Comprehensive Notes
in

Environmental Engineering – II

Civil Engineering
7th Semester

by

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This book does not claim to be a solution of any other textbook. This is an honest attempt of solving previous year university papers in order to get ideal solutions that will fetch students maximum marks.

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Preface to the First Edition

I am glad to present the first edition of *Environmental Engineering - II* as per CSVTU syllabus for the students of 7th semester pursuing B.E (Civil Engineering).

Emphasis has been given to topic wise description of all five units including complete solutions of past year university papers with ample figures and solved examples, which will help the readers to understand the concepts from scratch.

I wish to express my thanks to my publisher Mr. Ankit Jain for his valuable suggestions in development of this manuscript and also his team who did an excellent job in portraying the manual script in to such a lovely text book.

I also express my gratitude to my friends and family members, who contributed in making this book possible.

I welcome suggestions from readers for improving this book in any manner possible.

Akanksha Vijay Agrawal

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Semester : **VII**
Code: **320713 (20)**
Total Theory Periods: **50**

Subject: **Environmental Engineering-II**
Branch: **Civil Engineering**
Total Marks in End Semester Examination: **80**

Unit 1

Sewage and Sewarage, definitions and some common terms, object of sewage disposal. System of sanitation: Conservancy systems, Water system, sewage system-combined, separate and partially separate, patterns of collection system.

Amount of sewage-Estimation of domestic and storm sewage, variations in the quantity of sewage, Design of sewers (Only circular sewer) Manholes, Pumping stations, Wet well capacity.

Unit 2

Characteristics of sewage-physical, chemical and biological characteristics, fundamentals of aerobic & anaerobic process.

Sewage treatment-preliminary treatment systems, Racks and screens, comminuters, Grit chambers.

Primary treatment systems-Plain sedimentation, detention time and over-flow rates, types of inlets and outlets, onsite wastewater treatement- septic tank, Imhoff tank, oxidation pond.

Unit 3

Secondary treatment systems-(i) Attached growth process-Trickling filters, standard and high rates, efficiency (NRC) formula, operational problems of trickling filters (ii) Suspended growth process, principle of suspended growth process, Activated sludge process, Oxidation ditch aeration and mixing techniques, Operational problems of activated sludge systems, stablisation tools aerobic, anaerobic and facultative lagoon.

