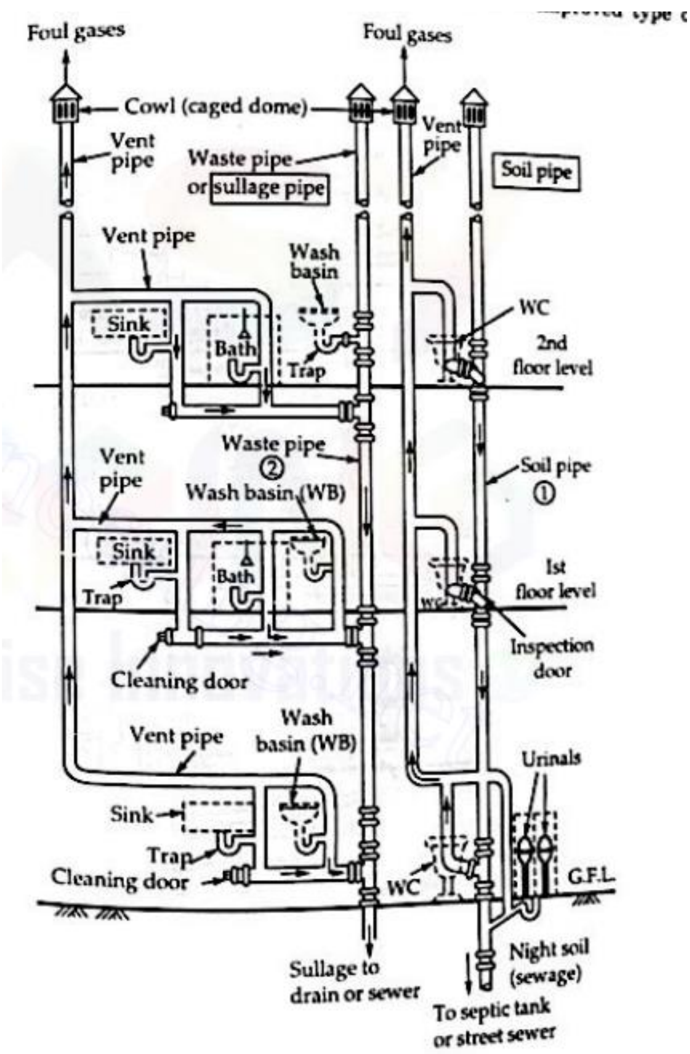
3. Single stack system

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.

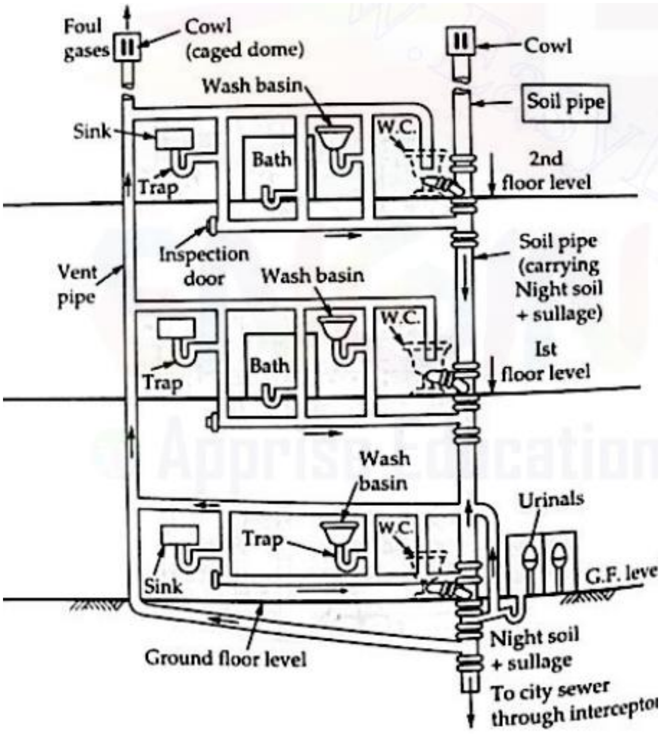


One pipe system:-

- 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

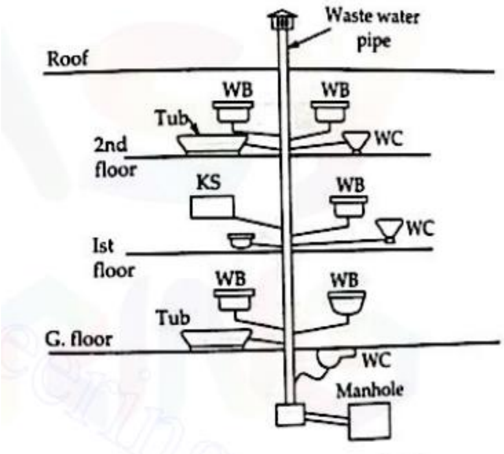
  which collects the night soil as well as the sullage water from their respective fixtures through the branch pipes.

- 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

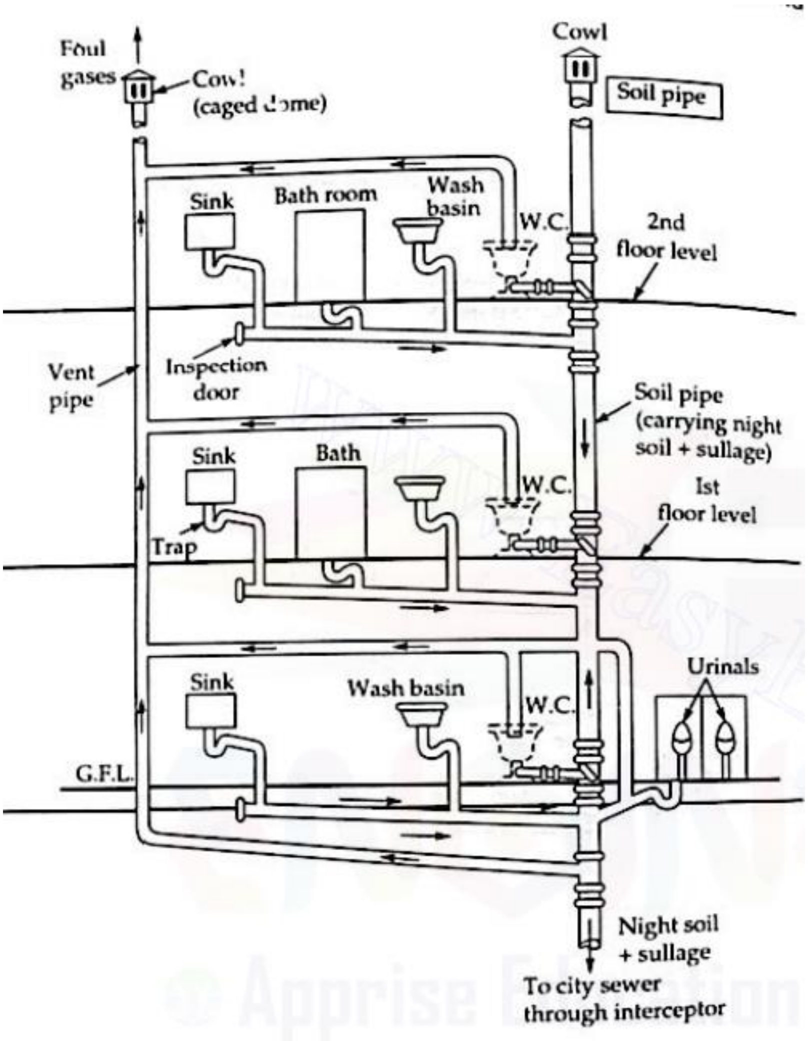
- This system is a single pipe system without providing any separate ventilation pipe.
- It uses only one pipe which carries the sewage as well as sullage, and is not provided with any separate vent pipe , except that it itself is extended up to about 2m higher than the roof level and provided with a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



1) Objectives :-

→ To remove oil and grease etc.,

→ To reduce the BOD level of Sewage about 25%

→ To remove larger inorganic solids.

2) Selection of Treatment process :-

*) treatment depends on the characteristics of the sewage.

*) Different Stages,

a) Preliminary treatment
b) Primary treatment
c) Secondary (Biological) treatment
d) Advanced (Final) Treatment.

a) Preliminary treatment :-

→ First stage in treatment process.

→ floating materials are separated from the sewage

Eg:- tree branches, dead animals, papers, wood.

b) Primary treatment :-

→ removes the larger suspended organic solids

→ Preliminary treatment grouped under primary treatment

1) Objectives :-

→ To remove oil and grease etc.,

→ To reduce the BOD level of Sewage about 25%

→ To remove larger inorganic solids.

---

2) Selection of Treatment process :-

*) treatment depends on the characteristics of the sewage.

*) Different Stages,

a) Preliminary treatment

b) Primary treatment

c) Secondary (Biological) treatment

d) Advanced (Final) Treatment.

a) Preliminary treatment :-

→ First stage in treatment process.

→ floating materials are separated from the sewage

Eg:- tree branches, dead animals, papers, wood.

b) Primary treatment :-

→ removes the larger suspended organic solids

→ Preliminary treatment grouped under primary treatment

(3)

*) treatment consists of.

→ Screening
→ Grit chambers
→ Skimming Tanks
→ Primary Sedimentation tank
→ Digestion tank

(c) Secondary (Biological) treatment.

→ Generally carried through the biological decomposition of organic matter.

*) treatment consists of

(i) Aerobic Biological Units
→ Aeration tank
→ Filters
→ Oxidation Ponds.

(ii) Anaerobic Biological Units
→ Septic tanks
→ Anaerobic lagoons,

(d) Advanced (Final) treatment:

*) removal of organic load (pathogenic bacteria)

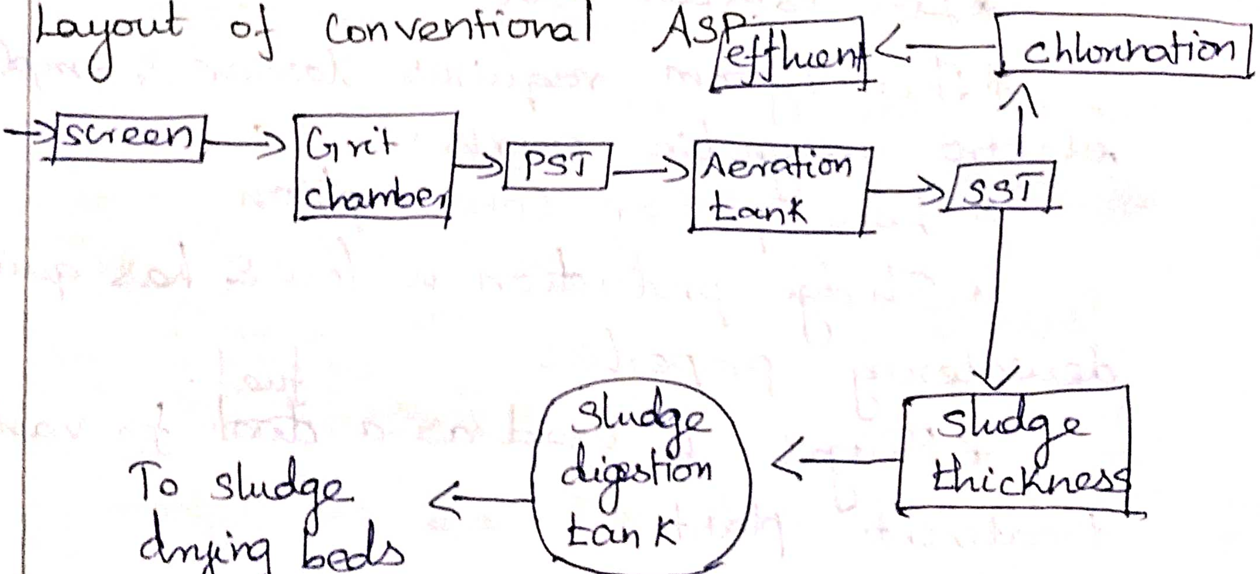
*) treatment consists of

(i) chlorination
(ii) ozonisation.

Activated sludge process:

The sewage effluent from the primary sedimentation tank is mixed with 20-30% of own volume of activated sludge containing large cone of highly active aerobic micro-organism. The mixture enters aeration tank. (4-8hrs) the micro organisms oxidizes the organic matter & the suspended & the colloidal matter tends to coagulate & settle in the secondary settling tank. The effluent from the ASP has BOD removal upto 80-95% & bacterial remove upto 90-95%.

