Arba Minch Water Technology Institute (AWTI)

Faculty of Water Supply and Environmental Engineering

Course title: - **Wastewater & Solid Waste Management**
Course Code: - **WSEE – 3172**
Credit hr: - **4 ECTS**
Prerequisites: - **Water supply & treatment, hydraulics II**
Target Groups: **3rd year Hydraulic and Water Resource Engineering**
Academic year:-**2019/20, Sem II**

Objective:

Students will learn the basic methods for industrial and municipal wastewater treatment facilities and about the processes involved; They will learn the basic design of wastewater treatment facilities And this course also provides students general knowledge on principles of solid waste managements mainly on waste reduction, reuse of materials, and recovery of materials and energy.

Outcomes:

After completion of this course students will be able to:- understand the design procedure for wastewater treatment facilities; sludge treatment and disposal methods; and onsite sanitation systems

Course contents

Chapter 1: Introduction to sanitation and sanitary engineering

1.1. Scope of sanitary engineering,
1.2. Systems of sanitation, (Conservancy and water carriage system)
1.3. Sewage systems
1.4. Quantity of sanitary and storm sewage determination,
1.5. Hydraulic Designs of sewers,
1.6. Sewers construction, maintenance and required appurtenances

Chapter 2: Characteristics and Examination of wastewater

2.1. Physical characteristics
2.2. Chemical characteristics
2.3. Biological characteristics and Oxygen demand determination

Chapter 3: Wastewater Treatment

3.1. Wastewater treatment process (Preliminary and Primary treatment)

3.2. Biological treatment of wastewater

3.3. Tertiary treatment of wastewater (Oxidation pond and septic tank)

3.4. Wastewater effluent disposal methods

Chapter 4: Solid waste management

3.1. Solid waste sources,

3.2. Composition and characteristics,

3.3. Solid waste quantity,

3.4. Collection systems, Separation, Transportation, Transfer

3.5. Solid waste processing and resource recovery.

- **Teaching & Learning Methods:** lectures, tutorial and lab exercise
- **Assessment/Evaluation & Grading System:** Continues Assessment (3 Quizs, 2 Tests and lab report)…………………………......50%
  Final exam…………………………………..50%
  - **Attendance Requirements:-** A student must attend at least 85 % of the classes and 100% during practice

References:

1. M.N.RAO .A.K. Datta. Wastewater treatment rational methods of design and industrial practice 3rd edition
2. Metcalf Eddy Wastewater Engineering treatment and reuse 4th edition
3. Any sewer system, wastewater treatment and solid waste management related books

CHAPTER 1

1. INTRODUCTION TO SANITATION & SANITARY ENGINEERING

Sanitation: - is the hygienic means of promoting health through prevention of human contact with the hazards of wastes as well as the treatment and proper disposal of sewage wastewater.

A sanitary engineer: - in applying certain engineering principles in order to preserve public health and safety. While the areas of concern to a sanitary engineer are largely related to the proper collection and disposal of waste materials, design and construction of water &waste treatment systems.

Terms usually related with sanitation system: -

- **Sewer: -** an underground conduit for carrying off drainage water and waste matter.
- **Sewage: -** waste water and excrement conveyed in sewers.
- **Sewerage: -** the removal of waste water and refuse by means of sewers or in a system of sewers.

1.1. Systems of Sanitation

The waste products of a society including the human excreta had been collected, carried and disposed of manually to a safe point of disposal, by the sweepers, since time immemorial. This primitive method of collecting and disposing of the society's wastes has now been modernized and replaced by a system, in which these wastes are mixed with sufficient quantity of water and carried through closed conduits under the conditions of gravity flow. This mixture of water and waste products, popularly called sewage, thus automatically flows up to a place, from where it is disposed of, after giving it suitable treatments; thus avoiding the carriage of wastes on heads or carts. The treated sewage effluents may be disposed of either in a running body of water, such as a stream, or may be used for irrigating crops.

This modern water-carried sewerage system has completely replaced the old conservancy system of sanitation in the developed countries like U.S.A. However, India being a developing country, still uses the old conservancy system at various places, particularly in her villages and smaller towns. The metropolitan cities and a few bigger towns of different countries, no doubt, have generally been equipped with the facilities of this modern water carriage sewerage system.

The modern water-carried sewerage system is preferred to the old. Conservancy system, because of its following advantages:

1) The water carriage system is more hygienic, because in this system, the society's Wastes have not to be collected and carried in buckets or carts, as is required to be done in the conservancy system. The free carriage of night soil in carts or as head load, which is required in the conservancy system, may pose health hazards to The term sewerage is applied to the art of collecting, treating and finally disposing of the sewage. sweepers and other residents, because often possibilities of flies and insects transmitting disease germs from these accessible carts to the resident's foods and eatables ; whereas, in modern sewerage system, no such danger exists, because the polluted sewage is carried in closed conduits, as soon as it is produced.
2) In the conservancy system, the waste products are generally buried underground, which may sometimes pollute the city's water supplies, if the water supply pipes happen to pass through such areas or the wells happen to draw water through such areas.
3) In the conservancy system of sanitation, the entire day's human feces are collected and then disposed of in the morning once a day, thus, from this type of latrines, pungent smells may continue to pollute the surroundings for the entire day. But since in the water, carried system, the human excreta is washed away as soon as it is produced, no such bad smells are produced. Moreover, in the conservancy system of sanitation, the waste waters from bath rooms, wash basins, kitchen sinks, etc. ; is carried through open road side drains, as this is supposed to be not so foul, since it does not contain human excreta. But these road side drains are generally abused by children or adults for passing their stools, particularly at night hours, thus creating foul and more unhygienic conditions. No such problems exist in the water carriage system.
4) In water carriage system, the sewage is carried through underground pipes (popularly called sewers) which owing to their being underground, do not occupy floor area on road sides or impair the beauty of the surroundings. The road side drains carrying foul liquid in the conservancy system, will no doubt pose such problems.

5) The water-carried system may allow the construction of latrines and bath-rooms together popularly called water-closets (W.C)], thus occupying lesser space with their compact designs. This system is also very helpful for multistoried buildings, where the toilets, one above the other, can be easily constructed, and connected to a single vertical pipe.

1.2. Types and Sources of Sewage and Sewerage Systems

This modern water carriage sewerage system not only helps in removing the domestic and industrial wastewaters, but also helps in removing storm water drainage. The run off resulting from the storms is also sometimes carried through the sewers of the sewerage system, or more generally is carried through separate set of drains (open or closed) directly discharging their drainage waters into a body of water, such as a lake or a river. Since the rain run-off is not so foul as the sewage is, no treatment 'is generally required to be given to the drainage discharge. When the drainage is taken along with sewage, it is called a combined system; and when the drainage and sewage are taken independently of each other through two different sets of conduits, it is called a separate system. Sometimes, a part of drainage water, especially that originating from the roofs or paved courtyards of buildings, is allowed to be admitted into the sewers ; and similarly sometimes, the domestic sewage coming out from the residences or institutions, etc., is allowed to be admitted into the drains, the resulting system is called a partially separate system.

There are three systems of sewerage:-

1. Separate system
2. Combined system
3. Partially combined or separate system

Separate system Advantages:-

- ✓ The size of sewers are small
- ✓ Sewage load on treatment units is small
- ✓ River or stream waters are not polluted
- ✓ Storm water can be discharged into streams or rivers without any treatment
- ✓ Economical for sewage pumping since the quantity is small

Separate system Disadvantages:-

- ✓ Small sewer easily get choked and are difficult to clean
- ✓ Laying two sets of sewer is costly
- ✓ Storm water sewers are only used during rainy season

Combined system Advantages:-

- ✓ Large sewer size don't clog easily and are easy to clean
- ✓ Laying one set of sewer is economical
- ✓ The strength of sewage is reduced by dilution
- ✓ Maintenance cost is reasonable

Combined system Disadvantages:-

- ✓ Large sewers are difficult for handling and transport
- ✓ Due to storm water load the treatment plant is high
- ✓ During heavy rains sewers may overflow causing nuisance
- ✓ Pumping is uneconomical
- ✓ Storm water is unnecessarily polluted

Partially combined or separate system Advantages:-

- ✓ Small sewers sizes are required
- ✓ Has the advantages of both systems
- ✓ Silting problem is eliminated
- ✓ The problem of disposing off storm water from homes is eliminated

Partially combined or separate system Disadvantages:-

- ✓ The velocity of flow may be low during dry weather
- ✓ The storm water increases the load on pumps and treatment units

Conditions to use Separate system:-

- ✓ In flat areas
- ✓ If sufficient fund is not available currently

- ✓ If annual precipitations very small
- ✓ Nearness of a natural river or drain
- ✓ If pumping is a must
- ✓ If existing sewerage system can be used only for sanitary sewage
- ✓ Is rocky areas

Conditions to use combined system:-

- ✓ If sufficient annual rainfall is present
- ✓ If pumping is required for both
- ✓ If space is limited
- ✓ If diversion of excess flow can be provided
- ✓ If existing system can carry both sewages

1.3.DESIGN SEWAGE QUANTITY ESTIMATION

1.3.1 Estimating Dry-whether flow

The sewage discharge which has to pass through a sewer must be estimated as correctly as possible; otherwise the sewers may either prove to be inadequate, resulting in their overflow, or may prove to be of too much of size, resulting in unnecessary wasteful investments. Theoretically speaking, the quantity of sewage (i.e., domestic sewage + industrial sewage) that is likely to enter the municipal sewers under design should be equal to the quantity of water supplied to the contributing area, from the water-works. But in actual practice, this is not the precise quantity which appears as sewage, but certain additions and subtractions do take place from it, as explained below:

a) Additions due to unaccounted private water Supplies:-

The accounted water supplied to the public through the public distribution system (the records of which are easily available from the water-works office), is not necessarily the only water consumed by the public. Some private wells and tube wells may sometimes be used by the public for their domestic needs; and similarly, certain industries may utilize their own sources of water.

This extra quantity of water used by the town is generally small, unless there are large industrial private water uses. This quantity can, however, be estimated by actual field observations.

b) **Additions due to infiltration**:- Whenever, the sewer pipes are laid below the ground

Water table, certain amount of ground water generally seeps into them, through their faulty leaky joints or cracks formed in the pipes due to bad materials or poor construction. The quantity of the ground water entering these sewer pipes Depends mainly upon the height of the water-table above the sewer invert level and the nature and extent of faults and fissures present in the sewer pipes. However, if the ground water-table is well below the sewer, the infiltration can occur only after rain, when water is moving down through the soil. In that case, the infiltration quantity will depend upon the permeability of the ground soil.

c) **Subtractions due to water losses:-** The water lost, due to leakage in the distribution

System and house connections of the water supply scheme, do not reach the consumers, and hence, never appears as sewage.

d) Subtraction due to water not entering the sewerage 'system. Certain amount of water may

be used by the public and industries for such uses which may not produce any sewage at all. For example, the water used in boilers for steam generation; the del' sprinkled over the roads, streets, lawns and gardens; the water used for automobile washings; the water consumed in industrial products, such as beverages, etc., the water used in air cooling etc., does not normally produce any sewage. Quantity of Sewage Produced. The net quantity of sewage produced will be equal to the accounted quantity of water supplied plus the water-works plus the additions due to factors (**a**) and (**b**) minus the subtractions due to factors (**c**) and (**d**), described above. The net value may vary between 70 to 130 per cent of the accounted water supplied from the water-works. However this value; generally taken as equal to 75 to 80% of the accounted water supplied from the water works.

The flow of sanitary sewage alone in the absence of storms in dry season is known as dry weather flow (DWF).

Quantity = per capita sewage contributed per day x Population

Generally the peak and minimum flow of waste water or sewage is the relation of population in thousands. The peak flow is the product of peak factor with average flow and the minimum flow is the product of minimum factor with average flow;-

$$\frac{Qpeak}{Qave} = \frac{5.5}{\left(\frac{P}{1000}\right)0.18}$$

$$\frac{Qmin}{Qave} = 0.2\left(\frac{P}{1000}\right)0.16$$

Where: - P = population in thousands

Q peak= peak sewage or waste water flow

Qmin & Qave = minimum & average sewage or waste water flow respectively.

Quantity of storm sewage

Storm water runoff is that the portion of precipitation which flows over the ground during and a short time after a storm. The quantity depends on:

1. Surface drainage area (ha)
2. Intensity of the rainfall (mm/hr)
3. The condition of surface (runoff coefficient, C)

Rational Method: - This method is used to determine the storm flow. It can be applied anywhere, and runoff is related to rainfall intensity by the formulae:

Q= 0.00278CIA

Where: - “Q” is in m3/s, “I” is in mm/hr and “A” is in ha.

Design Periods: - This quantity should be worked out with due provision for the estimated requirements of the future. The future period for which a provision is made in the water supply scheme is known as the **design period**. It is suggested that the construction of sewage treatment plant may be carried out in phases with an initial design period ranging from 5 to 10 years excluding the construction period.

Design period is estimated based on the following:-

- ✓ Useful life of the component, considering obsolescence, wear, tears, etc.
- ✓ Expandability aspect.
- ✓ Anticipated rate of growth of population, including industrial, commercial developments & migration-immigration.
- ✓ Available resources.
- ✓ Performance of the system during initial period.

1.4.DESIGN OF SEWERS

1.4.1. Minimum Size

In order to reduce the risk of blockages and to simplify maintenance, trunk, branch and lateral sewers will be kept at minimum. Example case of (Addis)

- ➢ The minimum pipe diameter for the trunk sewers is ∅ 300 mm;
- ➢ The minimum pipe diameter for secondary sewers ∅ 200 mm;
- ➢ The minimum pipe diameter for lateral sewers is ∅ 150 mm;

1.4.2. Depth

In general, sewers should be sufficiently deep to receive wastewater from basements. Sewers laid within highways should have a minimum cover of 1.2 m measured from the top of the pipe barrel to the finished road surface, in order to avoid interference with other underground utility pipes and cables. Where this is not practicable, special protective measures may be required.

Sewers not laid in the highway should be laid at a sufficient depth to avoid interference with land drains and cultivation. Cover over the shallowest part of the pipeline structure of 0.9 m would normally satisfy this requirement. From practical point of the maximum depth could also be limited to avoid difficulty is excavation due to right of way problem and other unforeseen obstacles in underground. It is therefore advisable not to allow depth greater than 5m.

1.4.3. Slope

1.4.3.1. Recommended Minimum Slopes

All sewers shall be designed and constructed to give mean velocities, when flowing full, of not less than 2.0 feet per second (0.6 m/s), based on Manning's formula using an "n" value of 0.013. The following are the recommended minimum slopes which should be provided for sewers 42 inches (1050 mm) or less; however, slopes greater than these may be desirable for construction, to control sewer gases or to maintain self-cleansing velocities at all rates of flow within the design limits.

Nominal Sewer Size in mm	**Minimum Slope in m per 100m**	**Nominal Sewer Size in mm**	**Minimum Slope in m per 100m**
200 mm	0.40	250 mm	0.28
300 mm	0.22	350 mm	0.17
375 mm	0.15	400 mm	0.14
450 mm	0.12	525 mm	0.10
600 mm	0.08	675 mm	0.067
750 mm	0.058	825 mm	0.052
900 mm	0.046	975 mm	0.041
1050 mm	0.037		

Table:-1.1 recommended slopes and sewer sizes.