Unit 4

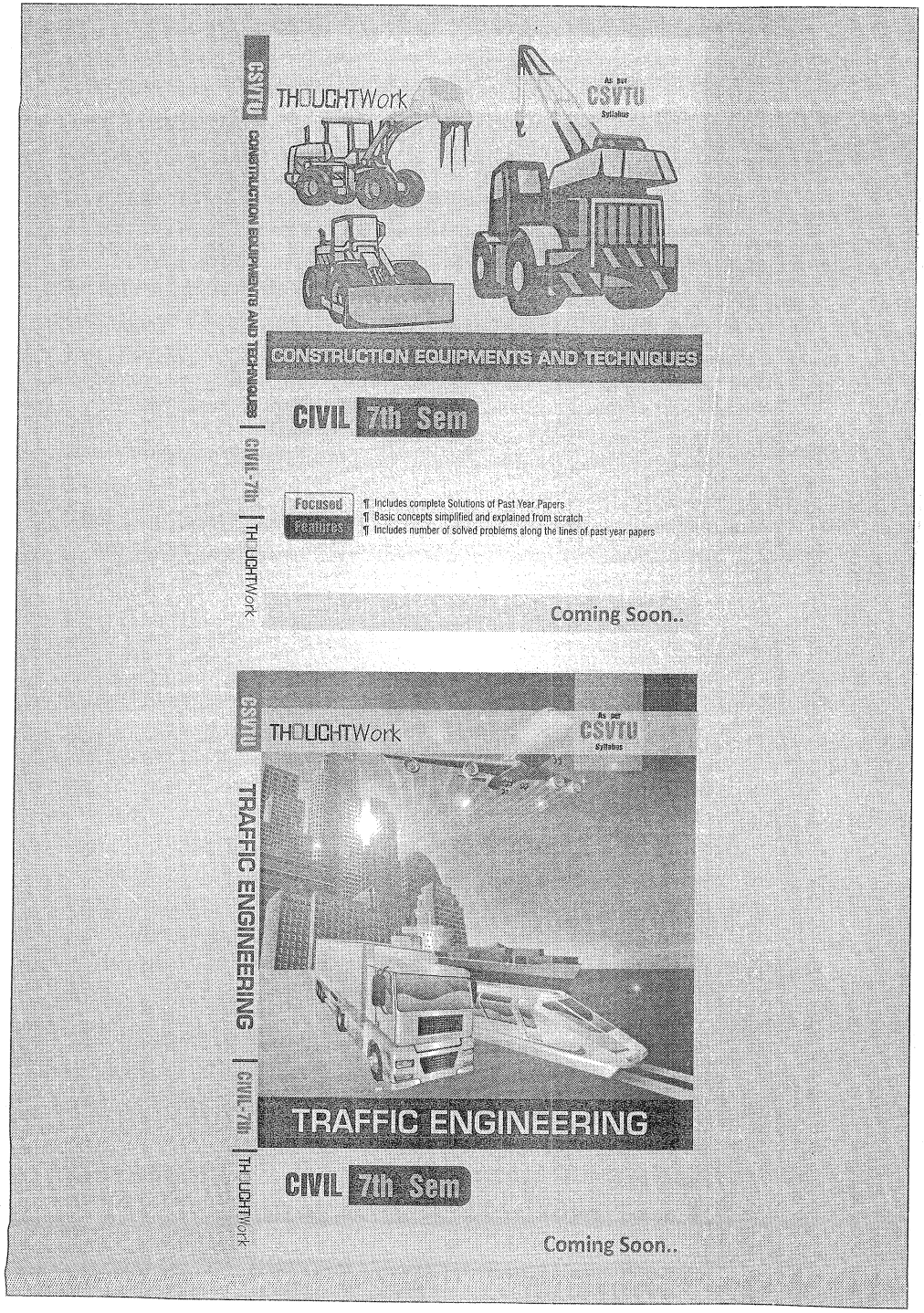
Sewage sludge treatment-Importance, amount and characteristics of sludge, sludge digestion, Anaerobic digestion, aerobic digestion, sludge drying beds.

Sewage disposal: disposal by dilution, self purification of polluted streams, factors affecting self purification, Sag curve, disposal on land surfaces.

Stream standards, Effluent standards, theories of waste treatment (Volume reduction, strength reduction, new Equalization and proportioning) Summery of Industrial waste, its origin, character and treatment.

Unit 5

Solid waste management, source and characteristics, environmental and health implications, refuse characteristics, collection methods, disposal of solid waste by land filling, composting and incineration methods. Collection and disposal of refuse, Composting of refuse.



Unit - 1

Sewage & Sewerage

1.1 Introduction

Sewage is made up of large amount of water and solid matter in suspension and dissolved state. The waste can be broadly classified as night soil, garbage, rubbish, sullage, sewage. Storm water, subsoil water etc. may be classified into two categories viz. solid waste and liquid waste. Both solid and liquid waste should be properly collected and conveyed for treatment and disposal.

Question 1

Define the following terms.

(1) Refuse
(2) Garbage
(3) Rubbish
(4) Sullage *(CSVTU, April-May 2012) (CSVTU, April-May 2011)*
(5) Sewage
(6) Sub-soil water
(7) Storm water
(8) Sanitary sewage
(9) Domestic sewage
(10) Industrial sewage
(11) Night soil
(12) Sewerage

Or

Term used to indicate the wash basin waste water:

(1) Sullage
(2) Sewage
(3) Night Soil
(4) Garbage *(CSVTU, April-May 2012)*

Ans.