Layout of conventional ASP



Primary Units of ASP

* Pre-removal of settlable solid prevents deposits on aeration devices.
* Shorter detention period for PST keeps the sewage fresh.
* For a depth of about 2.4m detention time = 1.4 hrs.

Aeration tanks of ASP

These are rectangular tanks of
4-6m wide.
20-200m in length.
3-4.5m deep.

The method of aeration provided are diffused aeration, Mechanical aeration, Combined aeration.

Purpose of aeration in waste water

* 70% of CO_2 can be removed by aeration & Corrosion of units is reduced to some extend.
* Removes H_2S gas & hence the odour is removed.
* Iron and mg gets oxidized to some extend by aeration

Diffused air aeration

Compressed air.

35-50 KW/m² by diffusion plate (or) tube diffusers.

Diffusion plates:

* porous plates made of Quartz or crystalline alumina.
* Square shaped plates with 30 x 30 cm & 25mm thick.

Tube diffuser:

60cm long with 75cm & thickness of wall = 15mm

Effective area of the plate & cube = 780cm² & 1160 cm² resp.

Types of aeration tank

* Bridge and furrow type
* Spiral flow type

Air required:

* On average 4000 - 8000 m^3 of free air is required per million litre of sewage.

* Usual rate is 100 m^3/day of air per kg of BOD removal.

Volume of return activated sludge:

It is expressed as the % of Q_R/Q

Where Q_R - return sludge in m^3 per day &
Q - sewage flow in m^3/day.

Mechanical aeration.

* The sewage is stir by mechanical devices like paddles & through mixing is achieved.

* Aeration period = 6-8 hrs.

* Quantity of return sludge of sewage flow = 25-30%.

Types of Mechanical aeration

* Haworth system of aeration.
* Hartley system of aeration
* Simplex system of aeration.

Size of each channel = 70 x 1.5 m.

Speed of surface aerators = 1.5 to 2 rpm.

Depth of channel = 1.2 m

detention period = 15 hrs

Return sludge = 20-25% of the sewage flow

TYPES

- Haworth system
- Hartley system
- Simplex aeration method

(i) HAWORTH SYSTEM

(Sheffield system)

1m depth — divided by thin walls

↓

Narrow channels

At @ mid of length,

↓

2 rows of paddles N = 1.5 rpm

Detention time = 15 hrs

Returned sludge = 15 to 20% of ww

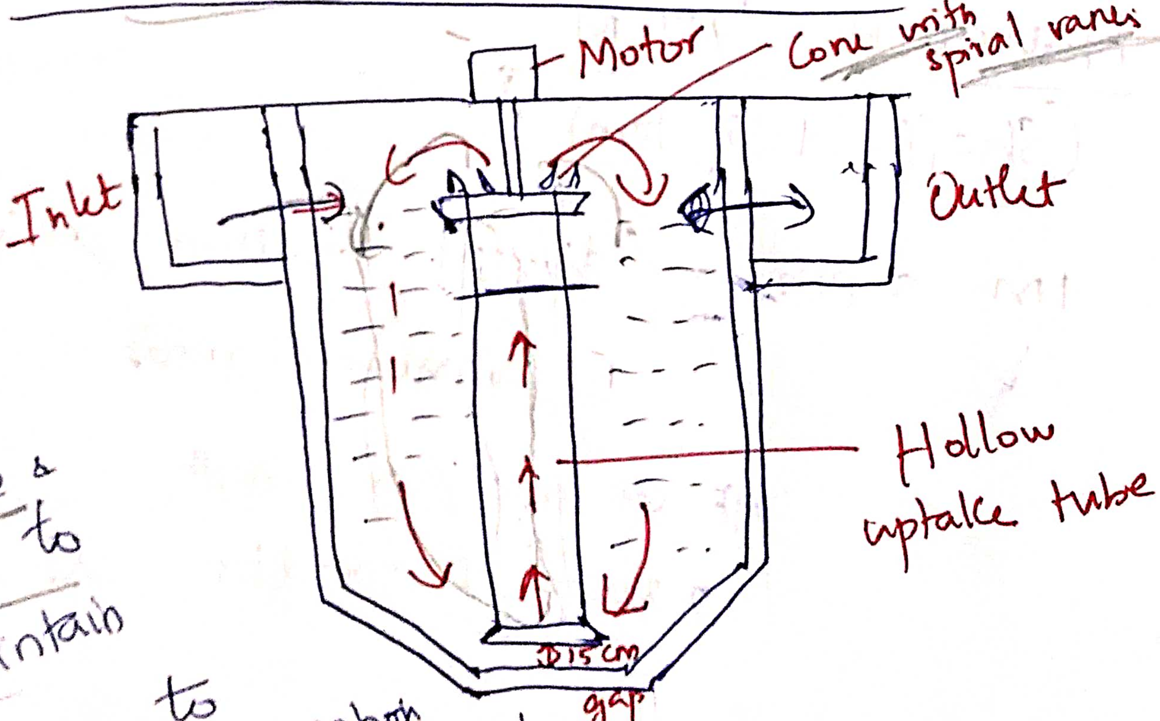
(ii) HARTLEY SYSTEM

Similar to Haworth

Modification → Paddles are inclined @ angle with vertical & fixed @ end of channel

Diagonal baffles → to maintain spiral flow.

(iii) SIMPLEX AERATION METHOD



↑ Popular
↓
Simple & easy to maintain

Sensitive to slight variation in water levels

* These are square tank in plan with copper bottom. The speed of rotation of uptake tube 60rpm.

* The rotation of cone causes suction effects and the sewage falls on the top surface.

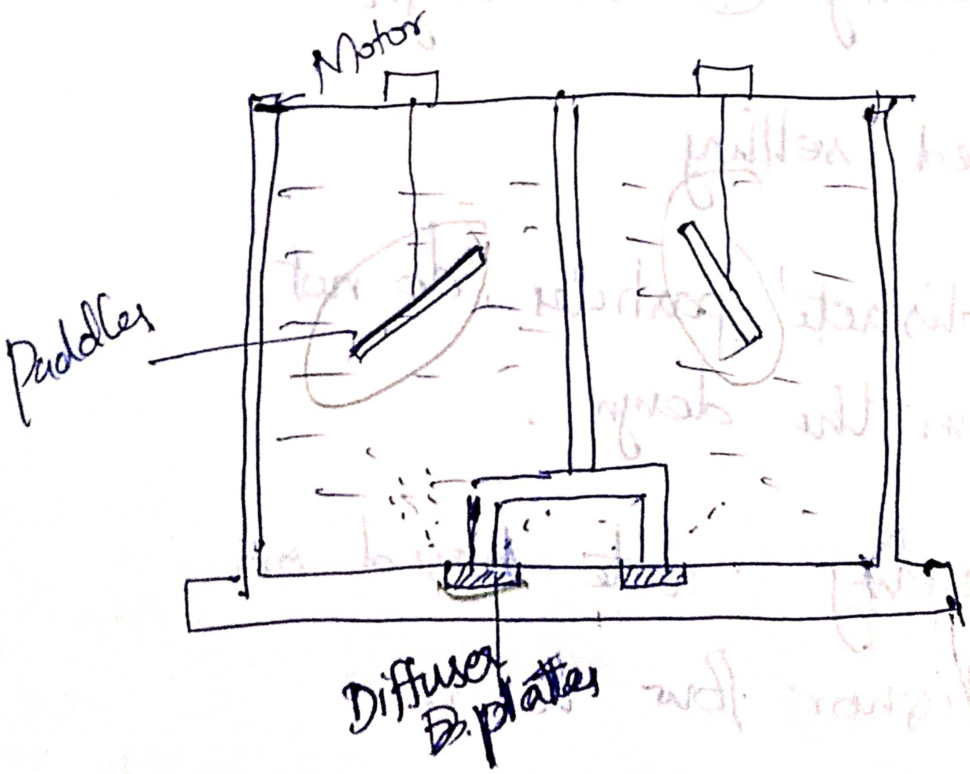
* In this operation air bubbles formed bringout the required aeration of sewage.

3) COMBINED AERATION :-
(Dorroco Aerator)

→ diffuses air through bottom diffuser plates + Rotating paddles @ 10 to 12 rpm.

→ Spiral motion sets up

Adv
* Efficient
* Detention period is smaller (3 to 4 hrs)
* Less amount of compressed air comp. to diffused air aeration.



& mechanical aeration.

Also known as Dorocco aerators

Detention time = 3 to 4 hrs.

Diffusing air is supplied to bottom diffuser plate & rotating paddles (10 to 12 rpm)

(*) 16m. Design of ASP:

The design of ASP is based on the aeration tank loading.

1) Hydraulic detention time HRT (t)

~~which the~~

It decides the loading rate at which the sewage is applied to the aeration tank

$$HRT(t) = \frac{V}{Q} \times 24 \text{ (hrs)}$$

where V = vol. of tank (m^3),

Q = rate of sewage flow (m^3/day)

2) volumetric BOD loading.

It is defined as BOD_5 load applied per unit vol of the aeration tank. It is also called as Organic loading.

$$\text{Organic loading} = \frac{Q\,Y_0 \text{ (gm)}}{V(m^3)}$$

where Y_0 = BOD_5 of the influent sewage mg/lit (or) g/m^3

(*) 16m

Design of ASP:

The design of ASP is based on the aeration tank loading.

1) <u>Hydraulic Retention time</u> (HRT)(t)

~~which the~~

It decides the loading rate at which the sewage is applied to the aeration tank.

$$HRT\ (t) = \frac{V}{Q} \times 24\ (hrs)$$

Where V = Vol. of tank (m^3),

Q = rate of Sewage flow (m^3/day)

2) <u>Volumetric BOD loading.</u>

It is defined as BOD_5 load applied per Unit Vol of the aeration tank. It is also called as Organic loading.

$$\text{Organic loading} = \frac{Q\,Y_0\ (gm)}{V(m^3)}$$

Where $Y_0 = BOD_5$ of the influent sewage mg/lit (or) g/m^3

3) F/M ratio

It expresses the BOD loading w.r.to the microbial mass in the system. The BOD load applied to the System (Kg (or) gm) is represented as the food & total microbial suspended solids in the mixed liquor of the aeration tank is represented as M.

$$F = Q Y_0 \ (gm/day).$$

$$M = MLSS \times V = X_T \times V.$$

$$F/M = \frac{Q \times Y_0}{X_T \times V}.$$

4) Sludge age / solids retention time (SRT)

Sludge age is the avg. time for which the particles of the suspended solids remains under aeration. It indicates the residence time of biological solids in the System. Also known as mean cell residence

$$\text{Sludge age } (\theta_c) \text{ in days} = \frac{\text{Mass of Suspended solids (MLSS) in the System}}{\text{Mass of solids leaving the System per day}}$$

5) Sludge ~~vol.~~ Volume Index (SVI)

It indicates the physical state of Sludge produced in the biological aeration System

SVI is defined as the vol. occupied in ml by 1 gm of solid in the mixed liquor after Settling for 30 min & determine experimentally

$$SVI = \frac{V_{ob}}{X_{ob}} \times 1000 \ (mL/g)$$

where V_{ob} = Settled Sludge vol.

X_{ob} = Conc. of Suspended Solids in mixed liquor (mg/L)

The SVI value b/w 50 to 150 ml/gm indicates good settling sludge

The SVI value (mg/L) is expressed as

$\frac{10^6}{SVI}$

6) <u>Wasting of excess sludge</u>

It is adopted to maintain a steady level of MLSS

In domestic sewage 0.50 to 0.75/kg BOD is removed for conventional sludge plant where the F/M ratio is b/w 0.4 to 0.3

Modification of ASP process :-

1. Tapered aeration process

In this process the rate of oxygen consumption is not uniform throughout the tank.

2. STEP AERATION PROCESS

The activated sludge is broad near the inlet end of the aeration tank and added along it instages as required.

It helps in observing the shock organic loading.

3. EXTENDED AERATION PROCESS:

It uses long aeration period of 24-48 hrs and produces less sludge volume and the digested sludge is directly taken to the sludge drying bed the operating cost is high.

4. CONTACT STABILISATION PROCESS:

In this process before giving primary settling the raw sewage and the recycled sludge are mixed and aerated for about 0.5-1.5 hrs in a special contact aeration tank.