1.4.3.2.Minimize Solids Deposition

The pipe diameter and slope shall be selected to obtain the greatest practical velocities to minimize settling problems.

1.4.3.3.Slope between Manholes

Sewers shall be laid with uniform slope between manholes.

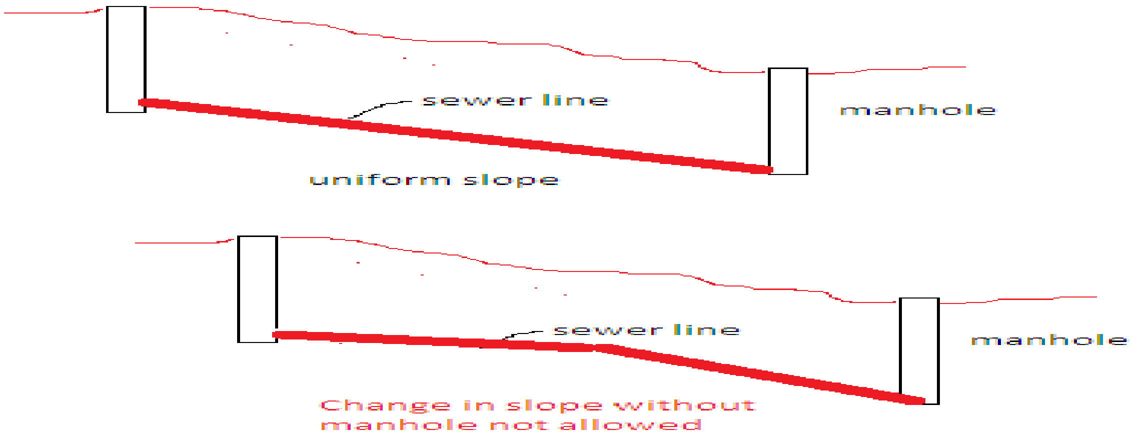


Fig:-1.1 Sewer line slopes

1.4.3.4.High Velocity Protection

The smooth interior surface of sewer pipe gets scoured due to the continuous abrasion caused by the suspended solids present in sewage. This scouring and wear and tear of the pipe interior is much more pronounced at velocities higher than what can be tolerated by the pipe materials. This wear and tear of the sewer pipes will not only reduce their life span but will also reduce their carrying capacities. In order to avoid these complications, it is therefore, necessary to limit the maximum velocity that will be produced in the sewer pipe at any time.

This limiting or non-scouring velocity will mainly depend up on the material of the sewer. The values are given below.

No.	Sewer Material	Limiting Velocity, m/s
1	Vitrified tiles and glazed bricks	4.5 - 5.5
2	Cast Iron sewers	3.5 -4.5
3	Cement Concrete Sewers	2.5 – 3.0
4	UPVC	Similar to Vitrified tiles and glazed bricks

Table:-1.2 sewer material with limiting velocity

The problem of controlling the high velocities generated in the sewers, mainly arises in hilly areas, where the available ground slopes may be very steep. In such cases, it is required to provide drop manholes to limit the design gradient.

1.4.3.5.Steep Slope Protection

Sewers on 20 percent slopes or greater shall be anchored securely with concrete, or equal, anchors spaced as follows:

- **a.** Not over 11 m centere to centere on grades 20 percent and up to 35 percent;
- **b.** Not over 7.3 m center to center on grades 35 percent and up to 50 percent; and
- **c.** Not over 4.9 m center to center on grades 50 percent and over.

1.4.4. Alignment of sewers

In general, sewers 600 mm or less shall be laid with straight alignment between manholes. Curvilinear alignment of sewers larger than 600 mm may be considered on a case by case basis provided specific pipe manufacturers' maximum allowable pipe joint deflection limits are not exceeded. Curvilinear sewers shall be limited to simple curves which start and end at manholes. When curvilinear sewers are proposed, the recommended minimum slopes must be increased accordingly to provide a minimum velocity of 0.6 m/s when flowing full.

1.4.5. Changes in Pipe Size

When a smaller sewer joins a large one, the invert of the larger sewer should be lowered sufficiently to maintain the same energy gradient. An approximate method for securing these results is to place the 0.8 depth point of both sewers at the same elevation.

1.4.6. Materials of sewers

While selecting a particular material for constructing sewer pipes, the following factors should be considered:-

- **a)** **Resistance to corrosion: -** Sewer pipes are likely to be acted upon by sewer gases, and thus get corroded, due to the presence of acids. Sewer materials should therefore, be resistant to corrosion.
- **b)** **Resistance to abrasion: -** When the sewage contains a lot of grit and sand particles, moving at a high velocity at the sewer invert, a lot of wear and tear of the sewer material may be caused due to abrasion. So the pipe must be strong enough to withstand such abrasions.
- **c)** **Strength and durability: -** Since pipes are generally laid below ground level, they are subject to considerable external loads. Therefore, sufficient thickness of the pipe wall or reinforcement must be provided.
- **d)** **Light weight: -** The materials should be light so that the sewers can be easily handled and transported.
- **e)** **Cost:** Cost of the pipes should be taken in to consideration in selection of pipe materials.

f) **Imperviousness: -** the sewer material should be impervious not to allow any seepage of the sewage.

g) **Hydraulically efficient: -** The sewer material should be smooth to provide hydraulically smooth surface.

Any generally accepted material for sewers will be given consideration, but the material selected should be adapted to local conditions, such as: character of industrial wastes, possibility of scepticism, soil characteristics, exceptionally heavy external loadings, abrasion, corrosion, and similar problems.

All sewers shall be designed to prevent damage from superimposed live, dead, and frost induced loads. Proper allowance for loads on the sewer shall be made because of soil and potential groundwater conditions, as well as the width and depth of trench. Where necessary, special bedding, and concrete protections shall be provided.

1.4.7. Installation of sewers

1.4.7.1.Trenching

a) The width of the trench shall be ample to allow the pipe to be laid and jointed properly and to allow the bedding and hatching to be placed and compacted to adequately support the pipe. The trench sides shall be kept as nearly vertical as possible. When wider trenches are specified, appropriate bedding class and pipe strength shall be used.

b) In unsupported, unstable soil the size and stiffness of the pipe, stiffness of the embedment and in-situ soil and depth of cover shall be considered in determining the minimum trench width necessary to adequately support the pipe.

c) Ledge rock, boulders, and large stones shall be removed to provide a minimum clearance of 4 inches (100 mm) below and on each side of all pipe(s).

1.4.7.2.Bedding, Hatching, and Initial Backfill

a. There are different bedding conditions depending on the pipe material to be laid and the soil material and ground water conditions. Width of the trench shall allow proper working condition.

b. If sewer pipes are laid well below ground, 4.2 to 6m deep below ground, they should be hatched. The full width of the bed is carried up to the level of the horizontal diameter of the pipe and then splays from this level are carried up from both sides of the pipe and finished tangentially at the top of the pipe.

c. Initial backfilling: Filling of the trench should not be done until it is tested and approved. When the pipes are not protected by concrete the first operation shall be to hand pack and tamp the selected fine material around the lower half of the pipe so as to buttress them to the sides of the trench

1.4.7.3.Final Backfill

- Final backfill shall be of a suitable material removed from excavation except where other material is specified. Debris, frozen material, large clods or stones, organic matter, or other unstable materials shall not be used for final backfill within 0.6 m of the top of the pipe.
- Final backfill shall be placed in such a manner as not to disturb the alignment of the pipe.

1.4.7.4.Test for obstruction and straightness

- By inserting at the higher end of the sewer a smooth ball of diameter 13mm less than the pipe bore. If there is no obstruction inside the pipe, the ball would roll down the invert of the pipe and emerge at the lower end.
- By means of a mirror at one end of the pipe and lamp at the other. If the pipe line is straight, the full circle of light shall be observed on the mirror.

1.4.8. Joints and Infiltration

1.4.8.1.Joints

The installation of joints and the materials used shall be included in the specifications. Sewer joints shall be designed to minimize infiltration and to prevent the entrance of roots throughout the life of the system.

1.4.8.2.Service Connections

Service connections to the sewer main shall be water tight and not protrude into the sewer. If a saddle type connection is used, it shall be a device designed to join with the types of pipe which are to be connected. All materials used to make service connections shall be compatible with each other and with the pipe materials to be joined and shall be corrosion proof.

1.4.8.3.Leakage Tests

Leakage tests shall be specified. This may include appropriate water or low pressure air testing. The testing methods selected should take into consideration the range in groundwater elevations during the test and anticipated during the design life of the sewer.

1.5.Sewer Appurtenances

Sewer appurtenances are the various accessories on the sewerage system and are necessary for the efficient operation of the system.

- Manhole
- Drop Manhole
- Flushing Tank
- Lamp hole
- Inverted Siphon
- Storm Water Inlets /Street Inlets
- Cover and Frames
- Catch Basin

1.6.MANHOLES

A manhole is an opening on the sewer line through which man can enter and make necessary inspection and repairs. They also serve for ventilation of the sewer lines. The other purpose of manholes is to join sewer lines coming from different directions. The manholes can be rectangular or circular in shape. The minimum dimension for shallow depth less than 1.5m is 1.2m x 0.9 m for rectangular ones and 1.0- 1.2m for circular manholes.

1.6.1. Types of Manhole

- **Junction chambers:-** constructed at the intersection of two large sewers
- **Drop man-hole:-** constructed in elevation difference
- **Flushing man-holes:-** located at the head of a sewer to flush out the deposits
- **Lamp-holes:-** constructed on the straight sewer lines between two man-holes far apart
- **Street inlets:-** openings through which storm water is admitted
- **Catch Basins:-** constructed below the street inlets
- **Inverted siphons: -** are depressed portions of sewers which flow full under pressure more than the atmospheric pressure due to flow line being below the hydraulic grade line.

1.6.2. Location

Manholes shall be installed: at the end of each line; at all changes in grade, size, or alignment; at all intersections; and at distances not exceeding certain limit.

1.6.3. Drop Type

A drop pipe shall be provided for a sewer entering a manhole at an elevation of 600 mm or more above the manhole invert. Where the difference in elevation between the incoming sewer and the manhole invert is less than 600 mm, the invert shall be filleted to prevent solids deposition.

The main purpose of the drop manholes is the steep gradients which otherwise would have to be given to the branch sewer will be avoided, thus avoiding a lot of earth work excavation.

The sewage trickling into the manhole from directly placed branch sewer is likely to fall on persons working in the manhole.

- Drop manholes should be constructed with an outside drop connection. Inside drop connections (when necessary) shall be secured to the interior wall of the manhole and provide access for cleaning.
- Due to the unequal earth pressures that would result from the backfilling operation in the vicinity of the manhole, the entire outside drop connection shall be encased in concrete.

1.6.4. Diameter

The minimum diameter of manholes shall be 48 inches (1200 mm); larger diameters are preferable for large diameter sewers. A minimum access diameter of 24 inches (610 mm) shall be provided.

1.6.5. Flow Channel

The flow channel straight through a manhole should be made to conform as closely as possible in shape, and slope to that of the connecting sewers. The channel walls should be formed or shaped to the full height of the crown of the outlet sewer in such a manner to not obstruct maintenance, inspection or flow in the sewers.

1.6.6. Bench

A bench shall be provided on each side of any manhole channel when the pipe diameter(s) are less than the manhole diameter. The bench should be sloped no less than ½ inch per foot (40 mm/m) (4 percent). No lateral sewer, service connection, or drop manhole pipe shall discharge onto the surface of the bench.

1.6.7. Water tightness

Manholes shall be of the pre-cast concrete or poured-in-place concrete type. Inlet and outlet pipes shall be joined to the manhole with a flexible watertight connection or any watertight connection arrangement that allows differential settlement of the pipe and manhole wall to take place.

Watertight manhole covers are to be used wherever the manhole tops may be flooded by street runoff or high water. Locked manhole covers may be desirable in isolated easement locations or where vandalism may be a problem.

1.7.INVERTED SIPHONS

Inverted siphons shall have not less than two barrels, with a minimum pipe size of 6 inches (150 mm). They shall be provided with necessary appurtenances for maintenance, convenient flushing, and cleaning equipment. The inlet and discharge structures shall have adequate clearances for cleaning equipment, inspection, and flushing. Design shall provide sufficient head and appropriate pipe sizes to secure velocities of at least 3.0 feet per second (0.9 m/s) for design average flows. The inlet and outlet details shall be so arranged that the design average flow is diverted to one barrel, and so that either barrel may be cut out of service for cleaning. The vertical alignment should permit cleaning and maintenance.

1.8.SEWERS IN RELATION TO STREAMS

1.8.1. Location of Sewers in Streams

1.8.1.1. Cover Depth

The top of all sewers entering or crossing streams shall be at a sufficient depth below the natural bottom of the stream bed to protect the sewer line. In general, the following cover requirements must be met:

a) One foot (0.3 m) of cover where the sewer is located in rock;
b) Three feet (0.9 m) of cover in other material. In major streams, more than 3 feet (0.9 m) of cover may be required; and
c) In paved stream channels, the top of the sewer line should be placed below the bottom of the channel pavement.

Less cover may be approved only if the proposed sewer crossing will not interfere with future modifications to the stream channel. Justification for requesting less cover shall be provided to the reviewing authority.

1.8.1.2. Horizontal Location

Sewers located along streams shall be located outside of the stream bed and sufficiently removed there from to provide for future possible stream widening and to prevent pollution by siltation during construction.

1.8.1.3. Structures

The sewer outfalls, headwalls, manholes, gate boxes, or other structures shall be located so they do not interfere with the free discharge of flood flows of the stream.

1.8.1.4. Alignment

Sewers crossing streams should be designed to cross the stream as nearly perpendicular to the stream flow as possible and shall be free from change in grade. Sewer systems shall be designed to minimize the number of stream crossings.

1.8.2. Construction of sewers

1.8.2.1. Materials

Sewers entering or crossing streams shall be constructed of ductile iron pipe with mechanical joints; otherwise they shall be constructed so they will remain watertight and free from changes in alignment or grade. Material used to backfill the trench shall be stone, coarse aggregate, washed gravel, or other materials which will not readily erode, cause siltation, damage pipe during placement, or corrode the pipe.

1.8.2.2.Siltation and Erosion

Construction methods that will minimize siltation and erosion shall be employed. The design engineer shall include in the project specifications the method(s) to be employed in the construction of sewers in or near streams. Such methods shall provide adequate control of siltation and erosion by limiting unnecessary excavation, disturbing or uprooting trees and vegetation, dumping of soil or debris, or pumping silt-laden water into the stream. Specifications shall require that cleanup, grading, seeding, and planting or restoration of all work areas shall begin immediately. Exposed areas shall not remain unprotected for more than seven days.

1.9.PROTECTION OF WATER SUPPLIES

When wastewater sewers are proposed in the vicinity of any water supply facilities, requirements of the GLUMRB "Recommended Standards for Water Works" should be used to confirm acceptable isolation distances in addition to the following requirements.

1.9.1. Cross Connections Prohibited

There shall be no physical connections between a public or private potable water supply system and a sewer, or appurtenance thereto which would permit the passage of any wastewater or polluted water into the potable supply. No water pipe shall pass through or come into contact with any part of a sewer manhole.