(1) **Refuse:** Refuse is a general term used to indicate what is rejected or left out as worthless. It may be in liquid, semi-solid or solid from, and many be divided into six categories: (i) garbage (ii) rubbish (iii) sullage (iv) sewage (v) subsoil water and (vi) storm water.

(2) **Garbage:** Garbage indicates dry refuse. It includes waste paper, decayed fruits and vegetables, grass and leaves, and sweepings from streets market and other public places. Thus garbage contain large amounts of organic and putritying matter.

(3) **Rubbish:** rubbish indicate sundry solid wastes from office, residences and other buildings materials, broken furniture paper rages etc. Generally, Rubbish is dry and is of combustible nature.

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(4) **Sullage:** Sullage is a term used to indicate the waste water from bath room, Kitchen and washing place and wash basins etc. It does not create bad smell since organic matter in it is either absent or is of negligible amount.

(5) **Sewage:** Sewage indicates the liquid waste from the community. It includes sullage discharge from latrines, urinals stables industrial waste and also the ground surface and storm water that may be admitted into the sewer. It is extremely putrescible; its decomposition produces large quantities of malodorous gases and it may contain numerous pathogenic or disease producing bacteria

(6) **Sub-soil water:** It is the ground water that find entry into sewers through leaks.

(7) **Storm water:** It indicates the rain water of the locality.

(8) **Sanitary sewage:** Sanitary swage or domestic sewage indicates sewage mainly derived from the residential building and industrial establishments. It is extremely foul in nature. Sanitary sewage may be classified as (i) domestic sewage and (ii) industrial sewage.

(9) **Domestic sewage:** It is the sewage obtained from the lavatory basins urinals and water closets of residential building office buildings theatres and other institution. Since it contains human excreta and urine, it is extremely foul and nature.

(10) **Industrial sewage:** It is waste water obtained from the industrial and a commercial establishment it may contains objectionable organic compounds that may not be amenable to conventional treatment process.

(11) **Night soil:** It is a term used to indicate the human and animal excreta.

(12) **Sewerage:** The entire science of collecting and carrying the sewage by water carriage system through sewers is known as sewerage.

Question 2

Zero specific gravity of sewage is: *(CSVTU Nov-Dec 2011)*

(1) Zero (2) Equal to 1 (3) > 1 (4) < 1

Ans. (3) > 1

1.2 Sewage Disposal

Question 3

Describe the conditions for satisfactory disposal of sewage. *(CSVTU April-May 2012)*

Ans. The following condition should be satisfied for the safe disposal of sewage.

1. The waste should not pollute the ground surface, nor is it exposed to atmosphere.
2. It does not give rise to the odor nuisance.
3. It does not give unsightly appearance.
4. It does not give rise to mosquito nuisance.
5. It should also not be accessible to insects and rodents.
6. It does not pollute the natural water resources.

Question 4

What is the objective of sewage disposal?

Ans. Following are the objectives of sewage disposal:

1. Proper disposal of human excreta to a safe place, before it starts decomposing and may cause insanitary conditions in the locality.
2. To take out all kinds of waste water from the locality, immediately after its production so that mosquitoes, flies, bacteria etc may not breed in it and cause nuisance.
3. Final disposal of sewage on land or in nearby water courses after some treatment, so that receiving land or water may not get polluted and unsafe for its further use.
4. As far as possible, the fertilizing element of sewage may be used in growing crops through sewage farming and getting some income in addition to the disposal of sewage.
5. In unsewered areas, the treatment of sewage from individual houses should be done by septic tank or other suitable means and the effluent should be disposed off.
6. If the sewage is disposed off on the land, it should have such degree of treatment that it may not affect the sub soil in any way.

Question 5

What do you mean by hygienic conditions? *(CSVTU Nov-Dec 2009)*

Ans. Hygienic condition is the science of maintaining cleanliness in order to prevent the spread of diseases and preserves health.

1.3 Quantity of Sewage

Question 6

How the amount of sewage is estimated? *(CSVTU April-May 2010)*

Ans. The quantity of sewage can be determined as follows.