5. COMPLETE MIXED PROCESS:

Here the complete mixing is achieved by distributing the sewage and returned sludge uniformly along one side of the tank and withdrawing the aerated sludge uniformly along the opposite side.

IV EXTENDED AERATION ~~TANK~~ SYSTEM – AT = 12–24 hrs

→ Operates in the endogeneous phase of microbial growth curve

Small Communities < 4 MLD

→ Without PST

→ Low organic loading rate
Longer aeration period } to generate less biomass solids (sludge)
↓
How? = Endogeneous respiration

Adv
↓ Solids produced is completely mineralised
↓
Eliminates separate sludge digestor

BOD removal 95-98%
(85-82%) – Normal

Note :-

Package Treatment Plants for small residential & Industrial ww treatment are based on EAS.

TRICKLING FILTERS

↳ [Percolating filters & Sprinkling filters]

↳ Consists of tanks of coarser filtering media

↳ sewage is allowed to sprinkle down

↓

By spray nozzles / rotary distributors.

↳ Percolating sewage collected @ bottom of tank through under-drainage system.

Process:- decomposition of org. matter / Purification of sewage

Micr. get attached to filter media - Micro org

↳ Organic matter (Sewage influent)

↓

Adsorbed on biological film [formed by microorganisms around sand particles

↓

Organic matter degraded by aerobic bacteria

Microorganisms grow

↳ Thickness of slime layer increases

↳ Diffused oxygen is consumed by upper portion of slime layer.

↳ Creates anaerobic environment around surface of media particles.

→ Adsorbed organic matter — Metabolised

→ Creates shortage of organic C @ media face

→ Microorganisms @ media face

→ Endogeneous phase of growth

→ Lose the ability to cling to media face.

Liquid sewage

→ Exerts shearing action

→ Breaks slime

→ New slime continues to grow

→ Balance in the thickness of formed biofilm.

Breakup of biomass from slime layer (detachment)

⇓

Sloughing

Sloughed material ~~separated~~ allowed to ~~from sewa~~ settle in sedimentation tank

⇓

Sloughed material & ~~Sew~~ Treated sewage are separated.

(7) 2m.

The phenomenon of breakup (or) detachment of biomass from slime Layer is known as sloughing. It is a function of hydraulic & organic loading of the bed.

Construction & operation of Trickling filter.

* Generally constructed above Ground & may be Rectangular (or) circular.

* The difference between action

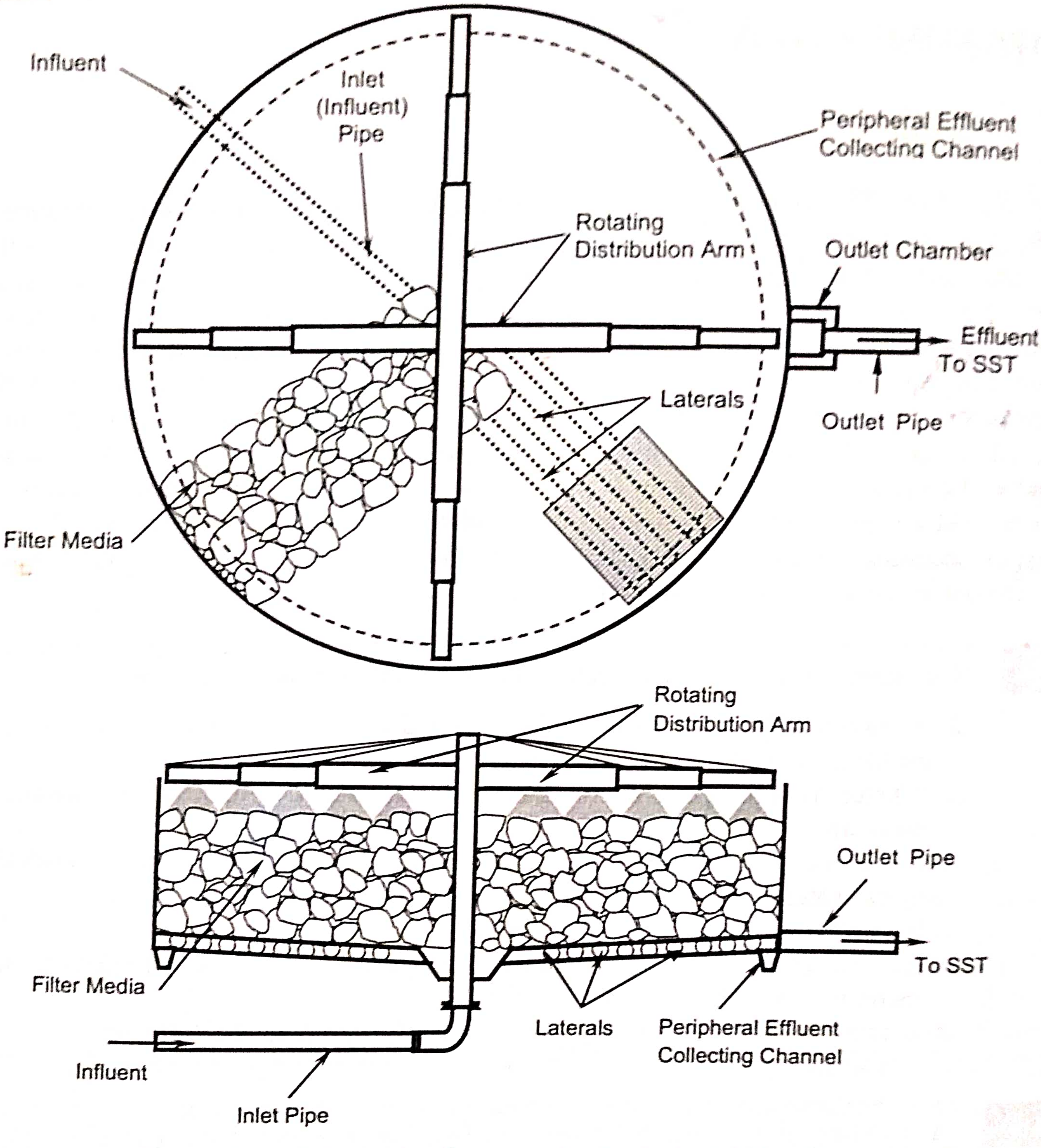


Figure 9.1 Schematic diagram of a typical trickling filter.

of rotary distributor & that of Spray nozzeles with rotary distributor is the application of sewage to the filter is practically Continous. but with Spray nozzeles the filter is closed for 3 to 5 mins & then rested for 5 to 10 mins before next application.

* Filter media Consist of Coarse materials like Cubically broken stones (or) slagged free from dust

* Material size = 25 to 75mm.

* Depth = 2 to 3m

* Min. Compressive Strength = $100 N/mm^2$

15-2-17 Operation of Trickling Filter.

* Sewage is supplied and Sprayed over the Surface area of the filter bed

* During Spray it may absorb oxygen from atmosphere

* Filtring media surface is covered with biofilm in which aerabic bacteria, algae, etc are developed Converting organic matter into stable form.

* Treated effluent is collected

through under drain. Due to Continous Operation filter media may be clogged and anaerabic Condition may develop. To avoid Such Condition upper layer of filter media is to be replaced by fresh Layer

Types of Trickling filter:

* Conventional (or) ordinary (or) Low rate Trickling filter.

* High rate Trickling filter.

Advantages

* Removes about 75% BOD and 80% Suspended Solids.

* Land area requirement is less and Smaller quantity of filter media required for installation.

* Working of Trickling Filter is Simple and doesnot require Skilled Supervision.

Disadvantages.

* Initial Cost is high.

* These filters cannot treat raw waste water and primary treatment is must

* Additional dosing tank involves extra Cost

* Process developes fly nuissance and bad odour

Parameters	Low rate filter	High rate filter
Hydraulic loading (ML/hect/day)	22 - 44	110 - 330
Organic loading BOD_5 in kg/m³/day	900 - 2200	6000 - 18000
Depth of filter Media	1.8 - 3	0.9 - 2.4
Recirculation	None	1:1 - 4:1
volume of bed	5 times	1
Sloughing	Intermittent	Continous
Effluent characteristics	95 Nitrified fully	Nitrification only at Low loading
Dosing interval	3-10 mins	Not more than 15 secs
Cost of Operation	More for Treating equal quantity of sewage	Less for Treating equal quantity of sewage.
Quality of Secondary produce	Black, Highly oxidised with slightly finer particles	Brown, Not fully oxidised with finer particles.

1 Design of trickling filter.

* It primarily involves design of diameter of circular filter tank and its depth.

* The design of rotary distributor and under drainage system is also involved in the filter design.

* The design of filter size is based upon the values of filter loading

(☒) 2m

* **Hydraulic loading** - It is the quantity of sewage per unit of surface area per day

$$HL = \frac{Q}{BL}$$

For standard rate filter = 22 - 44 ML/hect/day

For High rate filter = 110 - 330 ML/hect/day

(☒) 2m.

* **Organic loading** - It is the mass of BOD per unit volume of filtering media per day

$$\text{Organic loading} = \frac{BOD_5}{\text{volume of filter media}}$$

900 - 2200 kg / hec · m / day

Performance of conventional filter & their efficiencies

* BOD removal = 80 to 90% & less than 20 ppm

* Secondary sludge is thick with moisture content of 92% & is heavy and

easily digestable.

* The Efficiency of conventional filter is given by NRC eqn (National Research Council of USA) (or) Eckenfelder's eqn and gn as.

$$\eta(\%) = \frac{100}{1+0.0044\sqrt{u}}$$

Where η is the Efficiency of filter & its Secondary Clarifier in terms of % of applied BOD removed.

U is organic loading in kg/hec.m/day

* In case of recirculation the efficiency of High rate filters is gn as

(i) Single stage filters.

$$\eta(\%) = \frac{100}{1+0.0044\sqrt{\frac{Y}{V \times F}}} \quad \text{——— ①}$$

Recirculation Factor $F = \frac{1+R/I}{(1+0.1R/I)^2}$

Where Y is the Total Organic load in kg/day ie the total BOD in kg

V is the filter volume in hect.m

F is the recirculation factor

The term $Y/V \times F$ is the Organic loading u

R/I is called the recirculation ratio gn as the ratio of volume of sewage recirculated (R) to the volume of sewage (I).

*In case of second stage filter the efficiency achieved in first stage will be as per the eqn ① and in the second stage it is obtained as,

Final Efficiency in 2nd stage filter $\eta(\%) = \dfrac{100}{1+\dfrac{0.0044}{1-\eta}\sqrt{\dfrac{Y'}{V' \times F'}}}$

where Y' is the total BOD in effluent from the first stage in kg/day

V' volume of second stage filter in hectare m.

F' is the recirculation factor for the 2nd stage filter

(T)

Operational troubles in Trickling Filter

(X) 8m. Fly nuissance.

It can be controlled by,

* Flooding the filter with sewage for 24 hrs or more

* By using the following insecticides at a dosage of 1 to 2 mg/L based on the Total daily sewage flow for period of 2 hrs

(i) DDT

(ii) Chlordance

(iii) Benzene hexa chloride

Odour nuissance.

The formation of hydrogen sulphide gas can be controlled by chlorinating the sewage.

Ponding Trouble

The voids in the filter media gets clogged due to the heavy growth of fungi & algae. This is called as ponding of filter over the bed. This problem can be eliminated by chlorinating the sewage. It can also be control by addition of Copper sulphate

SEQUENCING BATCH REACTOR

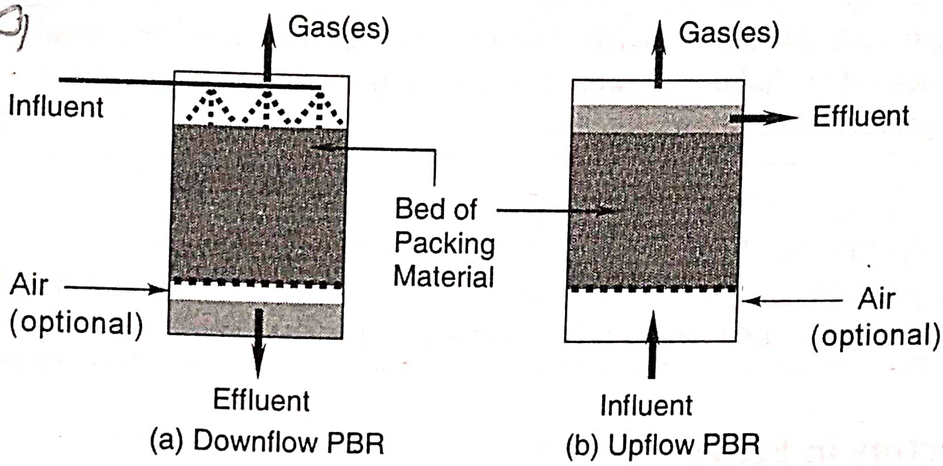


Figure 4.12 Schematic diagram of a typical PBR.