1.9.2. Relation to Water Works Structures

While no general statement can be made to cover all conditions, it is generally recognized that sewers shall meet the requirements of the appropriate reviewing agency with respect to minimum distances from public water supply wells or other water supply sources and structures.

All existing waterworks units, such as basins, wells, or other treatment units, within 200 feet (60 m) of the proposed sewer shall be shown on the engineering plans.

Soil conditions in the vicinity of the proposed sewer within 200 feet (60 m) of waterworks units shall be determined and shown on the engineering plans.

1.9.3. Relation to Water Mains

1.9.3.1. Horizontal and Vertical Separation

Sewers shall be laid at least 10 feet (3 m) horizontally from any existing or proposed water main. The distance shall be measured edge to edge. For gravity sewers where it is not practical to maintain a 10 foot (3 m) separation, the appropriate reviewing agency may allow deviation on a case-by-case basis, if supported by data from the design engineer. Such deviation may allow installation of the gravity sewer closer to a water main, provided that the water main is in a separate trench or on an undisturbed earth shelf located on one side of the gravity sewer and at an elevation so the bottom of the water main is at least 18 inches (460 mm) above the top of the sewer.

If it is impossible to obtain proper horizontal and vertical separation as described above for gravity sewers, both the water main and gravity sewer must be constructed of slip-on or mechanical joint pipe complying with public water supply design standards of the agency and be pressure tested to 150 psi (1034 kPa) to assure water tightness.

1.9.3.2. Crossings

Sewers crossing water mains shall be laid to provide a minimum vertical distance of 18 inches (460 mm) between the outside of the water main and the outside of the sewer. This shall be the case where the water main is either above or below the sewer. The crossing shall be arranged so that the sewer joints will be equidistant and as far as possible from the water main joints. Where a water main crosses under a sewer, adequate structural support shall be provided for the sewer to maintain line and grade.

When it is impossible to obtain proper horizontal and vertical separation as stipulated above, one of the following methods must be specified:-

a) The sewer shall be designed and constructed equal to water pipe, and shall be pressure tested at 150 psi (1034 kPa) to assure water tightness.
b) Either the water main or the sewer line may be encased in a watertight carrier pipe which extends 10 feet (3 m) on both sides of the crossing, measured perpendicular to the water main. The carrier pipe shall be of materials approved by the regulatory agency for use in water main construction.

1.10. Maintenance and Ventilation of Sewers

1.10.1. Maintenance of Sewers

Sewer maintenance generally involves their cleaning to keep them free from any clogging and to carry out the repairs to the damaged portions if any, so as to prolong their life and to ensure efficient functioning.

The proper maintenance of sewers is therefore absolutely necessary sewer maintenance generally includes:-

- ✓ Their frequent inspection and supervision,
- ✓ Measuring the rate of flow,
- ✓ Cleaning and flushing,
- ✓ Rap airing the leaking joints or any other damaged portions
- ✓ Protecting them against their misuse, preventing explosions, etc.

The most general complaint received in respect of their inefficient functioning is their clogging. The sewers get blocked or clogged due to silting and deposition of debris, grit and other floating matter present in the sewage. Although, the sewers are generally designed to flow with a self cleansing velocity, yet some silting may take place. This silting is more pronounced at low discharges, and in sewers laid on flatter gradients.

Greasy and oily matters from kitchens of hotels and restaurants or from such industries, further aid in clogging, because such matters stick to the interior of the sewer pipes and further catch the floating matter. Oil and grease traps should, therefore, be constructed at the sources of such oil and greasy sewage, and also along the sewer line. Many a times, the general public also throwaway their domestic wastes, and garbage etc. into the manholes, which may find its way into the sewers, thus increasing the chances of their deposition and consequent blockage of the sewer pipes. To avoid this, public opinion should be raised against such habits, and garbage dumping homes be made at frequent places, which should regularly be cleaned 'by municipal sweepers. In spite of all precautions taken to avoid their silting, sewers do silt, and, therefore, require frequent cleaning.

1.10.2. Ventilation of Sewers

The sewers must be properly ventilated for the following reasons:-

1) The decomposition and putrefaction of sewage inside the sewers may result in the

Production of various sewer gases, such as, carbon dioxide, carbon monoxide, methane hydrogen sulphide, ammonia, nitrogen, etc. These gases are disposed of into the atmosphere by exposing the sewage to the outside atmosphere by suitable methods of ventilation. These gases, if not removed, may cause serious problems, and prove hazardous to the workers entering the sewers. Methane gas being highly explosive, if not removed, may even blow off the manhole covers. Moreover, these gases have a tendency to interfere with the flow of sewage.

2) Another reason for ventilating sewers is to ensure a continuous flow of sewage inside the sewer. This is achieved by ventilation by keeping the surface of sewage in contact with free air and /thus preventing the formation of air-locks in the sewage. Methods of Ventilation Following methods are adopted for ventilating the sewers:

- ❖ Use of Ventilating Columns. In order to achieve proper ventilation, ventilating columns or shafts are generally placed at intervals of 150 to 300 m along the sewer
- ❖ Use of Ventilating Manhole Covers. The manhole covers are sometimes provided with perforations, through which the sewer gets exposed to the atmosphere. This will no doubt help in achieving some ventilation, but will cause

more nuisance, as the bad smells continue to erupt from them. Moreover, the openings of the manhole cover will permit admitting large quantities of storm water and other road dust, etc. This method is, therefore, of no practical utility, except that it may be adopted in very isolated places.

3) Proper Design of Sewers. The sewers should be properly designed as running half or two third full, thus reserving the top space for the sewer gases. Moreover, the velocity in the sewer should be self-cleansing so that sewage does not stay at one point for longer periods. The proper design of sewers ensures enough ventilation.

4) Unobstructed Outlets. In the case of storm water drains or sewers, they can also act as partial ventilators.

Chapter 2

2. Characteristics and Examination of sewage

2.1. Physical characteristics of sewage

The physical characteristics of wastewater include those items that can be detected using the physical senses. They are temperature, color, odor, solids, and turbidity.

a) Temperature

Temperature of wastewater varies greatly, depending upon the type of operations being conducted at your installation. Temperature of sewage the sewage is slightly more than that of water, because of the presence of industrial sewage. The temperature changes when sewage becomes septic because of chemical process. The lower temperature indicates the entrance of ground water into the sewage.

b) Color

Of fresh sewage is yellowish grey to light brown. While that of the septic is black or dark due to oxidation of organic matter.

c) Odor

Smell of the fresh sewage is oily or soapy while the septic sewage develops an objectionable. It smells as rotten egg odor and the major source of pollution is H_2S.

d) Solids

All matter except the water contained in liquid materials is classed as solid matter. The usual definition of solids, however refers to; "the matter that remain as residual upon evaporation and drying at 103 ± 20C".Those solids that are not dissolved in wastewater are called suspended solids. When suspended solids float, they are called floatable solids or scum. Those suspended solids that settle are called settle able solids, grit, or sludge.

All solids that burn or evaporate at 500°C to 600°C are called volatile solids. These solids serve as a food source for bacteria and other living forms in a wastewater treatment plant. Most organic solids in municipal waste originate from living plants or animals.

Those solids that do not burn or evaporate at 500°C to 600°C, but remain as a residue, are called fixed solids. Fixed solids are usually inorganic in nature and may be composed of grit, clay, salts, and metals.

e) Turbidity

The term "turbid" is applied to water or wastewater containing suspended matter or in which the visual depth is restricted.

2.2. Chemical Characteristics of Sewage (Wastewater)

Sewage contains both organic and inorganic chemicals in addition to various gases like H_2S, CO_2, CH_4, and NH_3… etc that are formed due to the decomposition of sewage. The chemical characteristics of wastewater of special concern are pH, DO (dissolved oxygen), oxygen demand, nutrients, and toxic substances.

a) PH

PH is used to describe the acid or base properties of water solutions. The pH of sewage is initially high and drops when the sewage becomes septic but becomes increases again with the treatment processes.

b) Dissolved oxygen (DO)

Wastewater that has DO is called aerobic or fresh. The solubility of oxygen in fresh water ranges from 14.6 mg/L at 0ºC to about 0.7 mg/L at 35ºC at 1.0 atmospheric pressure.

c) Oxygen Demand

It is the amount of oxygen used by bacteria and other wastewater organisms as they feed upon the organic solids in the wastewater.

d) Biochemical oxygen Demand (BOD)

The specifics of the analysis are discussed in detail in Standard Methods for the Examination of Water and Wastewater. The BOD test is one of the most basic tests used in the wastewater field. It is essentially a measure of the biological and the chemical component of the waste in terms of the dissolved oxygen needed by the natural aerobic biological systems in the wastewater to break down the waste under defined conditions. Generally the BOD test is carried out by determining the dissolved oxygen on the wastewater or a diluted mixture at the beginning of the test period, incubating the wastewater mixture at 20°C, and determining the dissolved oxygen at the end of 5 days which is given by the unit of mg/l. The difference in dissolved oxygen between the initial measurement and the fifth day measurement represents the biochemical oxygen demand. The BOD of domestic sewage usually will vary from 100 to 300 mg/1.

BOD5 = BOD intial – BOD after 5 days

Std.BOD5 = (Std. BOD5 of domestic sewage per person per day) x (population equivalent)

BOD is defined as the amount of oxygen required by the bacteria while stabilizing decomposable organic matter under aerobic condition. It is written as by BOD or $BOD_5 20$. “It is the amount of oxygen required by aerobic bacteria to decompose or stabilized the organic matter at a standard temperature of 20ºC for a period of 5 days”. For domestic sewage 5 days BOD represents approx. 2/3 times of demand for complete decomposition.

e) Chemical oxygen Demand (COD)

By definition the COD is the amount of oxygen required to stabilized the organic matter chemically, i.e. the COD is used as a measure of the oxygen equivalent of the organic matter contents of a sample that is susceptible to oxidation by a strong chemical oxidant. COD is other means of measuring the pollution strength of a wastewater. Typical COD values for domestic wastewater range from 200 to 500 mg/l.

f) Toxic substances

Most industrial use various types of toxic chemicals, the discharges of which can be harmful to wastewater treatment processes.

2.3. Biological Characteristics of Wastewater

Sewage consists of vast quantities of bacteria, most of which are harmless to man. However, pathogenic (disease-causing) organisms such as typhoid, dysentery, and other intestinal disorders may be present in wastewater. The bacteria in raw sewage may be expected to in the range from 500, 000 to 5,000,000 per ml. These bacteria are responsible for the decomposition of complex compounds to stable compounds with the help of some extracellular and intracellular enzymes. Depending upon the mode of action of bacteria may be divided into the following three categories;-

- ✓ Aerobic Bacteria
- ✓ Anaerobic Bacteria
- ✓ Facultative Bacteria

2.4.Sewage disposal methods

Sewage disposal methods are of two types:-

1. Dry or conservatory system: - transporting sewage wastes by using manually or trucks, carts. Generally it is an old system of sewage transportation and it is not more preferable.
2. Water carriage system (99.9%):- transporting sewage wastes by using water as transport media. It is modern system of sewage disposing and it is more preferable now a days.

Chapter 3

WASTEWATER TREATMENT

3.1. PRELIMINARY AND PRIMARY WASTEWATER TREATMENT METHODS

3.1.1. Preliminary Treatment

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

- ✓ Screening for removing floating papers, rags, clothes, etc
- ✓ Grit chambers or Detritus tanks for removing grit and sand; and
- ✓ Skimming tanks for removing oils and greases

3.1.1.1. Screening

Screening is the very first operation carried out at a sewage treatment plant, and consists of passing the sewage through different types of screens, so as to trap and remove the floating matter, such as pieces of cloth, paper, wood, cork, hair, fiber, kitchen refuse, fecal solids, etc. present in sewage. These floating materials, if not removed, will choke the pipes, or adversely affect the working of the sewage pumps. Thus, the main idea of providing screens is to protect the pumps and other equipments from the possible damages due to the floating matter of the sewage. Screens should preferably be placed before the grit chambers (described in the next article). However, if the quality of 'grit' is not of much importance, as in the case of land fillings, etc., screens may even be placed after the grit chambers. They may sometimes be accommodated in the body of the grit chambers themselves.

1. **Types of Screens, their Designs and Cleaning**

Depending upon the size of the openings, screens may be classified as coarse screens, medium screens, and fine screens.

(i) Coarse screens are also known as Racks, and the spacing between the bars (i.e. opening size) is about 50 mm or more. These screens do help in removing large floating objects from sewage. They will collect about 6 liters of solids per million liter of sewage. The material separated by coarse screens, usually consists of rags, wood, paper, etc., which will not putrefy, and may be disposed of by incineration, burial, or dumping.

(ii) In medium screens, the spacing between bars is about 6 to 40 mm. These screens will ordinarily collect 30 to 90 liters of material per million liter of sewage.

The screenings usually contain some quantity of organic material, which may putrefy and become offensive, and must, therefore, be disposed of by incineration, or burial (not by dumping).

Rectangular shaped course and medium screens are now-a-days widely used at sewage treatment plants. They are made of steel bars, fixed parallel to one another at desired spacing on a rectangular steel frame, and are called bar screens. The screens are set in a masonry or R.C.C. chamber, called the screen chamber.

Now-a-days, these screens are generally kept inclined at about 30 to 60° to the direction of flow, so as to increase the opening area and to reduce the flow velocity; and thus making the screening more effective. While designing the screens, clear openings should have sufficient total area, so that the velocity through them is not more than 0.8 to 1m/sec. This limit placed on velocity limits the head loss through the screens, and, thus, reduces the opportunity for screenings to be pushed through the screens.

The material collected on bar screens can be removed either manually or mechanically. Manual cleaning is practiced at small plants with hand operated rakes. The inclined screens help in their cleaning by the upward stroke of the rake. Large plants, however, use mechanically operated rakes, which move over the screens, either continuously or intermittently. The cleaning of screens by rakes will be hindered by cross bars, if at all provided. They are, therefore, generally avoided. Screens are sometimes classified as fixed or movable, depending upon whether the screens are stationary or capable of motion.

Fixed screens are permanently set in position. A most commonly used bar type screen is shownin Figure 3-1.

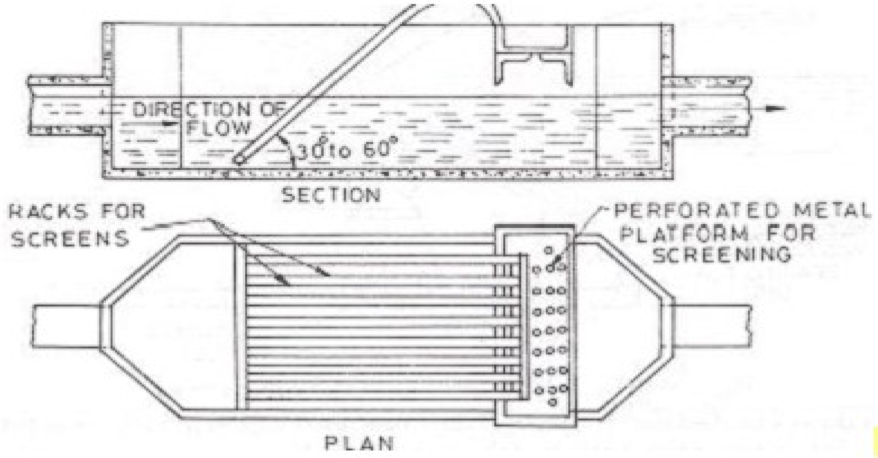


Figure 3-1 Fixed bar type coarse or medium screen

Movable screens are stationary during their operating periods. But they can be lifted up bodily

and removed from their positions for the purpose of cleaning. A common movable bar medium screen is a 3-sided cage with a bottom of perforated plates. It is mainly used in deep pits ahead of pumps.

(iii) Fine Screens have perforations of 1.5 mm to 3 mm in size.

The installation of these screens proves very effective, and they remove as much as 20% of the suspended solids from sewage. These screens, however, get clogged very often, and need frequent cleaning. They are, therefore, used only for treating the industrial wastewaters, or for treating those municipal wastewaters, which are associated with heavy amounts of industrial wastewaters. These screens will considerably reduce the load on further treatment units. Brass or Bronze plates or wire meshes are generally used for constructing fine screens. The metal used should be resistant to rust and corrosion the fine screens may be disc or drum type, and are operated continuously by electric motors.

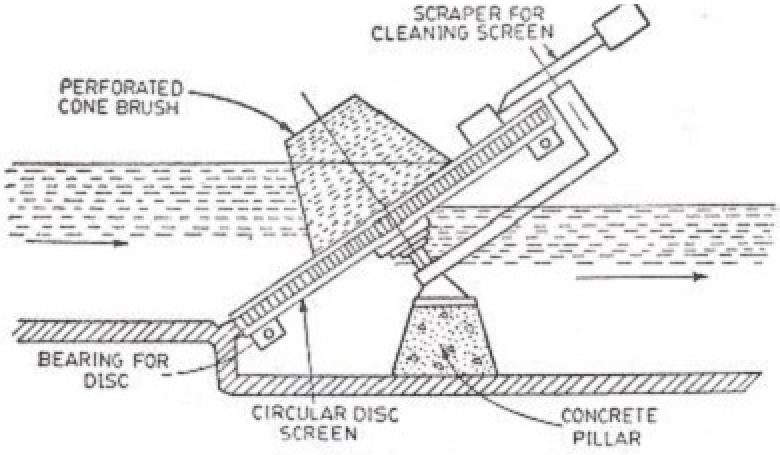


Figure 3-2 Reinsch-Wurl screen (disc type fine screen)

Generally, the preliminary and primary waste water treatment process are shown in the following flow chart. It is in more simplified form

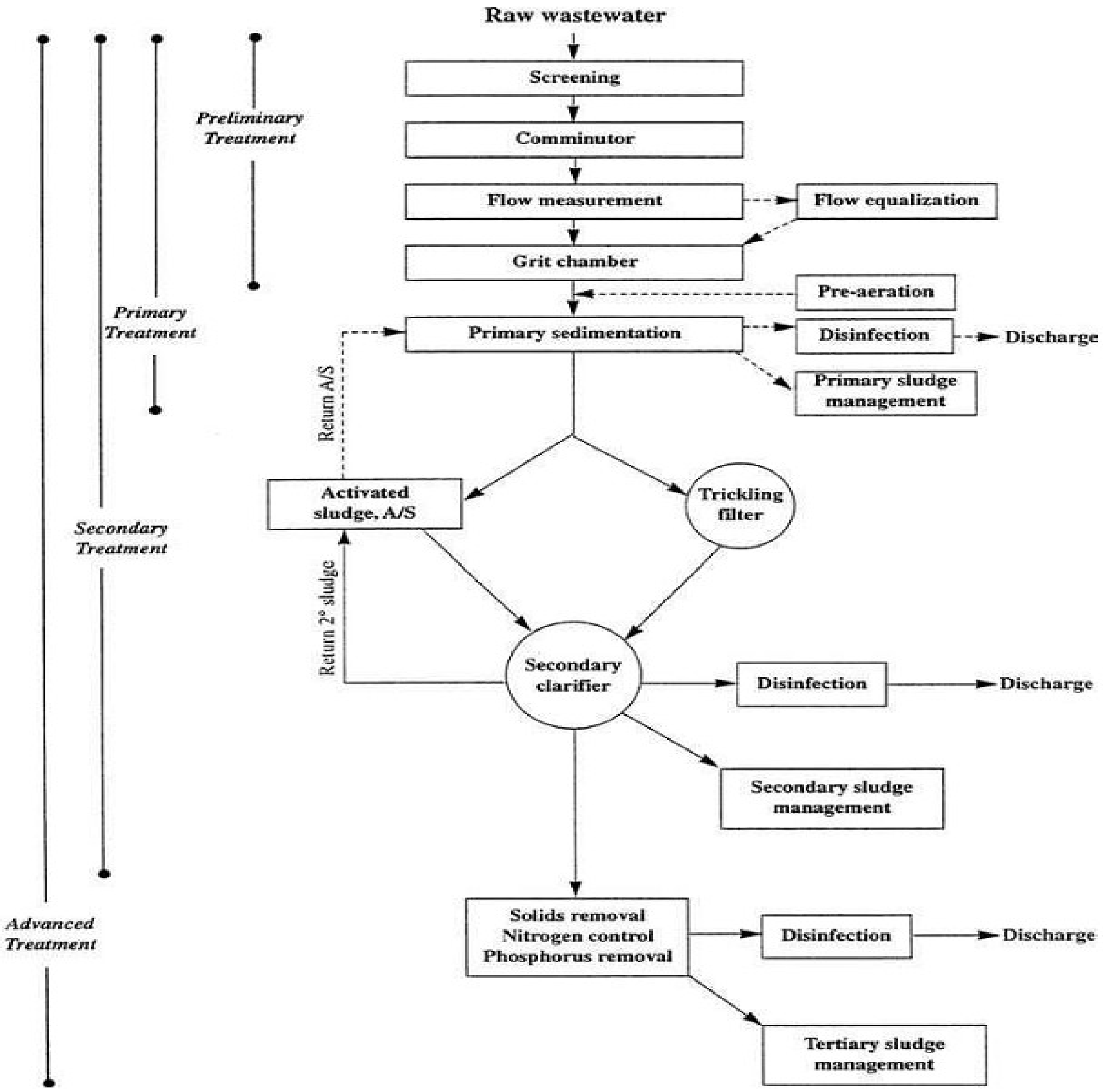


Fig. Flow chart of waste water treatment process

3.1.2 Primary Treatment

Primary treatment consists in removing large suspended organic solids. This is usually accomplished by sedimentation in settling basins. The liquid effluent from primary treatment, often contains a large amount of suspended organic material, and has a high BOD (about 60% of original). Sometimes, the preliminary as well as primary treatments are classified together, under primary treatment. The organic solids which are separated out in the sedimentation tanks (in primary treatment) are often stabilized by anaerobic decomposition in a digestion tank or are incinerated. The residue is used for landfills or soil conditioners.

- ✓ The main primary treatment unit is the primary sedimentation tank. It is used to separate (remove) settle able suspended solids.
- ✓ These tanks maybe circular or rectangular.
- ✓ The tanks are designed on the bases of overflow rate or the hydraulic surface loading rate (H) expressed as : Q/A ($m^3/m^2.d$), where A is the surface area of the tank. The overflow rate affects the efficiency of the tank. The range of (H) is 30-50 $m^3/m^2.d$ at the average design flow.
- ✓ Another important parameter is the weir loading rate expressed as WL = Q/L ($m^3/m^2.d$), where L is the effluent weir length. The maximum allowable WL = is 186 $m^3/m.d$ at the average design flow.
- ✓ The hydraulic detention time should not be less than 1.5 hrs based on the average flow. The hydraulic detention time is defined as $\Theta = V/Q$.
- ✓ The diameter of circular tanks is in the range of 3 to 60 m, and their depth is in the range of 3 to 6 m.
- ✓ The length of rectangular tanks is in the range of 10 to 100m, and the depth is in the range of 2.5 to 5 m. The width of the tank is in the range of 3 to 24 m. The ratio of length to width is in the range of 1.0 to 7.50. The ratio of length to depth is in the range of 4.2 to 25.

In the primary sedimentation tank the settling velocity of organic and inorganic particles are given with the relation of temperature and specific gravity of the particles. This given as

$$v_s = 60.6d * (G - 1) * \left(\frac{3T + 70}{100}\right)$$

For particles between 0.1 and 1mm, for inorganic solids, G = 2.65;

Settling velocity for inorganic solids can be:-

$$v_{s(in)} = 60.6d * (1.65) * \left(\frac{3T + 70}{100}\right)$$
$$v_{s(in)} = d * (3T + 70)$$

Similarly settling velocity for organic particles with G= 1.2 is given by

$$v_{s(or)} = 60.6d * (10.2) * \left(\frac{3T + 70}{100}\right)$$

$$v_{s(or)} = 0.12d * (3T + 70)$$

Example:

A circular primary sedimentation tank for a municipal wastewater treatment plant is to be designed for an average flow of 7570 m^3/d. The minimum side wall depth is 3 m. Assume The overflow rate (H_L) as 36.7 $m^3/m^2.d$ and the maximum allowable WL = is 186 m3/m.d at the average design flow. Determine:

1. The diameter of the tank.
2. The depth of the tank
3. Check the weir loading rate.

Solution:

1. $A = Q/ H_L = 7570/36.7 = 206.3\ m^2$

   $D = (4A/\pi)^{0.5} = ((4*206.3)/3.14)^{0.50} = 16.20\ m$

2. Select the minimum depth d =3 m and check for Θ :

   Volume of the tank (V) = $Ad = 206.3*3 = 618.9\ m^3$

   $\Theta = V/Q = 618.9/7570 = 0.08176$ day = 1.96 hrs > 1.50 OK

3. The circumference of the tank : $L = \pi*D = 3.14*16.2 = 50.868$ m

   $WL = Q/L = 7570/50.868 = 148.82\ m^3/m.d < 186$ Ok

3.2. Biological (secondary) Wastewater Treatment

Purpose: - The idea behind all biological methods of wastewater treatment is to introduce contact with bacteria (cells) which feed on the organic materials in the wastewater, thereby reducing its BOD content. In other words, the purpose of biological treatment is BOD reduction.

Typically, wastewater enters the treatment plant with a BOD higher than 200mg/L, but primary settling has already reduced it to a certain extent (30 – 35% of the original) by the time it enters the biological component of the system. It needs to exit with a BOD content no higher than about 20 - 30mg/L, so that after dilution in the nearby receiving water body (river, lake), the BOD is less than 2 - 3mg/L.

Principle: - Simple bacteria (cells) eat the organic material present in the wastewater. Through their metabolism, the organic material is transformed into cellular mass, which is no longer in solution but can be precipitated at the bottom of a settling tank or retained as slime on solid surfaces or vegetation in the system. The wastewater exiting the system is then much clearer than it entered.

A key factor is the operation of any biological system is an adequate supply of oxygen. Indeed, cells need not only organic material as food but also oxygen to breath, just like humans. Without an adequate supply of oxygen, the biological degradation of the waste is slowed down, thereby requiring a longer residency time of the wastewater in the system. For a given flow rate of wastewater to be treated, this translates into a system with a larger volume and thus taking more space.

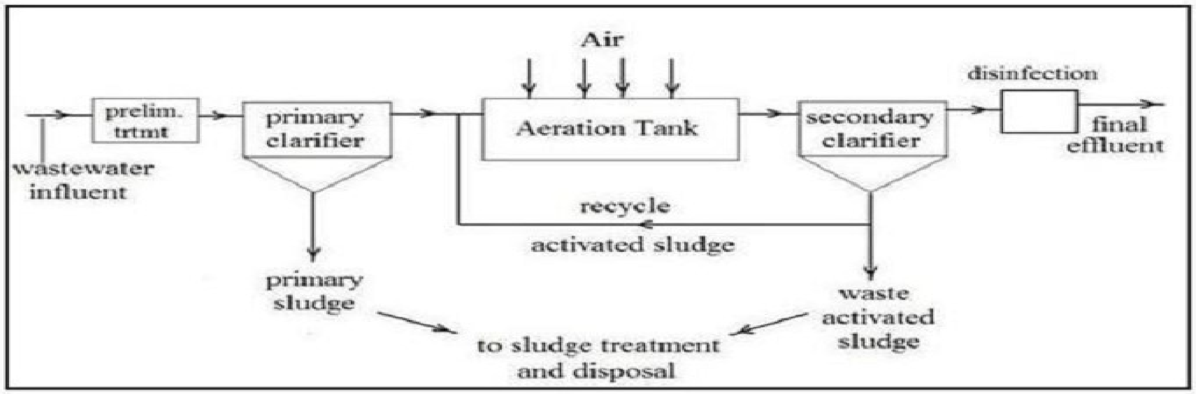
3.2.1. Types of Biological Process for Wastewater Treatment

The common methods of biological wastewater treatment are:

a) The activated sludge processes
b) Aerated lagoons (stabilization ponds)
c) Trickling filters
d) Rotating biological contactors

3.2.1. The activated sludge processes

The activated sludge process provides an excellent method of treating either raw sewage or more generally the settled sewage. The sewage effluent from primary sedimentation tank, which is, thus normally utilized in this process is mixed with 20 to 30 percent of own volume of activated sludge which contains a large concentration of highly active aerobic micro-organisms. The mixture of wastewater and activated sludge in the aeration basis is called mixed liquor. The biological mass (biomass) in the mixed liquor is called the mixed liquor suspended solids (MLSS) or mixed liquor volatile suspended solids (MLVSS). The MLSS consists mostly of microorganisms, non-biodegradable suspended organic matter, and other inert suspended matter. The microorganisms in MLSS are composed of 70 to 90 percent organic and 10 to 30 percent inorganic matter. The types of bacterial cell vary depending on the chemical characteristics of the influent wastewater tank conditions and the specific characteristics of the microorganisms in the flocks. Microbial growth in the mixed liquor is maintained in the declining or endogenous growth phase to insure good settling properties. See the figure below



Design considerations involved in an activated sludge plant

1. Aeration Tank Loadings

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

1) Aeration Period (i.e. Hydraulic Retention Time - HRT)
2) BOD loading per unit volume of aeration tank (i.e. volumetric loading)
3) Food to Micro-organism Ratio (F/M Ratio)
4) Sludge age
5) Sludge Volume Index (SVI)
6) Sludge Recycle and Rate of Return Sludge

1. The Aeration Period or HRT

The aeration period (t) empirically decides the loading rate at which the sewage is applied to the aeration tank. For continuous flow aeration tank, this value is determined in the same manner as it is determined for an ordinary continuous sedimentation tank as:

$$\text{Detention period} = \frac{\text{Volume of the tank}}{\text{Rate of sewage flow in the tank}}$$

$$= \frac{\text{V in m}^3}{\text{Q in m}^3/\text{d}}$$

$$t = \frac{V}{Q} * 24 \text{ hour}$$

Where; - t = aeration period in hours

V = Volume of aeration tank

Q = Quantity of wastewater flow into the aeration tank excluding the quantity of recycled sludge

2. **Volumetric BOD Loading**

Another empirical loading parameter is volumetric loading, which is defined as the BOD_5 1oad applied per unit volume of aeration tank. This loading is also called organic loading.