This is a fill and draw type of reactor which works on the principle of activated sludge process where reactions for aeration and waste conversion and clarification of effluent occur in the same reactor, but in sequencing steps [28, 37, 38, 42, 46].

Operational steps: The following are the operational steps of the SBR:

- ❑ The reactor is first filled with wastewater up to the desired volume and the flow is stopped.
- ❑ The content of wastewater is then aerated and mixed for the designed time period.
- ❑ Aeration is then stopped and clarification or sedimentation of biomass is carried out to separate the sludge.
- ❑ The clarified effluent is then withdrawn (or decanted) from the reactor.
- ❑ Finally the deposited sludge is removed from the bottom of the reactor.

Figure 4.13 shows the operating steps of an SBR used as an activated sludge process system.

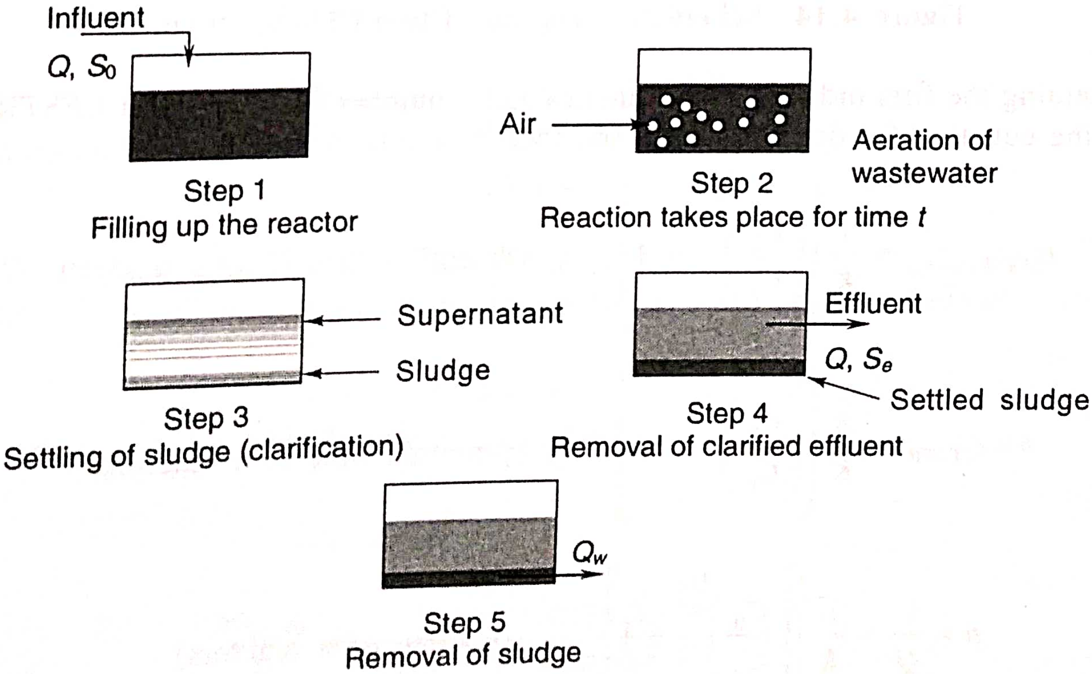
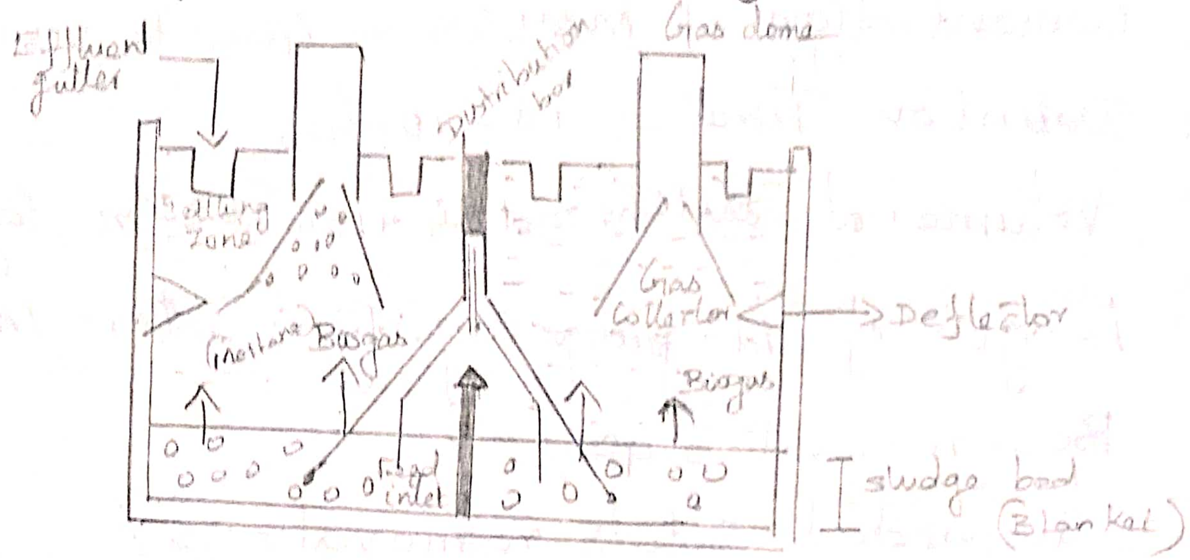


Figure 4.13 Operating steps of an SBR.

UASB [Upflow Anaerobic Sludge Blanket] Reactors:

16m



The process involves the conversion of a high rate of concentrated liquid waste into methane gas by maintaining a high concentration micro organisms in the reactor and preventing them to escape along with the effluent.

A gas-solid-liquid separator is provided at the top to provide a quiescent zone at the top of the reactor. ~~The So~~

The solid biomass contains microbial aggregates with settles upon the sludge layer forming granulated sludge called sludge blankets.

Biogas is the mixture of 65 to 70% of methane and 30-35% CO_2 which are separated and collected via gas collector

Design criteria.

Max sludge Retention time (SRT) = 15 to 30 days

Min hydraulic retention time (HRT) = 6 to 12 hrs.

Gas production = 0.35 m^3 of methane produced per 1 kg of COD reduction

Organic loading is represented in terms of COD loading & varies from 12 to 20 kg COD/ m^3/day

Advantages

* The Space requirement is Comparatively low (0.5 Acres)
* Low Capital Cost
* This system requires lesser & simpler electro magnetic parts.
* Low power consumption
* Sludge production is low & has quick dewatering properties
* Biogas produced in this system can be used as a ~~dead~~ fuel for various treatment plants.

Disadvantages:

* Reduces BOD & suspended solids only and does not remove heavy ~~methods~~ metals
* Pre treatment of Sewage with screening and grit chamber are necessary.
* Not efficient at low temperature
* Requires Large quantity of organic matter.

The Efficiency of BOD & Suspend solids removal is low compare to the ASP

OXIDATION POND (Waste stabilisation ponds)

↳ Low cost ~~WW~~ wastewater treatment units which stabilises the WW

Removal of BOD

under aerobic conditions

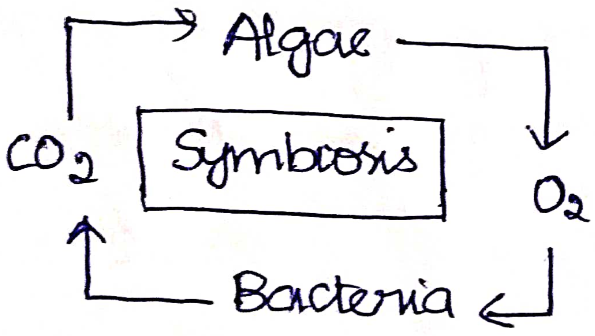
↳ Aerobic ~~WW~~ wastewater stabilisation ponds.

↳ Shallow dug earthen ponds provided with high embankment

↳ Open rectangular earthen tanks.

WORKING PRINCIPLE :

Algal Bacterial Symbiosis



8.6 WASTE STABILIZATION PONDS

Waste stabilization ponds, also known as *oxidation ponds*, are the simplest biological systems available for the treatment of wastewater, more particularly when high quality effluent is not the requirement and a large area of land is available for such treatment system. They are employed for the treatment of both domestic wastewaters and industrial wastewaters, which are liable to biological treatment.

The ponds are generally constructed in earthwork with relatively very small depths as compared to their large surface areas and bunds (embankments) are built all around to some height to exclude the entry of rainwater into the ponds. Normally wastewater to be treated is applied directly to the pond(s) after removing floating materials through bar racks without any primary treatment. The oxygen required for aerobic decomposition of organic solids is mostly supplied by the algae present in the system through the symbiotic actions of algae and bacteria as shown in Figure 8.15. The system has low construction and neligible operating cost as it requires minimum operation skills, and does not use any mechanical equipment to supply oxygen by aeration. Ponds may be multi-celled and can be provided in series or parallel [2, 3, 23, 28, 37, 38].

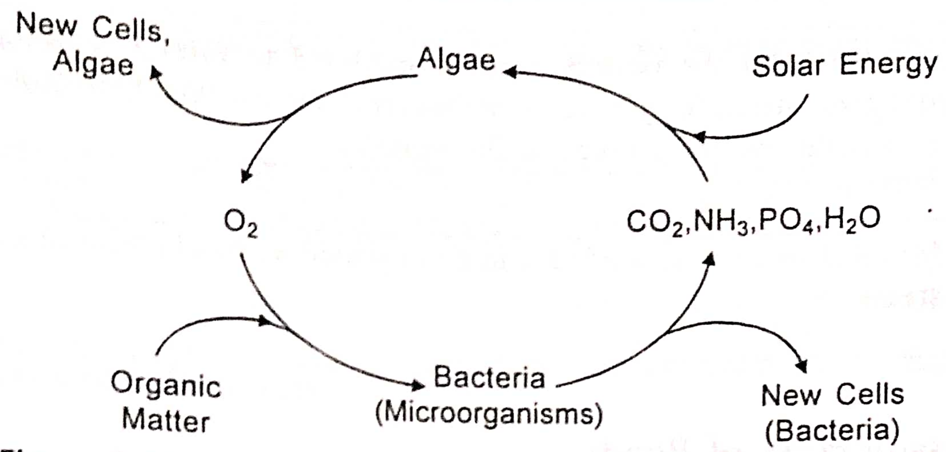


Figure 8.15 Symbiotic relation between bacteria and algae.

8.6.1 Removal Mechanism

When raw wastewater is fed to the basin after screening, the suspended solids settle to the pond bottom by gravity due to long retention time. The soluble organic matter in upper top and intermediate layers are decomposed (oxidized) under aerobic and facultative conditions to carbon dioxides (CO_2), nitrates, orthophosphate and water by the microorganisms (predominately bacteria) present in the waste. The required oxygen is supplied by the photosynthetic metabolism of algae present and synthesized in the pond. The solids settled at the bottom of ponds are decomposed to stable end products by anaerobic bacteria. Figure 8.16 shows the schematic representation of solids removal mechanism in a facultative waste stabilization pond.