Volumetric BOD loading or Organic loading

$$= \frac{\text{Mass of BOD applied per day to the aeration tank through influent sewage in gm}}{\text{Volume of the aeration tank in m}^3}$$

$$= \frac{Q * Y_o \text{ (gm)}}{V \text{ (m}^3\text{)}}$$

Where; - Q = Sewage flow into the aeration tank in m^3

Y_o = BOD_5 in mg/l (or gm/m^3) of the influent sewage

V = Aeration tank volume in m^3

3. **Food (F) to Micro-organisms (M) Ratio**

F/M ratio is an important rational organic loading rate adopted for an activated sludge process. It is a manner of expressing BOD loading with regard to the microbial mass in the system. The BOD load applied to the system in kg or gm is represented as food (F), and the total microbial suspended solid in the mixed liquor of the aeration tank is represented by M.

$$\text{F/M ratio} = \frac{\text{Daily BOD load applied to the aerator system in gm}}{\text{Total microbial mass in the system in gm}}$$

If Yo (mg/l) represents the 5 day BOD of the influent sewage flow of Q m3/day, then eventually, The BOD applied to the Aeration system = Yo mg/l or gm/m3

Therefore,

BOD load applied to the aeration system:- = F = Q ∗ Y୨ gm/day ……………… (i)

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

M = MLSS ∗ V

= X_t ∗ V ……………………………………………………………………… (ii)

Where, X_t is MLSS in mg/l , Dividing (i) by (ii), we get

$$\frac{F}{M}\text{ratio} = \frac{F}{M} = \frac{Q}{V} * \frac{Y_o}{X_t}$$

F/M ratio for an activated sludge plant is the main factor controlling BOD removal. The lower the F/M value the higher will be the BOD removal in the plant. The F/M ratio can be varied by varying the MLSS concentration in the aeration tank.

4. Sludge Age

The sludge age is an operation parameter related to the F/M ratio. It may be defined as the average time for which particles of suspended solids remain under aeration. It, thus, indicates the residence time of biological solids in the system. While aeration periods (i.e. liquid retention times) may be as short as 3 to 30h the residence time of biological solids in the system is much

Greater and is measured in days. While sewage passes through the aeration tank only once and rather quickly, the resultant biological growths and the extracted waste organics (solids) are repeatedly recycled from the secondary clarifier back to the aeration tank, thereby increasing the retention time of solids. This time is called Solids Retention Time (SRT) or Mean Cell Residence Time (MCRT) or Sludge Age.

The most common method of expressing sludge age usually represented by □c in days, is to express it as the ratio of the mass of MLSS in the aeration tank relatively to the mass of suspended solids leaving the system per day.

$$\text{Sludge age } (\theta_c) = \frac{\text{Mass of suspended solids (MLSS) in the system (M)}}{\text{Mass of solids leaving the system per day}}$$

For a conventional activated sludge plant with the flow (Q), concentrations of solids (Xt), and BOD5 (Y), we can easily write:

(a) Mass of solids in the reactor $= M = V * (MLSS)$

$$= V * Xt$$

Where, Xt is MLSS in the aeration tank (in mg/l).

(b)

(i) Mass of solids removed with the wasted sludge per day

$$= Q_w * X_R \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(i)}$$

(ii) Mass of solids removed with the effluent per day

$$= (Q - Q_w) * X_E \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(ii)}$$

Therefore, (b) Total solid removed from the system per day

= (i) + (ii)

$$= Q_w * X_R + (Q - Q_w) * X_E$$

Thus:

$$\text{Sludge age} = \theta_c = \frac{V * X_t}{Q_w * X_R + (Q - Q_w) * X_E}$$

Where, Xt = Concentration of solids in the influent of the aeration tank called the MLSS, mg/l

V = Volume of Aerator

Q_w = Volume of wasted sludge per day.

X_R = Concentration of solids in the returned sludge or in the wasted sludge in mg/l

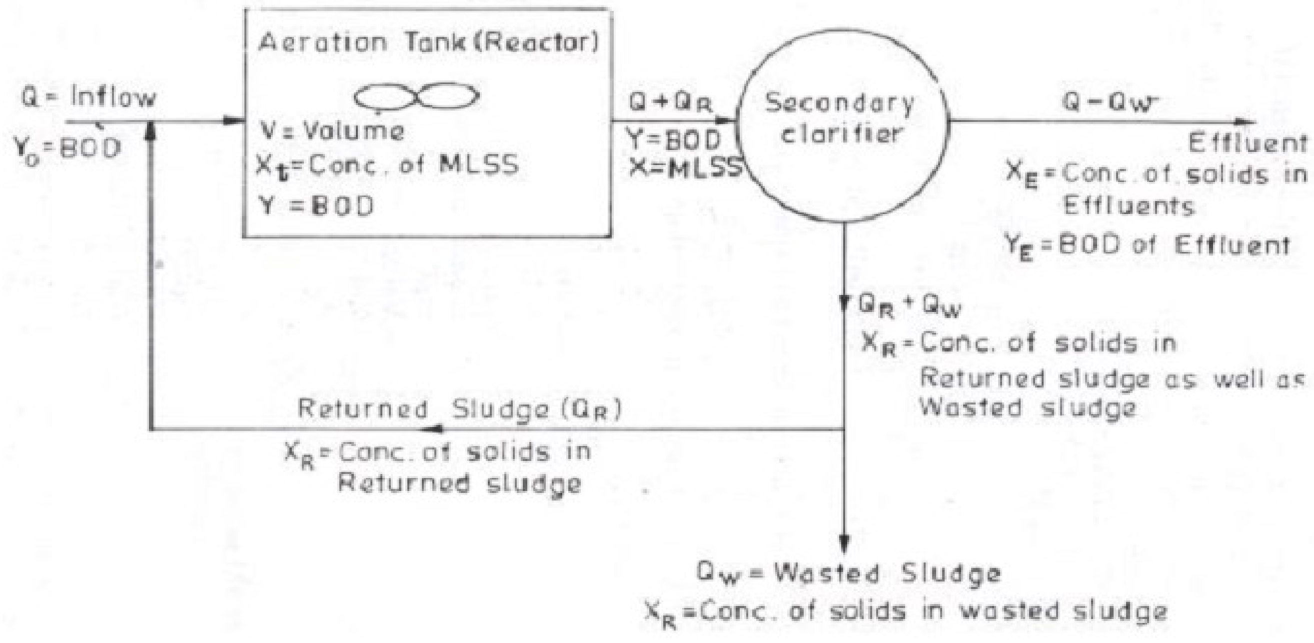
Q = Sewage inflow per day

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

When the value of XE (suspended solids concentration in the effluent of activated sludge plant) is very small, then the term $((Q - Q_w) * X_E$ in the above equation can be ignored, leading to:

$$\theta_c = \frac{V * X_t}{Q_w * X_R}$$

Figure :- Flow chart of conventional activated sludge plant is as shown below



In addition to using sludge retention time (ϴc) as a rational loading parameter, another rational loading parameter which has found wider acceptance is the specific substrate utilization rate (q) per day, and is defined as: $q = Q * \left(\frac{Y_o - Y_E}{V * X_t}\right)$ Under steady state operation, the mass of wasted activated sludge is further given by :-

$$Q_w * X_R = y * Q(Y_o - Y_E) - K_e * X_t * V$$

Where, y = maximum yield coefficient

$$= \frac{\text{microbial mass synthesized}}{\text{mass of substrate utilized}}$$

K_e = Endogenous respiration rate constant (per day) The values of y and Ke are found to be constant for municipal waste waters, their typical values

Being: y = 1.0 with respect to TSS (i.e. MLSS)

= 0.6 with respect to VSS (i.e. MLVSS)

Ke = 0.06 (per day) From the above equations, we can also work out as:

$$= \frac{1}{\theta_c} = yq - K_e$$

Since both y and K_e are constants for a given wastewater, it becomes necessary to define either θ_c or q.

The ɵc value adopted for the design controls the effluent quality and settle ability and drain ability of the biomass. Other parameters which are affected by the choice of ɵc values are oxygen requirement and quantity of waste activated sludge.

5. Sludge Volume Index (SVI)

The term sludge volume index or sludge index is used to indicate the physical state of the sludge produced in a biological aeration system. It represents the degree of concentration of the sludge in the system, and hence decides the rate of recycle of sludge (Q_R) required maintaining the desired MLSS and F/M ratio in the aeration tank to achieve the desired degree of purification. SVI is defined as the volume of sludge occupied in Ml by one gm of solids in the mixed liquor after settling for 30 minutes, and is determined experimentally. Then SVI is given by equation:-

$$\text{SVI} = \frac{\text{Vob (ml/l)}}{\text{Xob (mg/l)}} = \frac{V_{ob}}{X_{ob}} \text{ml/mg}$$

$$\text{SVI} = \frac{V_{ob}}{X_{ob}} * 1000\text{ml/g}$$

The usual adopted range of SVI is between 50 - 150 ml/gm and such a value indicates good Settling sludge.

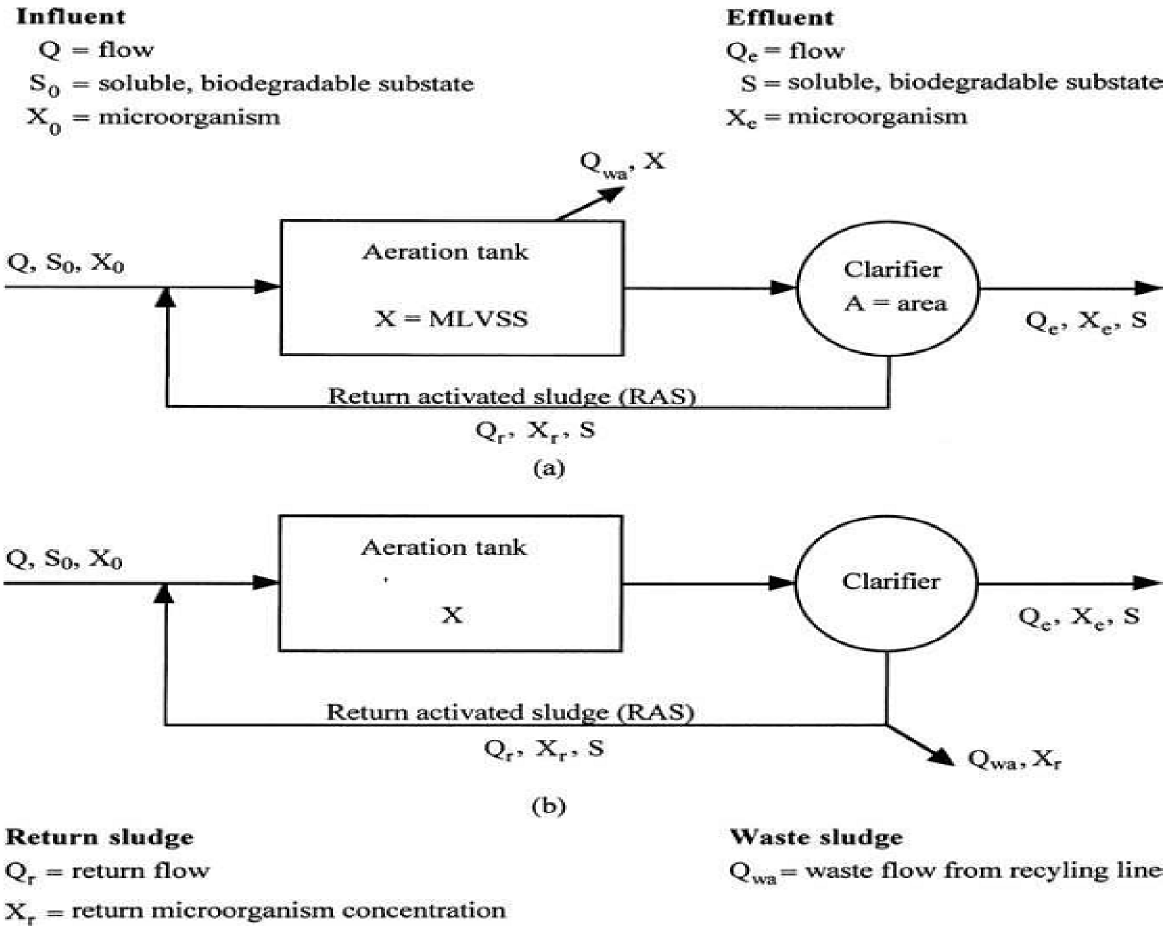


Figure:- Schematic chart of complete-mix activated sludge reactor: (a) sledging wasting from the aeration tank; (b) sludge wasting from return sludge line.

6. Sludge Recycle and Rate of Return Sludge

The MLSS concentration in the aeration tank is controlled by the sludge recirculation rate and the sludge settle ability and thickening in the secondary sedimentation tank.

The relationship between sludge recirculation ratios $\frac{QR}{Q}$ with Xt (MLSS in tank) and X_R (MLSS in returned or wasted sludge) is given as:

$$\frac{Q_R}{Q} = \frac{X_t}{X_R - X_t}$$

Where, Q_R = Sludge recirculation rate in m^3/d

X_t = MLSS in the aeration tank in mg/l

X_R = MLSS in the returned or wasted sludge in mg/l

3.2.2. Trickling Filters

The conventional trickling filters and their improved forms, known as high rate trickling filters are now almost universally adopted for giving secondary treatment to sewage. These filters, also called as percolating filters or sprinkling filters, consist of tanks of coarser filtering media, over which the sewage is allowed to sprinkle or trickle down, by means of spray nozzles or rotary distributors. The percolating sewage is collected at the bottom of the tank through a well designed under-drainage system. The purification of the sewage is brought about mainly by the aerobic bacteria, which form a bacterial film around the particles of the filtering media. The action due to the mechanical straining of the filter bed is much less. In order to ensure the large scale growth of the aerobic bacteria, sufficient quantity of oxygen is supplied by providing suitable ventilation facilities in the body of the filter; and also to some extent by the intermittent functioning of the filter. The effluent obtained from the filter must be taken to the secondary sedimentation tank for settling out the organic matter oxidized while passing down the filter. The sewage influent entering the filter must be given pre-treatments including screening and primary sedimentation.

Figure: - Photographic view of rotary distributors

Design of Trickling Filters

The design of the trickling filter primarily involves the design of the diameter of the circular filter tank and its depth. The design of the rotary distributors and under-drainage system is also involved in the filter design. The design of the filter size is based upon the values of the filter-loadings adopted for the design.

This loading on a filter can be expressed in two ways:-

1. By the quantity of sewage applied per unit of surface area of the filter per day this is called hydraulic-loading rate and expressed in million liters per hectare per day. The value of hydraulic loading for conventional filters may vary between 22 and 44 (normally 28) million liters per hectare per day. The hydraulic loading can still be increased to about 110 to 330 (normally 220) M.L/ha/day in the high rate trickling filters.
2. By the mass of BOD per unit volume of the filtering media per day. This is called organic loading rate, and expressed in kg of BOD5 per hectare meter of the filter media per day. The value of organic loading for conventional filters may vary

Between 900 to 2200 kg of BOD_5 per ha-m. This organic loading value can be further increased to about 6000 - 18000 kg of BOD5 per ha-m in high rate trickling filters. With an assumed value of organic loading (as between 900 to 2200kg/ha-m), we can find out the total volume of the required filter, by dividing the total BOD5 of the sewage entering the filter per day in kg by the assumed value of the organic loading. The organic loading can thus, decide the volume of the filter.

The efficiency of such a conventional filter plant can be expressed by the equation evolved by National Research Council of U.B.A., and given by:

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

Where, η = Efficiency of the filter and its secondary clarifier, in terms of percentage of applied BOD removed

u = Organic loading in kg/ha-m/day applied to the filter (called unit organic loading)

Efficiency of High Rate Filters

The efficiency of high rate filters depend upon the volume of the re-circulated flow (in comparison to the volume of raw sewage) and also upon the organic loading.

The ratio $(\frac{R}{I})$ of the volume of sewage re-circulated (R) to the volume of raw sewage (I) is called recirculation ratio, and is an important feature in obtaining the efficiency of the filter plant (or to work out the required degree of treatment for obtaining certain efficiency), The recirculation ratio is connected to another term called ***recirculation factor*** (F) by the relation:

$$F = \frac{1 + \frac{R}{I}}{\left(1 + 0.1 * \frac{R}{I}\right)^2}$$

The efficiency of the single stage high rate trickling filter can then be worked out by using the equation,

$$\eta(\%) = \frac{100}{1 + 0.0044\sqrt{\frac{Y}{V * F}}}$$

Where, Y - the total organic loading in kg/day applied to the filter, i.e. the total BOD in kg. The term $\frac{Y}{V*F}$ is also called unit organic loading on filter, i.e., u

V - Filter volume in hectare meters

F - Recirculation factor

In a two stage filter, the efficiency achieved in the first stage will be obtained by the previous equation; and in the second stage, it is obtained as: Final efficiency in the two stage filter

$$\eta' = \frac{100}{1 + \frac{0.0044}{1-\eta} * \sqrt{\frac{Y'}{V' * F'}}}$$

Where, Y' - Total BOD in effluent from first stage in kg/day

V' - Volume of second stage filter in ha-m

F' - Recirculation factor for the second stage filter

η‘- Final efficiency obtained after two stage filtration

These equations are very important, as they form the basis of designing high rate filters.

3.2.3. Sludge Disposal

The following are regarded as common method of sludge disposal

- **Incineration:** is the combustion of sludge converting the material into gases and residues which are an agent for green house effect (CO2, SO2) are abandoned now a day.
- **Dumping**: dumping into sea and quarry site, if it is far from residential area and highway.
- **Land spreading**: the land application is designed with the objective of providing further sludge treatment; sun light and soil micro organism destroy pathogens and mineral toxic organic compound.
- The most widely employed disposal options
- Agricultural land
- Forest land
- Disturbed land

- From the above alternative the possible recommendation is land spreading, either Agricultural land or forest land, whichever is available in the distance that is affordable.

3.2.4. Septic Tank

This system consists of a closed, often prefabricated tank and is usually applied for primary sewage treatment. The treatment consists of sedimentation, flotation and digestion procedures.Septic tank is designed to receive all kinds of domestic wastes (kitchen, domiciliary laundries, washrooms, latrines, bathrooms, showers, etc) and it is economically viable to attend to 100 inhabitants.

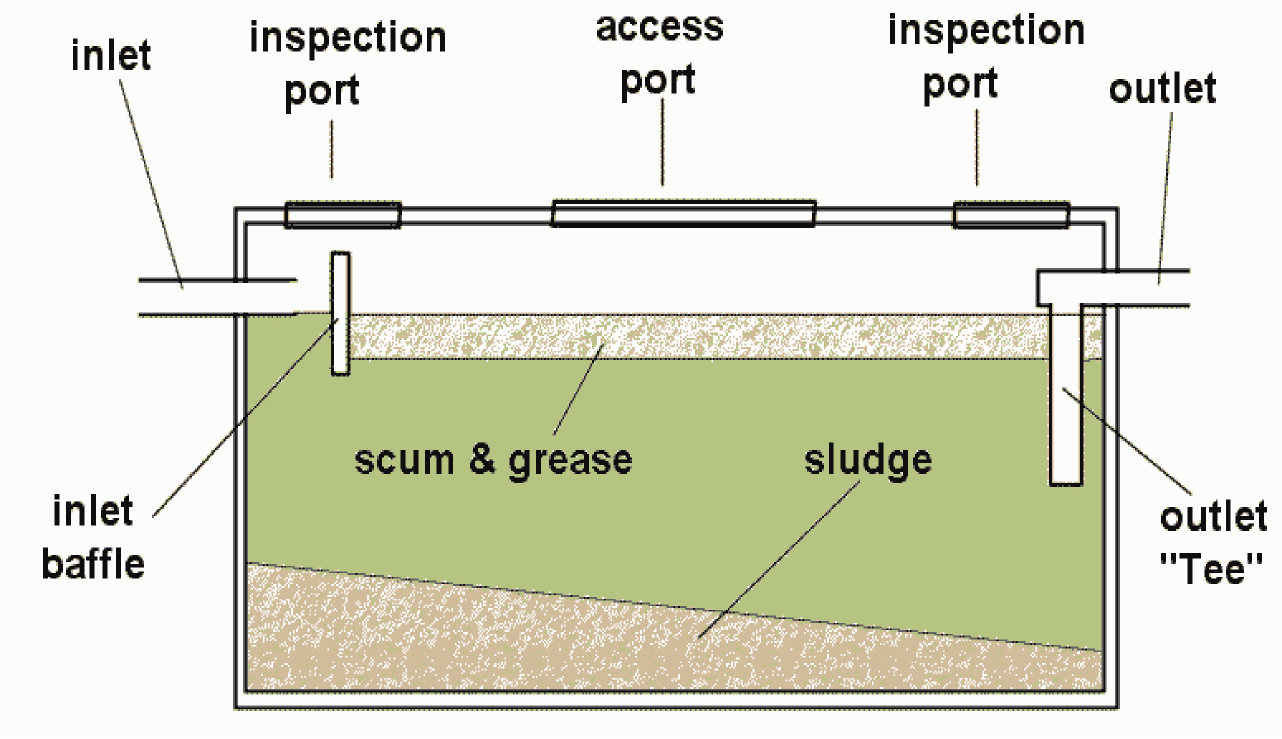


Figure: - Atypical parts of septic tank

Chapter 4

4. Solid waste management

4.1. Solid waste sources

Solid wastes are the wastes arising from human activities which are solid and discarded as useless or unwanted. The term **municipal solid waste** refers to solid wastes from houses, streets and public places, shops, offices, and hospitals. Agricultural, mining and industrial wastes are not included in urban waste (MSW). Industrial solid wastes need to be taken into account when dealing with municipal solid waste. As they often end up in the municipal solid waste stream.

Solid waste is generated:

- in the beginning, with the recovery of raw materials and
- at every step in the technological process as the raw material is converted to a product for consumption

Generation of solid waste during technological processes involving mining, manufacturing and packaging. The process of consumption of products results in the formation of solid waste in urban areas as shown in the figure below. In addition, other processes such as street cleaning, park cleaning, waste-water treatment, etc. also produce solid waste in urban areas. A society receives energy and raw material as inputs from the environment and gives solid waste as output to the environment. Fig. below. In the long-term perspective, such an input-output imbalance degrades the environment.

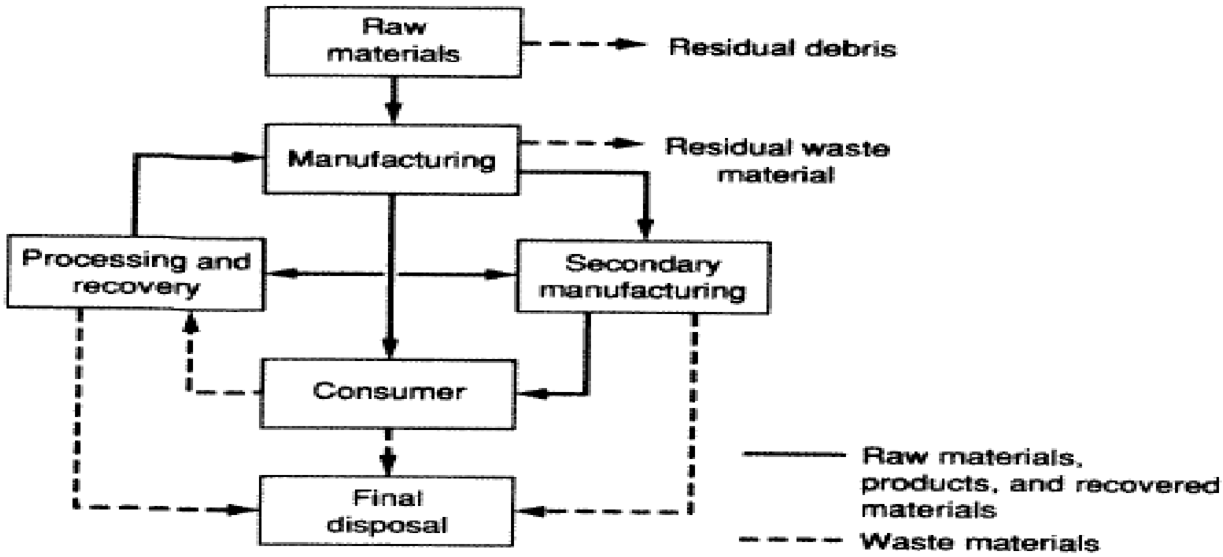


Fig. 1 Materials flow and the generation of solid waste in a technological society

Table: - Sources of solid wastes within a community

Source	Typical facilities, activities, or locations where wastes are generated	Types of solid waste
Residential	single family and multifamily detached dwellings, slow-, medium-, and high-rise apartments, etc.	Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, tin cans, aluminum, other metals, ashes, street leaves, special wastes (including electronic items, white goods, yard wastes, batteries, oil, and tires), Household hazardous wastes.
Commercial	Stores, restaurants, markets, office buildings, hotels, motels, print shops, service stations, auto repair shops, etc.	Paper, card board, plastics, wood, food waste, glass, metals, special wastes (see above), hazardous wastes, etc.

Institutional	Schools, hospitals, prisons, governmental centers	As above in commercial
Construction and demolition	New construction sites, road repair/ renovation sites, broken pavement	Wood, steel, concrete, dirt, etc.
Municipal services (excluding treatment facilities)	Street cleaning, landscaping, parks and beaches, other recreational areas.	Special wastes, rubbish, street sweepings, landscape and tree trimmings, general wastes from parks, beaches, and recreational areas
Treatment plant sites; municipal incinerators	Water, waste water, and industrial treatment processes, etc.	Treatment plant wastes, principally composed residual sledges.

4.2. Composition of solid wastes

Composition is the term used to describe the individual components that make up a solid waste stream and their relative distribution, usually based on percent by weight. Information and data on the physical composition of solid wastes are important in the

- selection and operation of equipment and facilities
- assessing feasibility of resource and energy recovery
- analysis and design of landfill disposal facilities

Table: Estimated composition of all components of MSW generated in a typical community

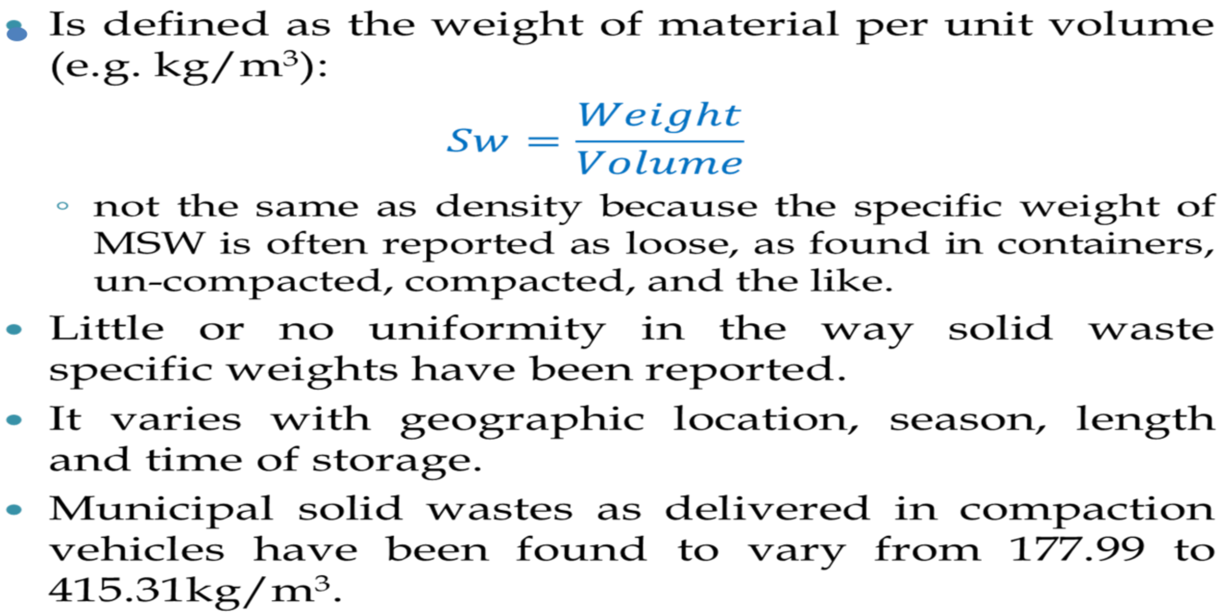
Waste category	**Percentage by weight**	
	Range	**typical**
Residential and commercial, excluding special and hazardous wastes	50 - 75	62
Special (bulky items, white, batteries, tires, etc.)	3 - 12	5
hazardous	0.01 - 1.0	0.1
Institutional	3 - 5	3.4
Construction and demolition	8 - 20	14
Municipal services		
Street and alley cleanings	2 - 5	3.8
Tree and landscaping	2 - 5	3
Parks and recreational areas	1.5 - 3	2
Catch basin	0.5 - 1.2	0.7
Treatment plant sludge	3 - 8	6
Total		4..

4.3. Physical, chemical, and biological properties of municipal solid waste

These properties must be known to develop and design integrated solid waste management of MSW.

1. Physical properties:
    a. Specific weight
    b. Moisture content
    c. Particle size and size distribution
    d. Field capacity
    e. Permeability of compacted waste
2. Chemical properties of MSW
    i. Proximate analysis
    ii. Fusing point of ash
    iii. Ultimate analysis (elemental analysis) (major elements)
    iv. Energy content
3. Biological properties of MSW

a) Specific weight



- Is defined as the weight of material per unit volume (e.g. kg/m^3):

$$Sw = \frac{Weight}{Volume}$$

  - not the same as density because the specific weight of MSW is often reported as loose, as found in containers, un-compacted, compacted, and the like.
- Little or no uniformity in the way solid waste specific weights have been reported.
- It varies with geographic location, season, length and time of storage.
- Municipal solid wastes as delivered in compaction vehicles have been found to vary from 177.99 to 415.31kg/m^3.

b) Moisture content

A transfer of moisture takes place in the garbage can and truck, and thus, the moisture content of various components changes with time. The moisture content becomes important when the waste is processed into fuel or when it is fired directly. Expressed as wet-weight or dry-weight method

Wet-weight method: the moisture in a sample is expressed as percentage of the wet weight of the material. Commonly used method

Dry-weight method: expressed as a percentage of the dry weight of the material

$$M = (\frac{w-d}{w})100$$

Where, M - moisture content, wet basis %

w - Initial (wet) weight of sample as delivered, kg

d - Weight of sample after drying at 105^0C, kg

The moisture content of any waste can be estimated by: Knowing the *fraction of various components* and using either measured values of moisture content or typical values from a list.

c) Particle size and size distribution

The size and distribution of the components of wastes are important for the recovery of materials, especially when mechanical means are used, such as trommel screens and magnetic separators. No single value can adequately hope to describe a mixture of particles. Probably the best effort in that direction is to describe the mixture by means of a curve showing percent's of particles (by either number or weight) versus the particle size.