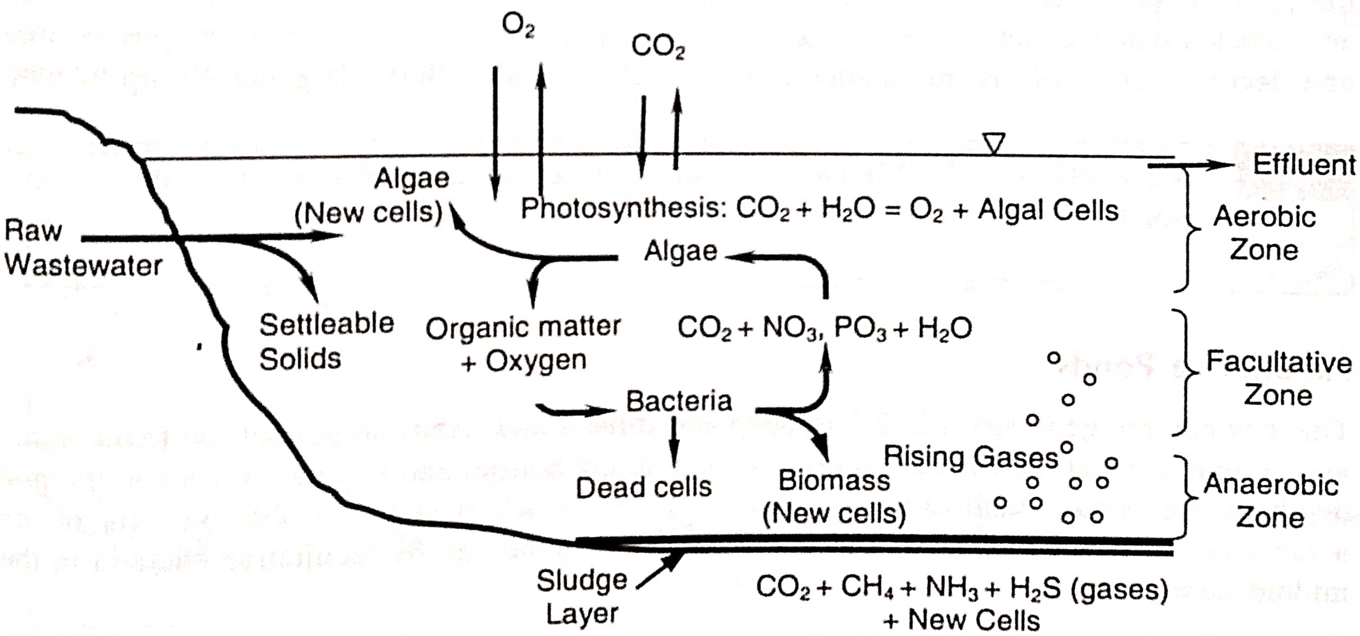


Figure 8.16 Schematic of solids removal mechanism in a facultative stabilization pond.

8.6.2 Classification of Ponds

The waste stabilization ponds have been classified as follows:

Aerobic Ponds

These ponds are generally 0.3–1.5 m deep and have further been classified as *low rate* and *high rate* aerobic ponds. While low rate aerobic ponds are used for reducing soluble BOD_5 and aerobic conditions are maintained throughout the pond depth, high rate aerobic ponds are commonly used for production and harvesting of algal cultures. Though removal of soluble BOD_5 is as high as 95%, effluents have large concentrations of algae, which may ultimately exert a higher BOD_5 into receiving streams.

Anaerobic Ponds

These ponds are generally 2.5–5.0 m deep in which anaerobic conditions prevail throughout the pond depth except for a surface zone of few centimetres. Usually these types of ponds are installed with facultative ponds in series. Stabilization of organic solids involves precipitation and decomposition of organic matter and removal of soluble BOD_5 is generally up to 85%.

> **TIP** More efficient UASB can be used in place of anaerobic waste stabilization ponds.

Facultative Ponds

These ponds are generally 1.2–2.5 m deep and three zones exist throughout the pond depth, viz. aerobic zone at the surface, anaerobic zone at the bottom and facultative zone at the mid depth of the pond. Stabilization of organic solids is achieved by aerobic bacteria in the aerobic zone, by anaerobic bacteria at the bottom of pond and by facultative bacteria in the middle zone.

Maturation Ponds

These ponds are generally 1.0–1.5 m deep and are normally designed for 5–10 days of HRT. They are generally used after facultative ponds with the prime objective of destructing the pathogenic organisms.

DESIGN OF OXIDATION POND

(OM)

I BOD LOADING RATE (OR) ORGANIC LOADING RATE:

SA or plan area = LB

$$SA = \frac{\text{Total BOD applied to the pond}}{\text{BOD loading rate}}$$

$$SA = \frac{QY_i}{OLR}$$

BOD loading rate is dependent on latitude of the place

$$\text{Lat} \propto \frac{1}{\text{temperature}}$$

hot → $\eta \uparrow$ ↓ ↑ BOD load

Temp ∝ η of OP

Temp ∝ BOD loading rate

$$\text{Lat} \propto \frac{1}{\text{BOD loading rate}}$$

② II DETENTION TIME (t)

t = 2 to 6 weeks

(*)

$$t = \frac{1}{K} \ln \frac{y_i}{y_e}$$

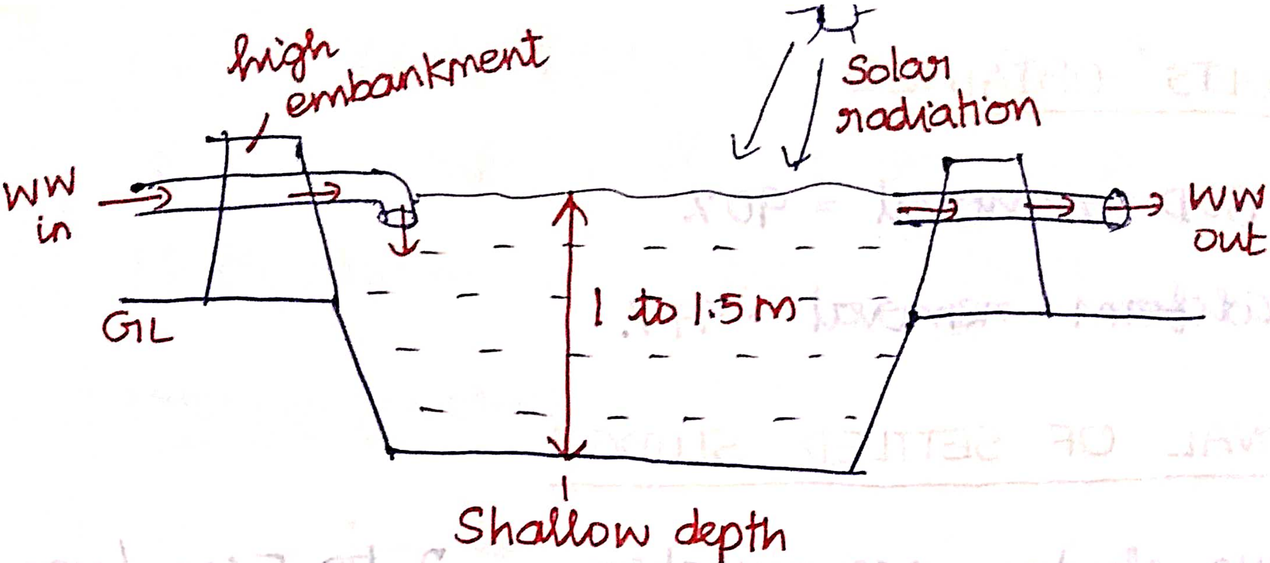
$$t = \frac{1}{K_D} \log_{10} \frac{L}{L-Y}$$

K → pond rate constant

Volume of OP = $Q \times D_t$

$$V = Q D_t$$

Note: As we move away from screening D_t increases.



DESIGN CRITERIA

1) OLR = 150 to 300 kg/ha/day [hot tropical countries - India]

   = 60 to 90 kg/ha/day (cold countries)

2) Area = 0.5 to 1 ha

3) depth = 1 to 1.5 m

   FB = 1m

NOTE:

If per capita BOD production = 0.08 kg/ha, then 1 ha land will suffice for

$$\frac{300}{0.08} = 3750 \text{ to } \frac{60}{0.08} = 750 \text{ persons.}$$

RESULTS OBTAINED :

BOD removal = 90%

Coliform removal = 99%

REMOVAL OF SETTLED SLUDGE

Avg sludge accumulation = 2 to 5 cm / year

Slude removal = 6 years (1.2 m deep)

= 12 years (1.5 m deep)

[to ensure mini liquid depth = 0.3 m]

ADVANTAGES

* Hot dry countries like India
* Places where 200 or more sunny days are expected / year
* Small towns & cities where large land areas are cheaply available - 0.5 to 1 km away from the habitation.
* Cheap [initial & maintenance cost]

↓

10 to 30% of conv ASP / TF

* No skilled supervision is required
* Flexible - Do not get upset due to fluctuations in organic loading.

DISADVANTAGES

* Mosquito breeding

Measure : Banks of pond can be kept clear of grasses & bushes

* Bad odour

Measures : Located far away from residences
By avoiding overloading

NOTE :

When a pond gets overloaded, Algae growth is stimulated by adding sodium nitrate

plant food & oxidising agent

1) Standards for Disposal :-

Table 5.1. BIS (ISI) standards for discharge of sewage and industrial effluents in surface water sources and public sewers*

S.No.	Characteristic of the effluent	Tolerance limit for sewage effluent discharged into surface water sources, as per IS 4764 –	Tolerance limit for individual effluent discharged into	
			Inland surface waters, as per IS 2490 – 1974	Public sewers as per IS 3306 - 1974
(1)	(2)	(3)	(4)	(5)
1.	BOD_5	20 mg / l	30 mg / l	500** mg / l
2.	COD	-	250 mg / l	
3.	PH value	-	5.5 to 9.0	5.5 to 9.0
4.	Total suspended solids (TSS)	30 mg / l	100 mg / l	600 mg / l
5.	Temperature	-	40°C	45°C
6.	Oil and grease	-	10 mg / l	100 mg / l
7.	Phenolic compounds (as phenol)	–	1 mg / l	5 mg / l
8.	Cyanides (as CN)	-	0.2 mg / l	2 mg / l
9.	Sulphites (as SO_3)	-	2 mg / l	-
10.	Fluorides (as F)	-	2 mg / l	-
11.	Total residual chlorine	-	1 mg / l	-
12.	Insecticides	-	Zero	-
13.	Arsenic (as As)	-	0.2 mg / l	-
14.	Cadmium (as Cd)	-	2 mg / l	-
15.	Chromium, hexavalent (as Cr)	-	0.1 mg / l	-

16.	Copper	-	3 mg / *l*	3 mg / *l*
17.	Lead	-	0.1 mg / *l*	2 mg / *l*
18.	Mercury	-	0.01 mg / *l*	-
19.	Nickel	-	3 mg / *l*	2 mg / *l*
20.	Selenium	-	0.05 mg / *l*	-
21.	Zinc	-	5 mg / *l*	15 mg / *l*
22.	Chlorides (as CI)	-	-	600 mg / *l*
23.	% Sodium	-	-	60%
24.	Ammoniacal nitrogen (as N)	-	50 mg / *l*	50 mg / *l*
25.	Radioactive materials (*i*) α - emitters (*ii*) β - emitters	-	 10^{-7} µC / ml(micro curie / ml) 10^{-6} µC / ml	- -

5) Sludge Treatment :-

→ Before disposing the sludge, it should undergo various unit processes,

*) Sludge Thickening

*) Sludge Digestion

*) Elutriation

*) Sludge Dewatering.

→ Objectives of Sludge Treatment.

*) To reduce the cost of transport for heavy volume of disposal.

*) To minimize the land requirement.

*) To save the additional fuel required for incineration method of sewage disposal.

(i) Sludge Thickening :-

→ The process of reducing the moisture (or) water content of the sludge.

→ sludge from primary sedimentation tank (and) sludge from secondary sedimentation units contains 96 % to 99 % of moisture content in its volume.

(25)

→ there are three types of sludge thickeners.

*) Gravity thickeners

*) Floatation thickeners

*) Centrifugal thickeners.