The size of a waste component may be defined by one or more of the following measures:

$$Sc = (\frac{l+w}{2})$$

$$Sc = l$$

$$Sc = (\frac{l+w+h}{3})$$

Where *Sc* - Size of component, in (mm)

l - Length, in (mm)

w - Width, in (mm)

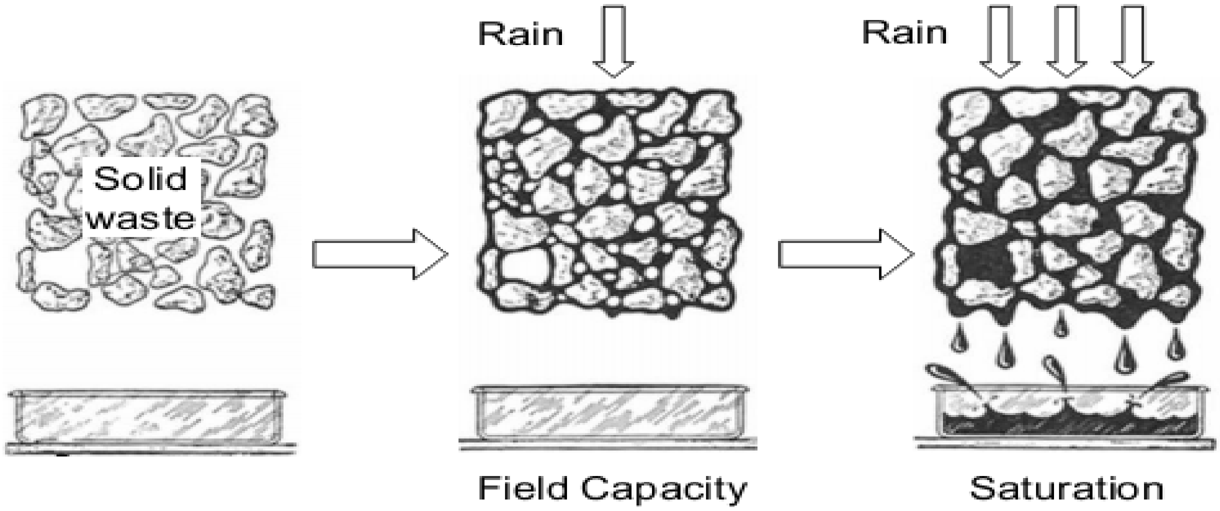
$$Sc = \sqrt{(l * w)}$$

h - Height, in (mm)

$$Sc = \sqrt[3]{(l * w * h)}$$

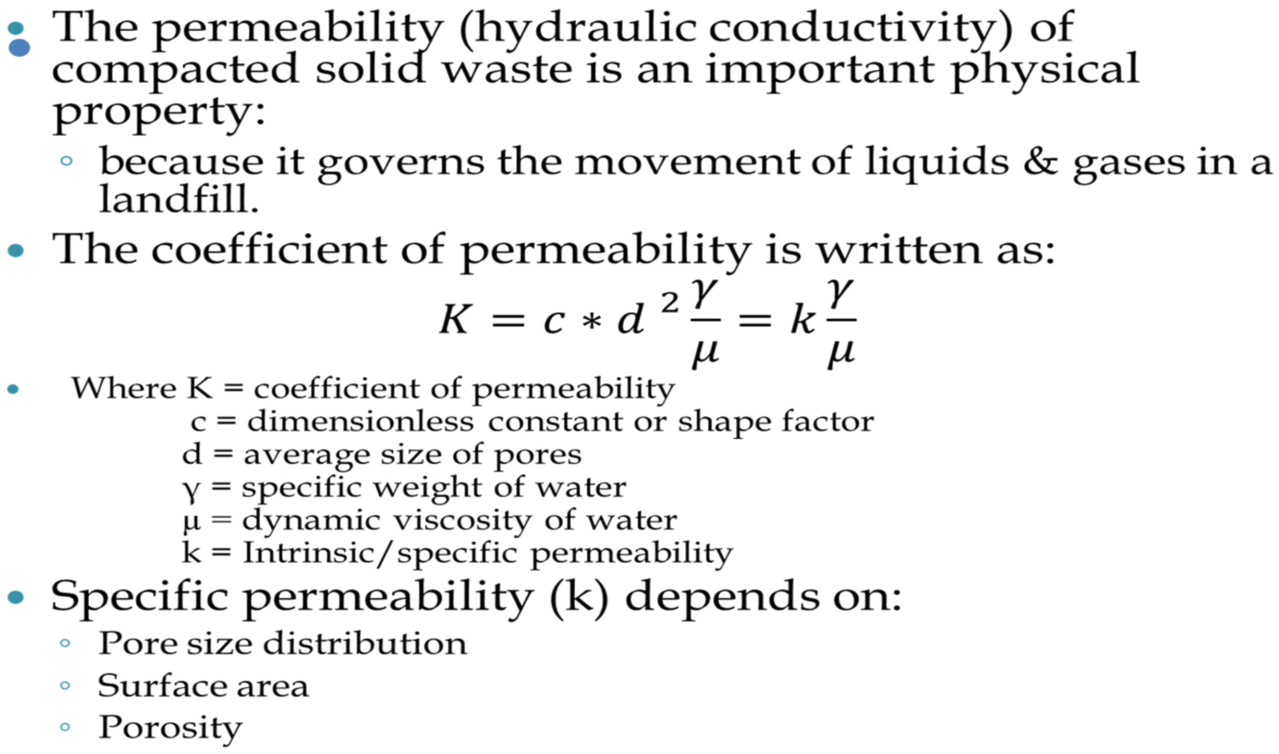
d) Field Capacity (FC)

The total amount of moisture that can be retained in a waste sample subject to the downward pull of gravity.



Leach ate is any liquid that, in passing through matter, extracts solutes, suspended solids or any other component of the material through which it has passed.

e) Permeability of Compacted Waste



- The permeability (hydraulic conductivity) of compacted solid waste is an important physical property:
  - because it governs the movement of liquids & gases in a landfill.
- The coefficient of permeability is written as:

$$K = c * d^2 \frac{\gamma}{\mu} = k \frac{\gamma}{\mu}$$

- Where K = coefficient of permeability
  c = dimensionless constant or shape factor
  d = average size of pores
  γ = specific weight of water
  μ = dynamic viscosity of water
  k = Intrinsic/specific permeability
- Specific permeability (k) depends on:
  - Pore size distribution
  - Surface area
  - Porosity

4.4. Solid waste quantity

Importance of Waste Quantities, The quantities of solid waste generated and collected are of critical importance:

i. In determining compliance with law such as AB939, in US, which mandates 25% reduction/ recycling by 1995 and 50% reduction by 2000?

ii. In selecting specific equipment

iii. In designing of:

   ✓ waste collection routes

   ✓ materials recovery facilities (MRF’s) and

   ✓ disposal facilities

iv. The design of special vehicles for the curbside collection of source-separated wastes depends on the quantities of the individual waste components to be collected.

v. The sizing of MRFs depends on the amounts of waste to be collected as well as the variations in the quantities delivered hourly, daily, weekly and monthly.

vi. The sizing of landfills depends on the amount of residual waste that must be disposed of after all the recyclable materials have been removed.

4.4.1. Estimation of Waste Quantities

Waste quantities are usually estimated on the basis of data gathered by:

- ✓ Conducting a waste characterization study
- ✓ using previous waste generation data
- ✓ Or combination of the two approaches

Methods commonly used to assess solid waste quantities are:

- ✓ Load-count analysis
- ✓ Weight- volume analysis
- ✓ Material-balance analysis

Load-count analysis

- In this method:
  - ✓ The number of individual loads and the corresponding waste characteristics (types of waste, estimated volume) are noted over a specified time period.
  - ✓ Solid waste volume and general composition are estimated and this is converted to mass by multiplying with specific weight (density) at transfer site or disposal site.
  - ✓ Unit generations are determined by using the field data, where necessary, published data.

4.5. Collection systems and Transportation

Collection of solid waste includes:

- ✓ gathering or picking up from various sources
- ✓ hauling of SW to the location where the contents of the collection vehicles are emptied

The unloading of collection vehicle is also considered part of the collection operation.

Gathering or picking up of SW will vary with:

- ✓ The characteristics of facilities, activities, or locations where wastes are generated and
- ✓ The methods used for onsite storage of accumulated wastes between collections.

Information of collection is presented in four parts:

- ✓ The types of collection services
- ✓ The types of collection systems
- ✓ Analysis of collection system
- ✓ The general methodology involved in setting up of collection routs

The collection systems have been classified according to their mode of operation into two categories

a) hauled container systems

b) stationary container systems

Hauled Container System (HCS): -

- ✓ Container is moved to disposal site
- ✓ Used for construction & demolition waste
- ✓ High generation rates (open markets)
- ✓ One drive and frequent trips
- ✓ low volume utilization unless loading aids are provided

Stationary Container System (SCS):-

- ✓ Container remains at site (residential and commercial)
- ✓ May be manually or mechanically loaded
- ✓ Container size and utilization are important

Means of Transport: -

- ❖ Motor vehicles, railroads and ocean-going vessels are the principle means used to transport solid wastes.

- ❖ Vehicles used for transport should satisfy the following requirements:
  - ✓ Wastes must be transported at minimum cost
  - ✓ Wastes must be covered during hauling operation
  - ✓ Vehicles must be designed for highway traffic
  - ✓ Vehicles capacity must be such that the allowable weight limits are not exceeded
  - ✓ Methods used for unloading must be simple and dependable

4.6. Solid waste processing and Resource recovery

Waste processing is used to:

- ✓ reduce the volume of solid waste
- ✓ recover reusable materials
- ✓ alter the physical form of the solid waste

Processing of SW at Residential Dwellings: -

- ✓ Grinding of food waste
- ✓ Separation of wastes
- ✓ Compaction
- ✓ Composting

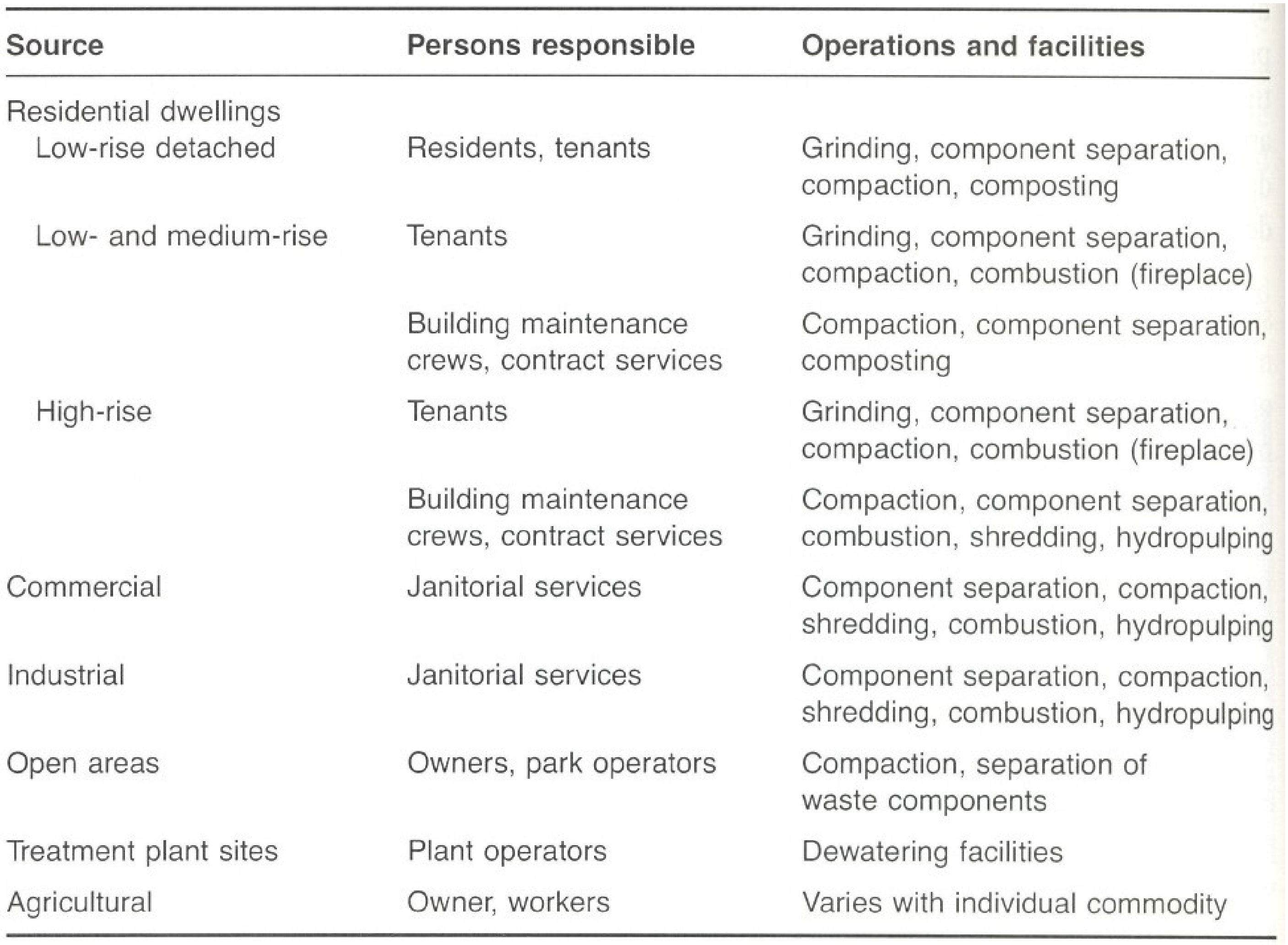
- ✓ Combustion

Processing of SW at Commercial and Industrial Facilities

- ✓ Onsite processing operations carried out at commercial and industrial facilities are generally similar to those described for residential sources.
    - However, compaction is very important in commercial facilities.
- ✓ Compaction, Shredding and Hydropulping[1] are commonly used as means of processing of solid wastes at commercial and industrial facilities

Paper recycling process called *hydro pulping* that separates the *paper* from the plastic and aluminum.