Gravity thickeners

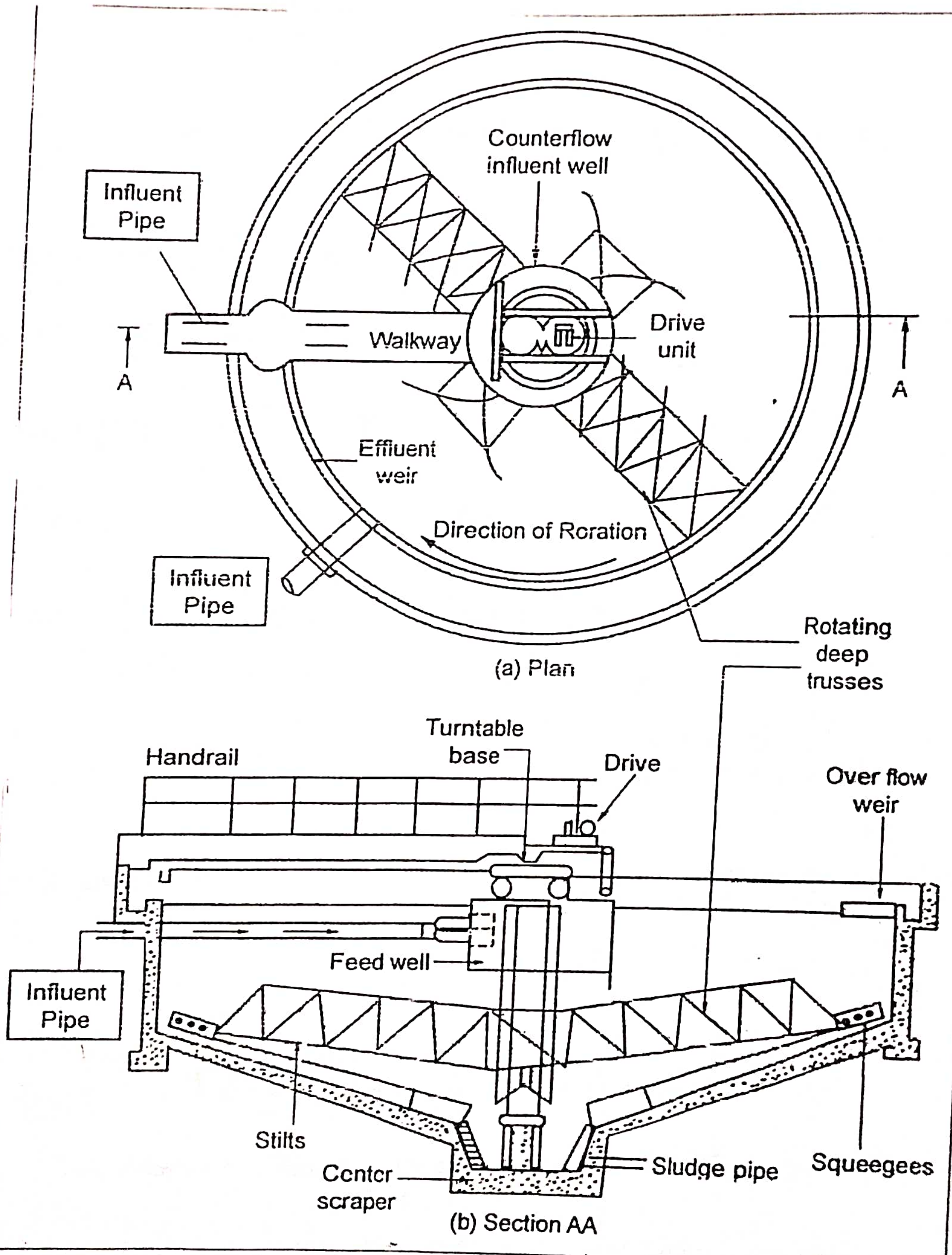


Fig. 5.7. Typical gravity sludge thickener

→ Gravity thickners consists of a small circular open tank

→ similar to the plain sedimentation tank.

→ designed for a hydraulic loading of 20,000 to 30,000 litres / day / m^2

→ It may create odour problems.

→ Continuous thickness are mostly having 3 m water depth.

→ detention period = 24 hours.

→ During peak conditions, lesser detention times will have to be adopted.

(ii) Sludge Digestion :-

→ the process of decomposing the organic matter of sewage sludge under anaerobic conditions of adequate operational control.

→ Carried out in two different ways.

a) Anaerobic Digestion (absence of oxygen)
b) Aerobic Digestion. (presence of oxygen)

A) anaerobic sludge digestion:

→ The sludge is broken into three different forms.

*) Digested sludge

*) Supernatant liquid

*) Gases of decomposition.

→ 3 stages of sludge Digestion

*) Stages I - Acid production stage

*) Stages II - Acid regression Stage

*) Stages III - Alkaline fermentation stage

→ Factors affecting the sludge digestion

*) Temperature (practical range is 26° c to 35°c)

*) Sludge seeding

*) Mixing

*) pH Value (desired range 6.8 to 7.2)

*) Other factors

→ Sludge Digestion Tanks

*) Following are the essential parts.

→ Enclosure (dia - 5 m to 35 m; depth - 3m to 12 m)

→ Floor (slope - 1:1 to 1:3)

→ Gas done (made of metal sheet)

→ Heating arrangements

→ Inlet and outlet

→ Mixing devices

→ Roof (floating type (or) Fixed type)

→ Scum breaking devices.

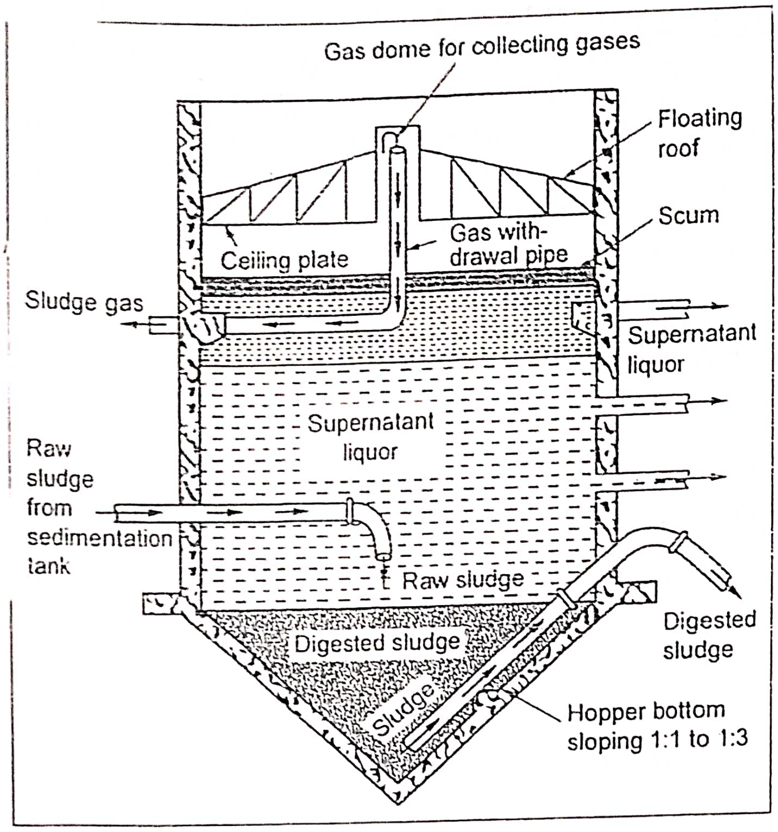


Fig. 5.9. Sludge digestion tank

b) Aerobic Sludge digestion.

→ Stabilize the waste sludge by long term aeration.

→ It is carried out in one (or) more tanks mixed by diffused aeration.

→ Following factors to be Considered,

*) Detention time

*) Loading criteria

*) Oxygen requirement

*) Mixing and process operation.

→ required 10 to 132 days at 20°c

→ oxygen desirable limit — 1 and 2 mg/l.

(iii) Sludge Conditioning (Elutriation)

→ also known as 'washing the sludge'

→ It is the process of improving the dewatering characteristics of the sludge.

→ 2 Methods :

a) chemical Conditioning
b) Heat treatment.

→ chemical Conditioning.

- → process of adding the chemical to sludge
- → used to facilitate the easy extraction of moisture.
- → Example chemicals - ferric, aluminium salts with lime

→ Elutriation

- → process of washing the sludge
- → to remove the organic & fatty acids from the sludge
- → It is done by plant effluent.
- → Methods.
  - → Single stage washing
  - → Multi stage washing
  - → Counter current washing

→ Single stage elutriation = 2.5 time of two stage elutriation

→ Single stage elutriation = 5 times of counter current elutriation

(iv) Sludge Dewatering :-

→ It is the process of removing (or) drying the water from the digested sludge from digestion tank.

→ Factor to be Considered,

*) First Cost
*) Cost of operation
*) Land area available
*) Proximity of residences
*) climate
*) Size of plant
*) Number of operators
*) plant loading
*) Type of plant
*) Topography.

→ Methods,

*) Vaccum filters
*) Presses
*) Flash drying incinerators
*) Air drying.

Vaccum Filters :-

→ It's the type of mechanical sludge dewatering equipment

→ filter Consists of

→ hallow cylinder Covered with filtering cloth.

→ Supported on a wire netting.

→ cylinder rotates on a horizontal axis

→ pump is also provided which air and water from inside the drum.

→ rotation may be less than 30 cm/min.

→ cake having a thickness of about 7mm.

→ Canke can also be removed by knife edge scooping device

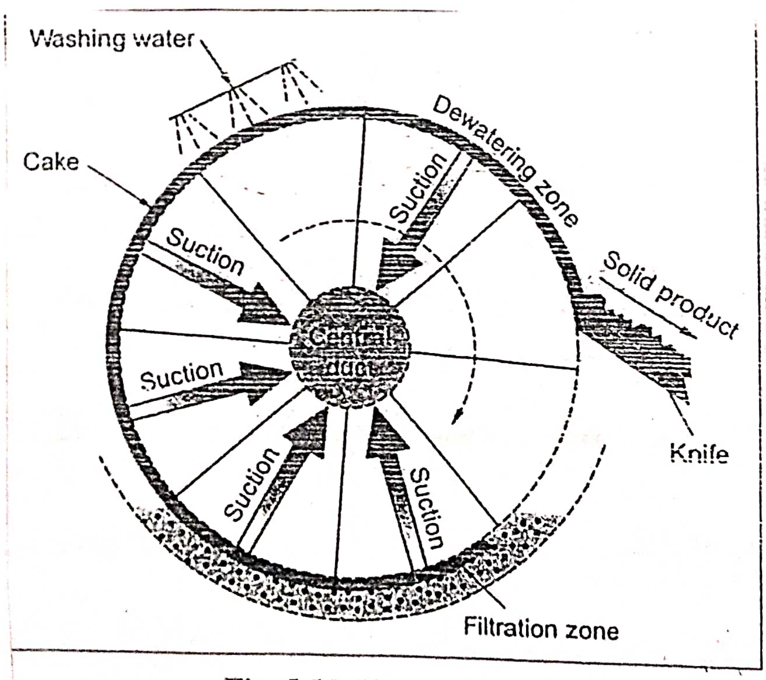


Fig. 5.10. Vacuum filters

6) Sludge characteristics :-

→ sludge has an objectionable odour
→ it may pollute the environment
→ It is bulky and Contains large amount of water
→ Specific gravity nearly equal to that of water.
→ In 100 parts of sludge,
  ↳ 98 % of water
  ↳ 2 %. of Solid matter.
→ Moisture Content of the sludge,
  ↳ 70 % to 80 %. — known viscous form.
  ↳ 10 % — dry and powder form

7) Sludge Disposal :-

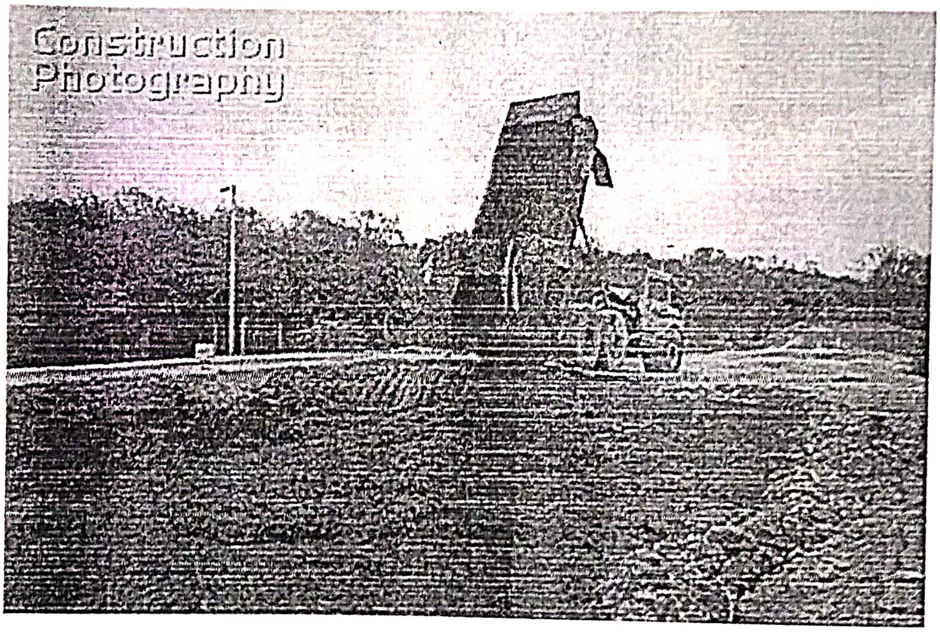
→ Various Methods

*) Disposal on land
*) Distribution by pipe line
*) Drying on drying beds
*) Incineration
*) Dumping into sea
*) Heat drying
*) Lagooning or ponding
*) Filters
*) Digestion followed by drying.

a) Disposal on Land :-

→ Sludge can be disposed off on laid in two ways

Ploughing Method	Trenching Method
→ The sludge is mixed with either lime slurry (or) with powdered lime	→ trench 1 m wide, 600 mm depth → parallel row distance 1.5 m



b) Distribution by pipe line :-

→ This is a simple method

→ This method is not in practice

→ Sludge is Conveyed through the pipe line to the nearest farms and used as fertilizer.

c) Drying on Drying beds :-

→ useful method of sludge disposal.
→ sludge is dried by spreading over the land.

→ Construction

*) ground is excavated for the required depth

*) Valleys formed for the under drains.

*) Valleys are Constructed at 3m to 5m centres.

*) Consists of two valleys.

*) Valleys filled with gravel

*) depth of gravel above drain – 250 mm to 300 mm

*) graded size – 40 mm to 6 mm.

*) depth of sand layer – 150 mm to 300 mm

*) size of sand ~ 0.3 mm to 0.5 mm.

*) Slope – 1 in 100

(35)

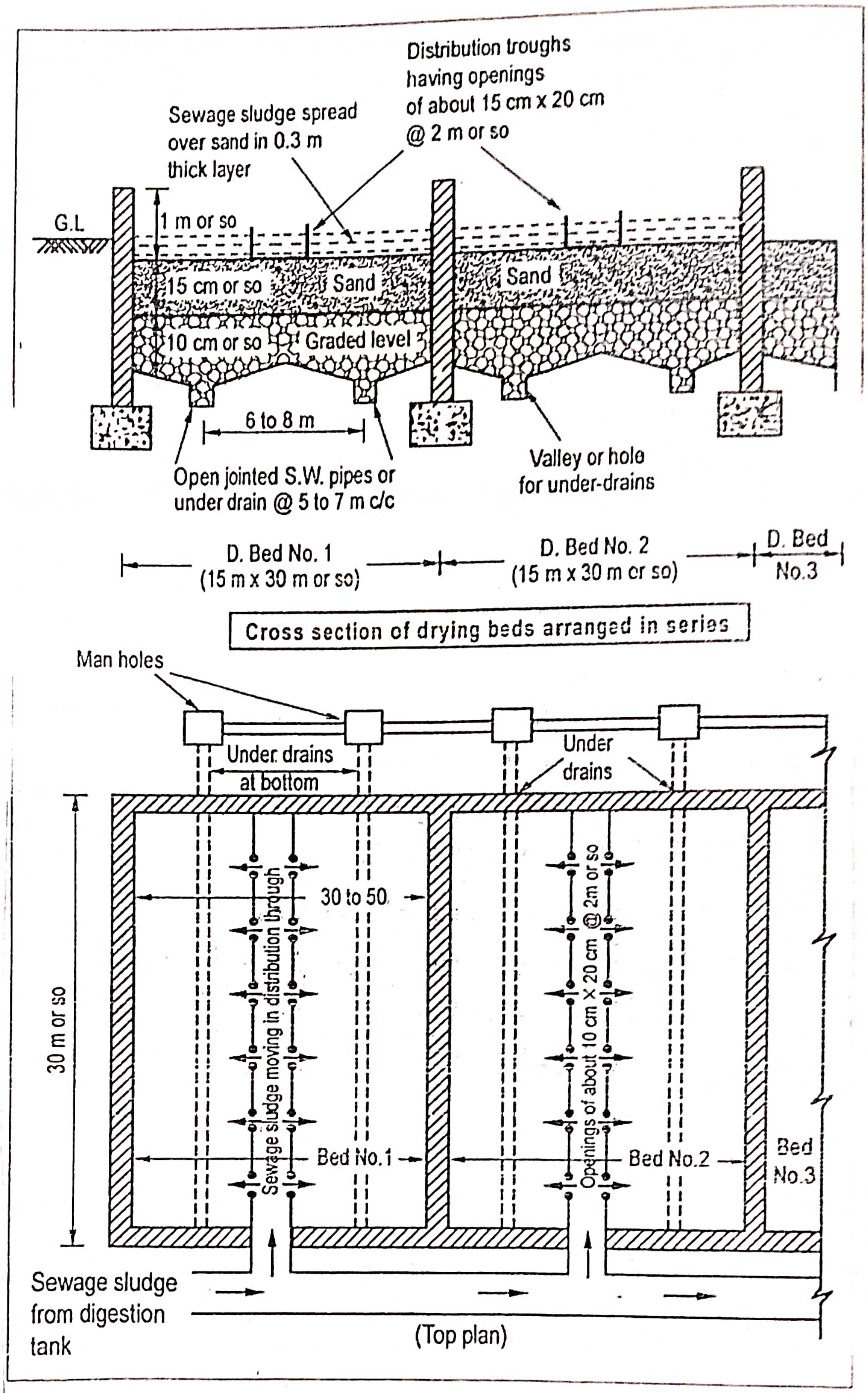


Fig. 5.11. Drying beds

→ side wall projection – 800 mm above G.L

→ minimum 4 no. of beds are provided.

→ rectangular Shape

→ length 30 m to 40 m

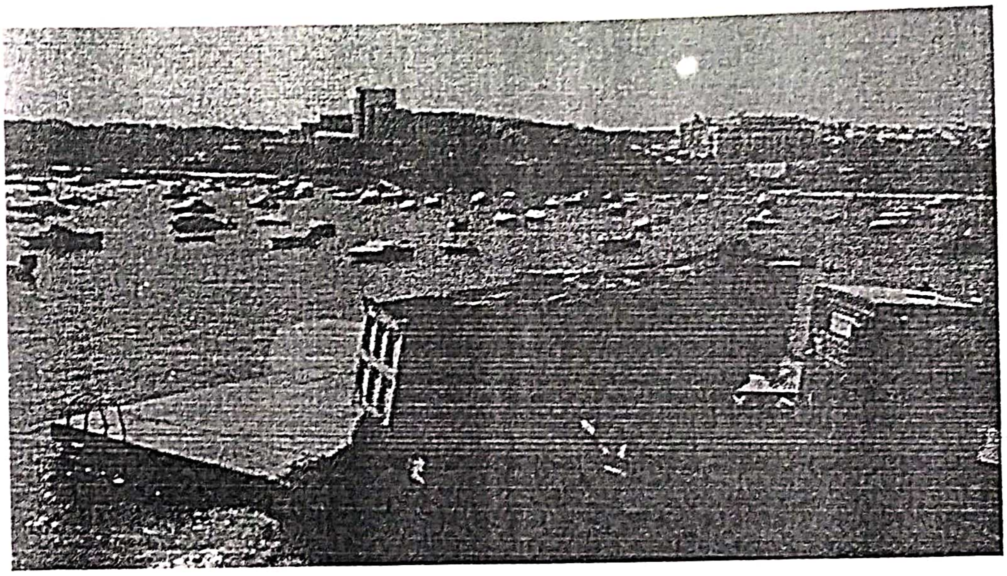
→ width 12 m to 18 m

d) Dumping into the Sea :-

→ sludge is conveyed and discharged into the sea.

→ This method is adopted nearer to the sea.

→ To avoid any possible chances of nuisance by the sludge.

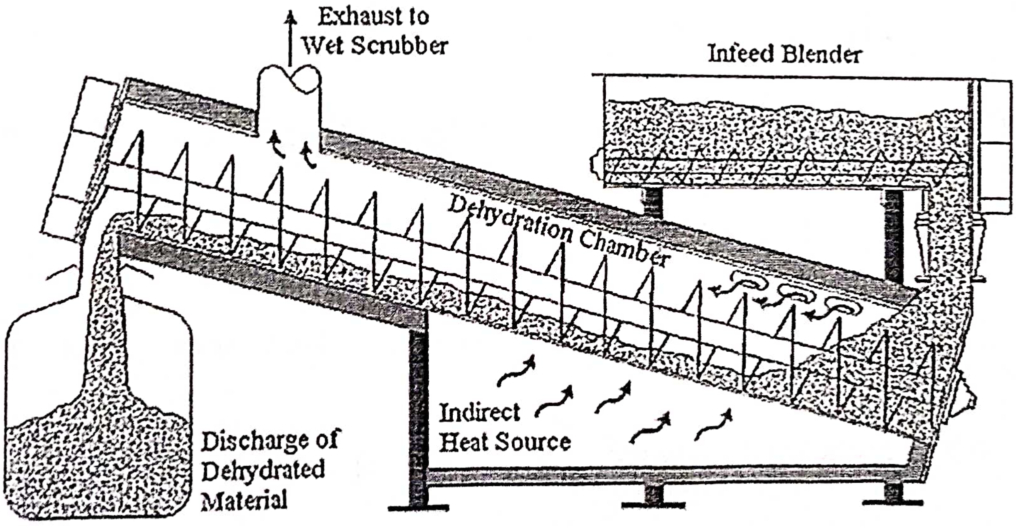


e) Heat - Drying :

→ the sludge is heated to become dry.

→ used to convert the sludge from ASP in to fertilizer directly.

→ Cost of operation is high.



37

(f) Lagooning and Ponding :-

→ lagoon - is a shallow pit formed by excavating the ground.

→ depth - 0.6 m to 1.2 m

→ At the bottom of the lagoon, layer of ashes depth 150 mm

→ Under drains 100 mm diameter. placed at distance of 3m.

→ embankments are formed from the excavated material

→ drying of sludge require 2 to 6 months,

→ lagoon may be covered with lime (or) fine soil.

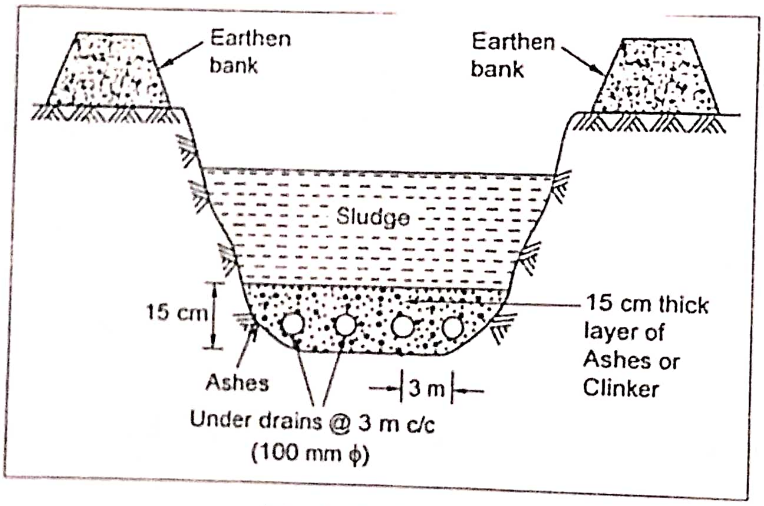


Fig. 5.12. Lagoon

(g) Disposal by filters :-

→ Consists of a series of cast-iron plates

→ Sludge is filled in cotton bags

→ the bags are placed between the plates.

→ applied pressure - 0.4 to 0.55 N/mm²

→ pressing of plates, removes the water from the sludge

→ required 45 minutes for complete cycle of filling the bags.

→ Example :

Vacaum filter.

(h) Disposal by incineration :-

→ the process of burning the sludge in incinerators at a temperature of about 760°c to 820°c.

→ types of incinerator.

(i) Multiple Hearth Furnace
(ii) Fluid Bed Furnace
(iii) Flash type Furnace
(iv) Infra-red Furnace.

(i) Multiple Hearth Furnace :-

→ Vertical structure, having a series of circular refractory hearths.

→ hearth may be numbered as 1, 2, 3, 4 from top to bottom.

→ diameter - 3 m to 7.5 m

→ No. of. unit - 6 no's

→ Wet sludge or sludge cake is fed by gravity from the top of the furnace.

→ Central shaft speed of 1 rpm to 2 rpm.

→ requires a heat of about 750°c and a dentention time of at least 0.5 sec.