Table:- Typical operations and facilities used for the processing of solid waste at the source of generation



Source	Persons responsible	Operations and facilities
Residential dwellings		
Low-rise detached	Residents, tenants	Grinding, component separation, compaction, composting
Low- and medium-rise	Tenants	Grinding, component separation, compaction, combustion (fireplace)
	Building maintenance crews, contract services	Compaction, component separation, composting
High-rise	Tenants	Grinding, component separation, compaction, combustion (fireplace)
	Building maintenance crews, contract services	Compaction, component separation, combustion, shredding, hydropulping
Commercial	Janitorial services	Component separation, compaction, shredding, combustion, hydropulping
Industrial	Janitorial services	Component separation, compaction, shredding, combustion, hydropulping
Open areas	Owners, park operators	Compaction, separation of waste components
Treatment plant sites	Plant operators	Dewatering facilities
Agricultural	Owner, workers	Varies with individual commodity

Recovery of Materials in MSW: -

- The methods used to recover source-separated waste materials include:
    - ✓ curb side collection and
    - ✓ homeowner delivery of separated materials to drop-off and buy-back centers
- Further separation and processing of wastes that have been source-separated, as well as the separation of the commingled wastes, usually occur :
    - ✓ at materials recovery facilities (MRFs) or at large integrated materials recovery/transfer facilities (MR/TF)

Materials recovery and transfer

- ❖ Integrated Materials Recovery/Transfer Facilities (MR/TFs) may include the functions of:
  - ✓ drop-off center for separated wastes
  - ✓ materials separation facility
  - ✓ facility for the composting and bioconversion of wastes
  - ✓ facility for the production of refuse-derived fuel
  - ✓ transfer and transport facility
- ❖ Materials separated from MSW can be used directly as:
    - ✓ raw material for remanufacturing and reprocessing
    - ✓ feedstock for production of biological and chemical conversion products
    - ✓ fuel source for the production of energy
    - ✓ land reclamation
  - ✓ In assessing the opportunities for recycling
    - ✓ the available options for separation and processing of waste materials
    - ✓ the economics of material recovery and material specifications

4.7. Disposal of Solid Wastes and Residual Material

Land filling Process

- ❖ Landfills are physical facilities used for the disposal of residual solid wastes in the surface soils of earth.
- ❖ Sanitary landfill is an engineered facility for the disposal of MSW, designed and operated to minimize public health and environmental impacts.
- ❖ Land filling is the process by which residual solid waste is placed in a landfill.

It includes:

- ✓ Monitoring of the incoming waste stream
- ✓ Placement and compaction of waste, and
- ✓ Installation of landfill environmental monitoring and control facilities

Land filling terms: -

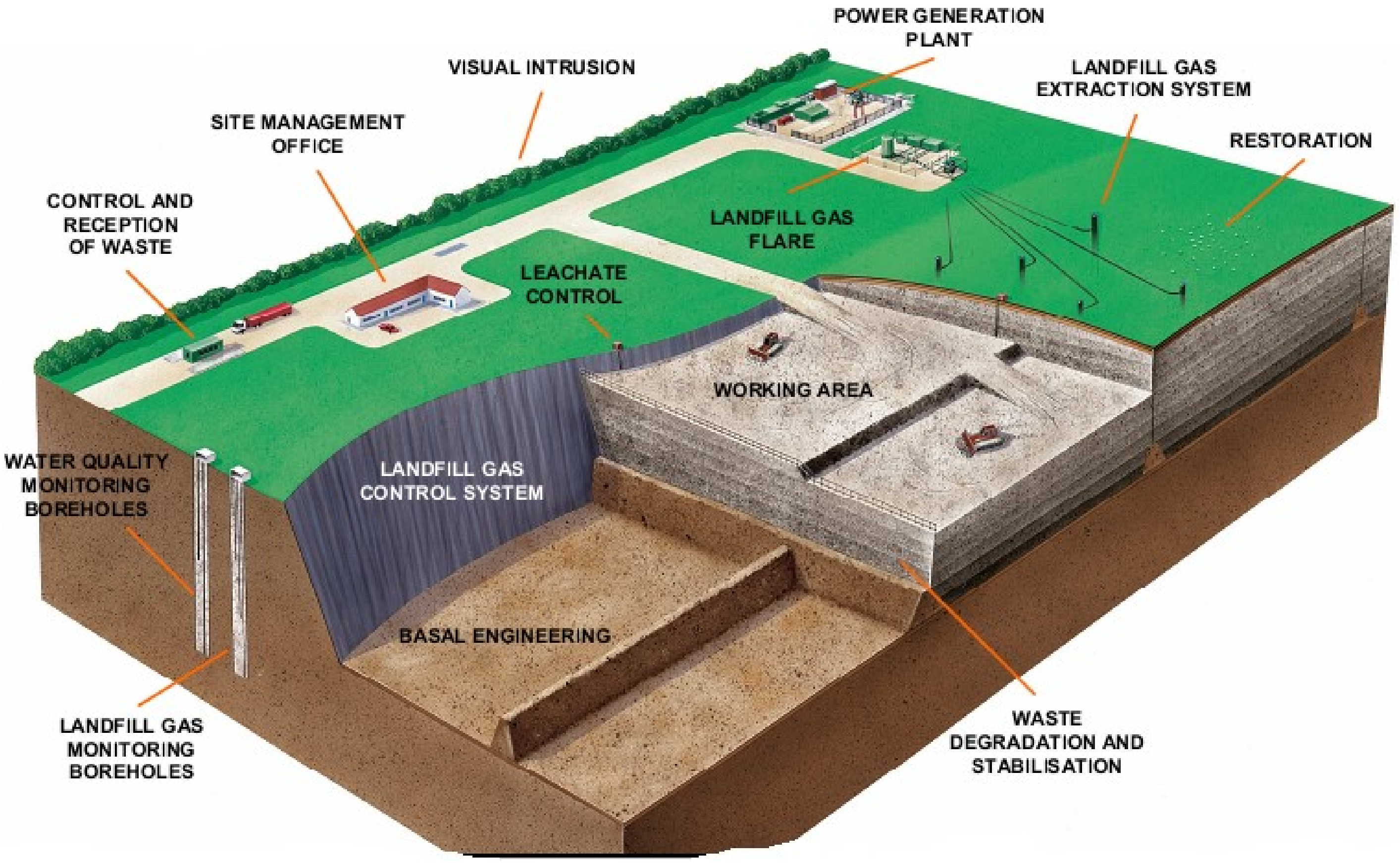
- ✓ **Cell** is the volume of material placed in a landfill during one operating period, usually one day.
- ✓ **Lift** is a complete layer of cells over the active area of landfill.
- ✓ **Daily cover** is the soil or alternative materials such as compost that are applied to the working faces of the landfill at the end of each operating period. usually consists of 15 to 30 cm of native soil
- ✓ **Intermediate covers** are placed at the end of each phase (series of lifts); these are thicker than daily covers, typically 45 cm
- ✓ **Final cover** is applied to the entire landfill surface after all landfilling operations are complete.
- ✓ **Bench (or terrace)** is used to maintain the slope stability of the landfill, for placement of surface water drainage channels and for the location of landfill gas recovery piping.
- ✓ **Landfill gas** is mixture of gases found within landfill. It mainly consists of **CH_4 & CO_2**
- ✓ Liquid that collects at the bottom of a landfill is known as **leachate.**
- ✓ It is a result of percolation of precipitation and uncontrolled runoff.

It can also include water initially contained in the waste as well as infiltrating groundwater.

4.7.1. Landfill planning, design and operation

The principal elements that must be considered:

- Landfill layout and design
- Landfill operations and management
- Reactions occurring in landfill
- Management of landfill gases
- Management of leachate
- Environmental monitoring
- Landfill closure and post-closure care

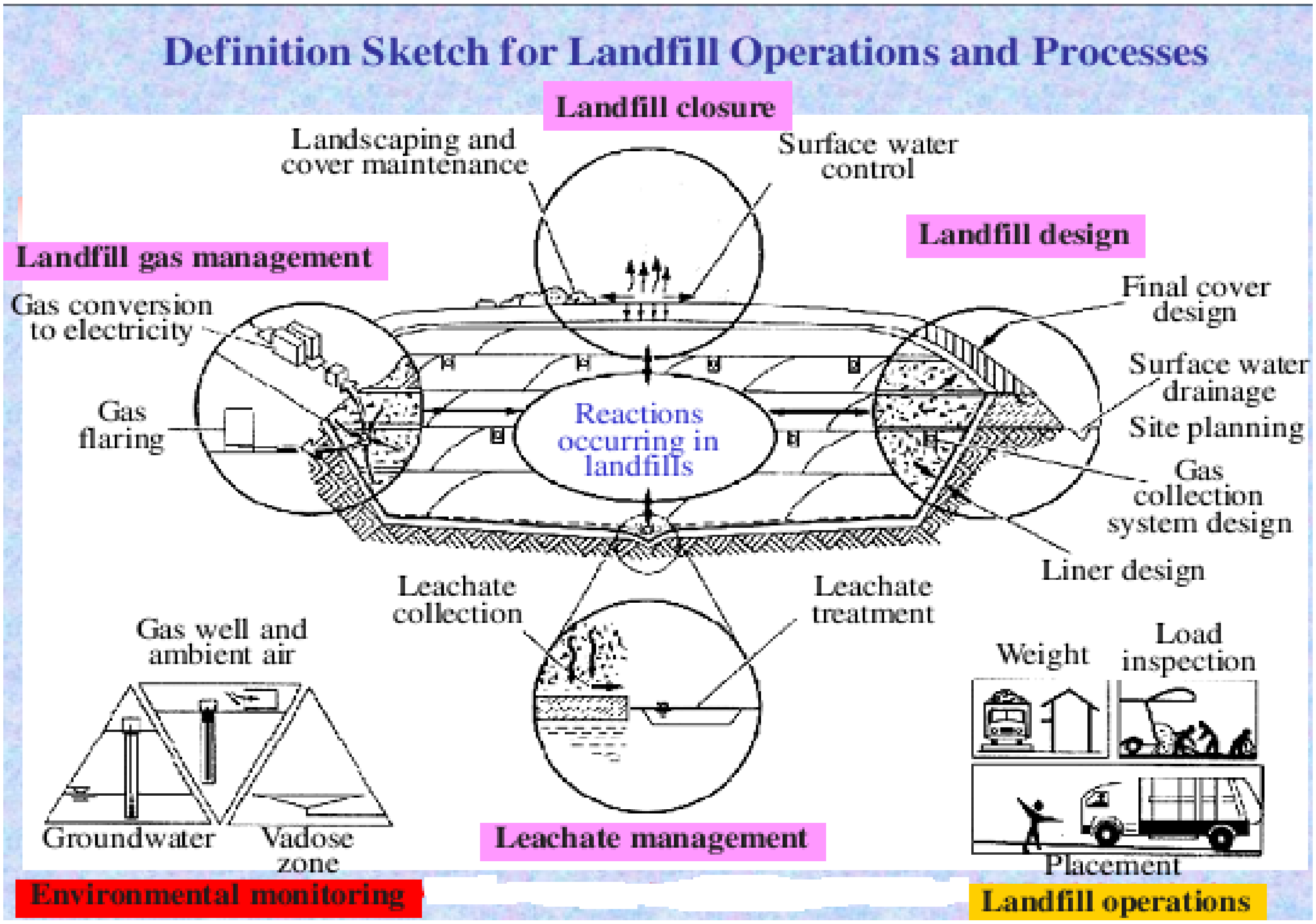


Preparation of site for land filling:-

- Existing site drainage is modified to route any runoff away from the intended landfill area
- Access roads and weighing facilities are constructed and fences are installed

- Landfill bottom and subsurface sides are excavated and prepared. Excavations are carried out over time, rather than preparing the entire landfill bottom at once
- The bottom is shaped to provide drainage of leachate and a low-permeability (clay, geo-membrane) liner is installed.
- Leachate collection and extraction facilities are placed within or top of the liner.

Landfill operations and processes



Land filling Methods

1. **Excavated cell/trench Method**

✓ It is ideally suited to areas where an adequate depth of cover material is available at the site and where water table is not near the surface.

- ✓ The soil excavated is used for daily and final cover.
- ✓ Excavated cells are typically square and trenches are long ditches.

2. **Area Method**

   - ✓ It is used when the terrain is unsuitable for excavation.
   - ✓ High-groundwater conditions necessitate the use of this type.
   - ✓ Cover material must be hauled by truck or earthmoving equipment from adjacent land or from borrow-pit areas.
   - ✓ Compost produced from MSW can be used as intermediate cover material.

3. **Canyon/depression Method**

   - ✓ Canyons, ravines, dry borrow pits, and quarries are used.
   - ✓ Control of surface drainage often is critical factor in the development of canyon/depression sites.
   - ✓ Filling for each lift starts at the head end of the canyon and ends at the month, so as to prevent the accumulation of water behind the landfill.
   - ✓ Cover material is excavated from the canyon walls or floor before the liner is installed.

Layout & Preliminary Design of Landfills

- Important topics that must be considered in a landfill design:
  - ✓ Layout of landfill site
  - ✓ Types of wastes that must be handled
  - ✓ The need for a convenience transfer station
  - ✓ Estimation of landfill capacity

- ✓ Evaluation of the geology and hydrology of the site
- ✓ Selection of landfill gas and leachate control facilities
- ✓ Layout of surface drainage facilities
- ✓ Aesthetic design considerations
- ✓ Monitoring facilities
- ✓ Determination of equipment requirements Development of an operations plan

Layout of Landfill Sites

- In planning the layout of a landfill site, the location of the following must be determined:
  - ✓ Access roads, office space and plantings
  - ✓ Equipment shelters and (if used) scales
  - ✓ Storage and/or disposal sites for special wastes
  - ✓ Areas to be used for waste processing
  - ✓ Areas for stockpiling cover material
  - ✓ Drainage facilities
  - ✓ Location of landfill gas management facilities
  - ✓ Location of leachate treatment facilities
  - ✓ Location of monitoring wells

Design of Landfills

- Important factors to consider in the design of landfills:
  - ✓ Access (roads to landfill site, temporary roads to unloading area)
  - ✓ Land area (large enough for 10 - 25 years)

- ✓ Land filling method (excavated cell/trench, area, canyon)
- ✓ Completed landfill characteristics (slope of final cover: 3 -6%)
- ✓ Surface drainage (to divert surface water runoff)
- ✓ Intermediate cover material (waste to cover ratio: 5 – 10: 1)
- ✓ Final cover (multilayer design)
- ✓ Landfill liner (multilayer design, leachate collection system)
- ✓ Cell design and construction Groundwater protection (divert any underground springs)
- ✓ Landfill gas management (passive and active control)
- ✓ Leachate collection (determine Q_{max} and size of collection pipes)
- ✓ Leachate treatment (Based on expected leachate flow rate and discharge standards to select the appropriate treatment process)
- ✓ Environmental requirements (gas and liquid monitoring facilities)
- ✓ Equipment requirements
- ✓ Fire prevention

- Waste Volume and Landfill Capacity: - The total landfill area should be approximately 15% more than the area required for land filling to accommodate all infrastructure and support facilities. There is no standard method for classifying landfills by their capacity.
- However, the following nomenclature is often observed in literature:
  - ➢ Small size landfill   : less than 5 hectare area
  - ➢ Medium size landfill : 5 to 20 hectare area
  - ➢ Large size landfill   : greater than 20 hectare area.

Landfill Closure and Post closure Care

- They are the terms used to describe what is to happen to a completed landfill in the future.
- Development of Long-Term Closure Plan
    - Cover and landscape design
    - Control of landfill gases
    - Collection and treatment of leachate
    - Environmental monitoring systems
- Post closure Care
    - Routine inspections
    - Infrastructure maintenance
    - Environmental monitoring systems