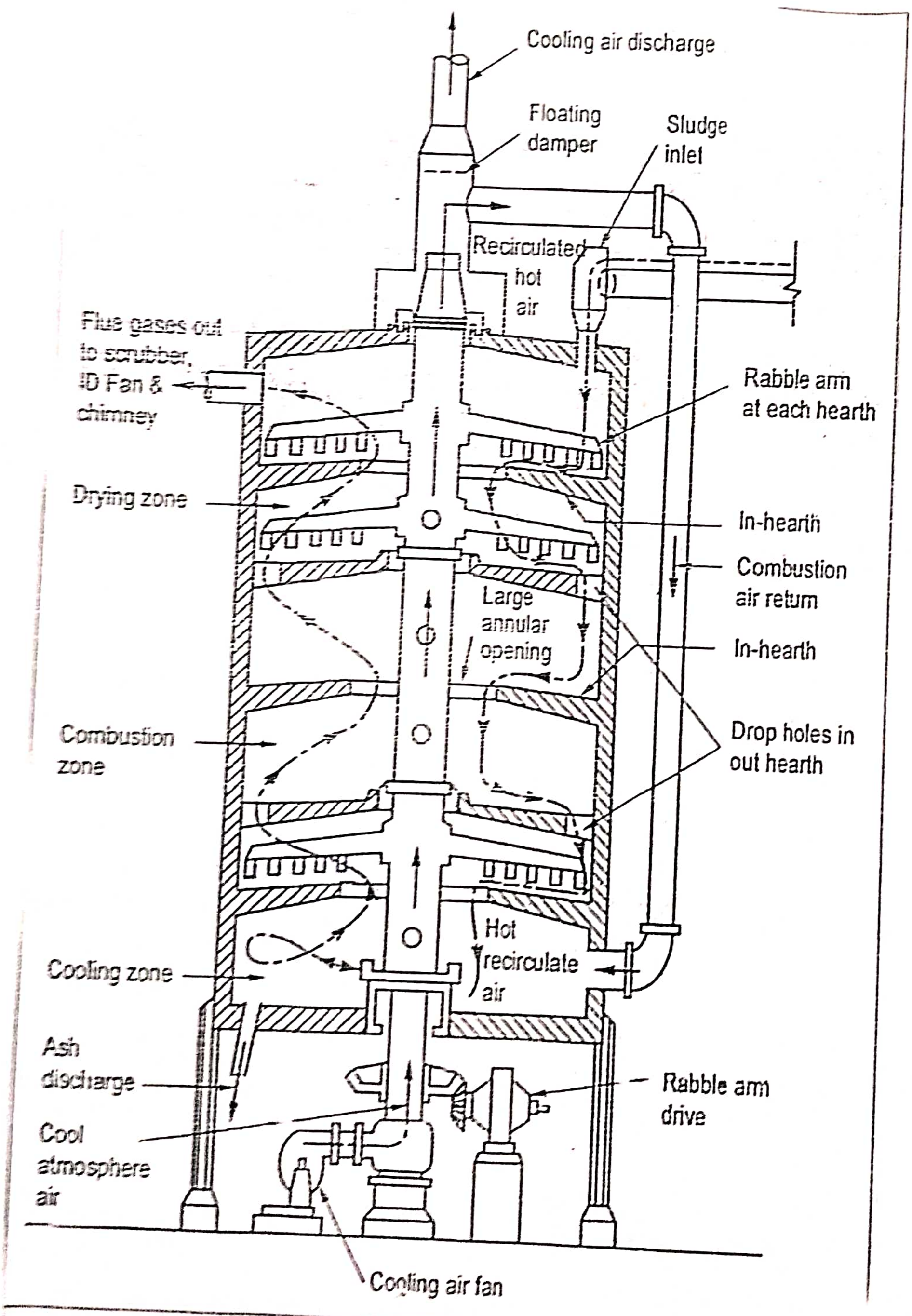


Fig. 5.13. Multiple hearth furnace

(ii) Fluid bed Furnace :-

→ Fluid bed incinerators are vertical cylindrical steel shell consists of a furnace with silicon sand in its bottom.

→ Furnace consists of series of tyres.

→ sand bed is preheated up to 700°c

→ depth - 0.6 m to 2.4 m

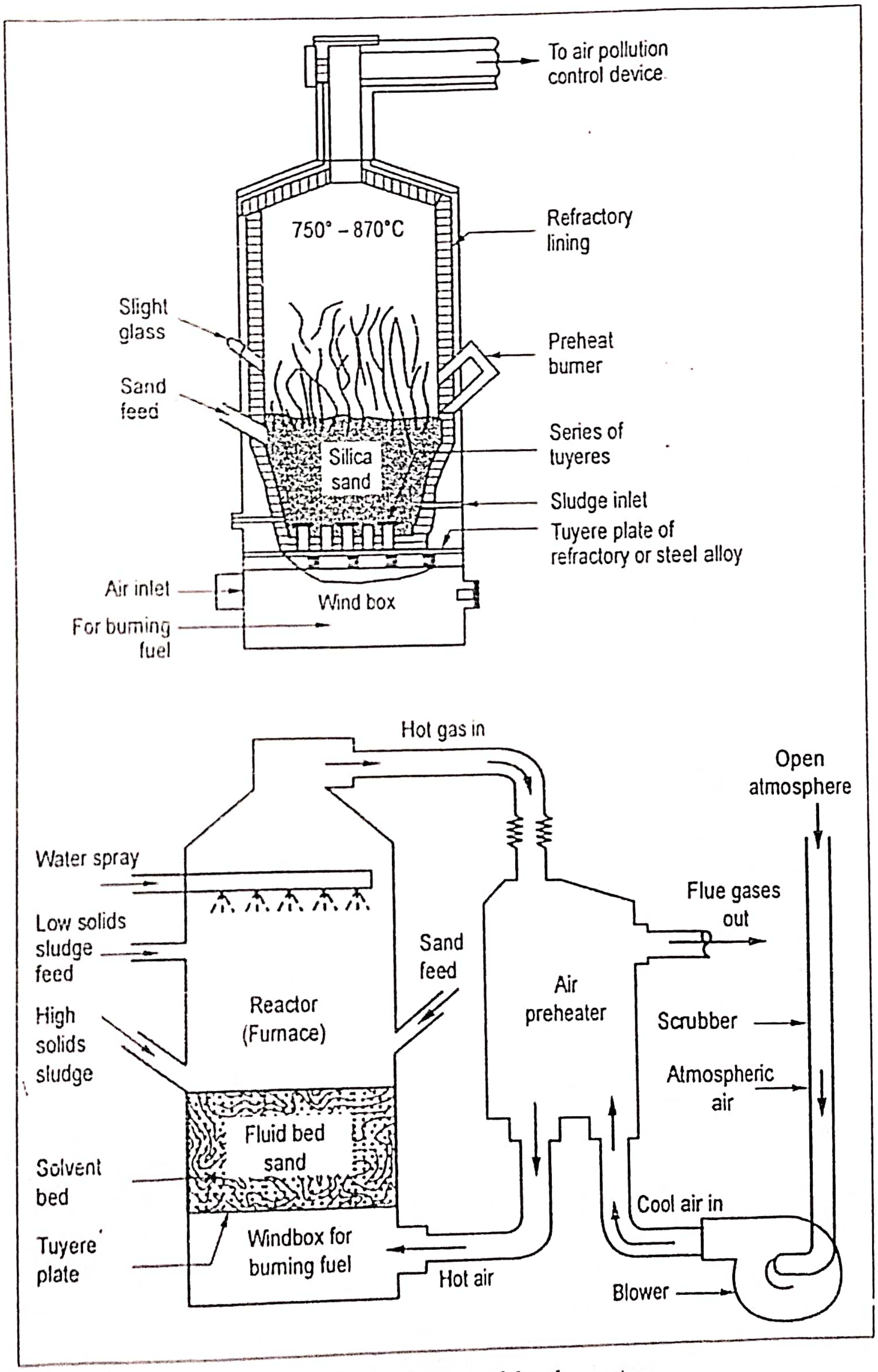


Fig. 5.14. Fluid bed incinerator

(A1)

(iii) Flash type Furnace :-

→ It's consists of a tower

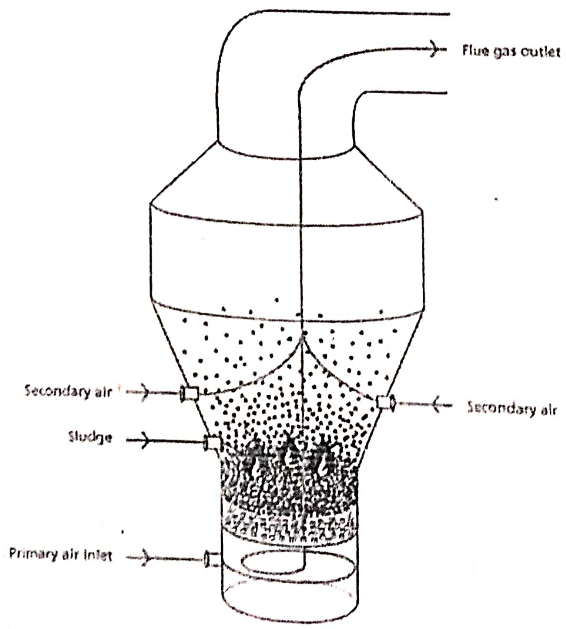
→ heated in the beginning by burning the fuel.

→ Wet sludge is passed from the top of the tower

→ Super heated gases coming from the bottom of the tower.

→ rising hot gases remove the moisture from the sludge.

→ water vapour will pass along with hot gases.



(iv) Infra-red Furnace (Incinerator)

→ This is a Conveyor belt system passing through a long refractory-lined chamber.

→ Combustion air is introduced at the discharge end of the conveyor belt.

→ Wet sludge cake is feed by gravity to the belt.

→ The belt speed and travel is selected.

→ Electrical energy or fossil fuel may be used to provide a supplemental fuel for startup of furnace.

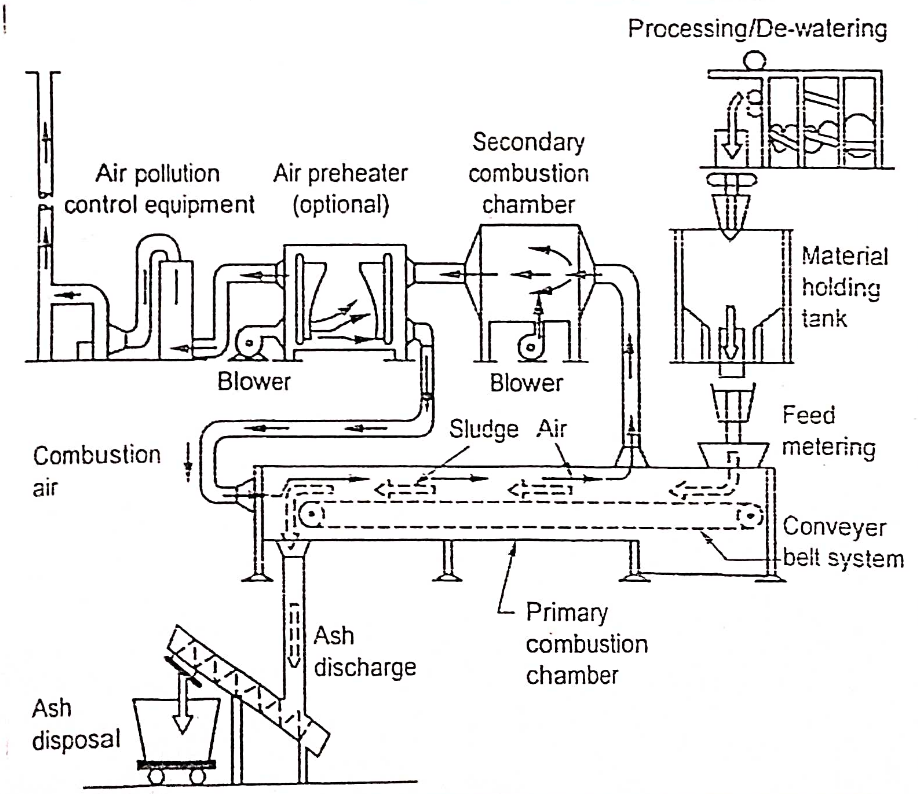


Fig. 5.15. Infra-red incineration system