Quantity of sewage =

[Total quantity of water supply]+[Addition due to infiltration etc]-[Subtraction due to leakage and consumption]

From the experiment, it is found that the quantity of sewage is equal to 70 - 80 %of the total water supplied to the consumers.

Question 7

What is importance of quantity of sewage? *(CSVTU Nov-Dec 2010)*

Ans. The quantity of sewage is the controlling factor in the design of sewer. During the design of sewer, the discharge to be carried is first determined, then the velocity of the flow and the gradient of the sewer are properly determined to achieve the required result.

1.4 System of Sanitation

Question 8

Explain the different systems of sanitation. *(CSVTU, April-May 2010)*

Or

What do you understand by the 'Conservancy System' and 'Sewerage System'? *(CSVTU, April-May 2013)*

Ans. System of sanitation is classified on the basis of method of collection and conveyance of water produced in a community.

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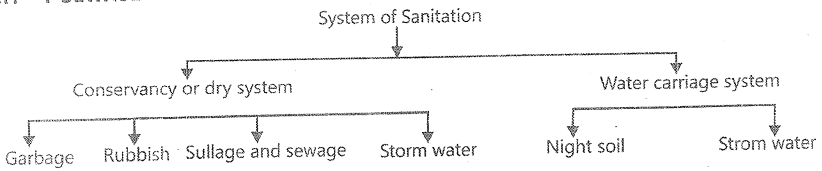


Fig. 1.1

(a) **Conservancy or Dry System** - This system is also called as dry system. In this system, various types of refuse and storm water are collected, conveyed and disposed off separately by different methods. Therefore this method is also called as *conservancy system*.

The method of collection of various types of refuse or waste in this system is as follows:

1) **Garbage:** Garbage or dry refuse of the town is collected in dustbins placed along the roads and streets, from where it is conveyed by trucks or covered carts once or twice in a day to the point of disposal. The flammable garbage such as dry leaves, waste paper, broken furniture etc. should be burnt where as the inflammable garbage such as sand, dust, clay; ashes etc. are used for filling the low lying areas.

2) **Night Soil / Human Excreta:** These are collected separately in the privies or conservancy latrines. The liquid and semi liquid waste are collected in separate drains of the latrines from where they are removed through human agency and carried in carts, trucks etc to a place away from the town. The night soil is buried in the trenches.

3) **Sullage / Storm Water:** These are carried separately in closed or open drains up to the point of the disposal and finally allowed to discharge in to the river or stream.

(b) **Water Carriage System** - The system in which the water is used as medium for conveying the sewage of the treatment plant and final disposal is known as *water carriage system*. In this system, the excretal matters are mixed up in large quantity of water and are taken out from the city through properly designed sewerage system where they are disposed off after the necessary treatment. The sewage so formed in the water carriage system consists of 99.99 percent of water and 0.1 percent of solid matters. All these solids remain in suspension in sewage and do not change the specific gravity of the water.

Question 9

Explain the advantages and disadvantages of conservancy system.

Ans. Following are the advantages and disadvantages of conservancy system.

a) **Advantages of the Conservancy System**

1. It is cheap because very little quantity of water is required for its working.
2. The quantity of the sewage before reaching the disposal point is low.
3. In floods, if the water level of the river rises at the out fall, it will not be costly to pump the sewage.

b) **Disadvantages of the Conservancy System**

1. It is highly unhygienic and develops insanitary condition because the excreta start decomposing within few hours of its production.
2. The system requires considerable land for the disposal of the different types of wastes.
3. The working of the system depends entirely on the mercy of labour.
4. If sullage is carried in open drains, may result in insanitary condition.
5. Due to improper or careless disposal of refuse or wastes, there are chances of outbreak of sewage. In rainy season or in flood, the night soil trenching ground may be submerged and it may cause water pollution.
6. Initially it is seen to be cheap, but the maintenance cost is very high.

Question 10

Explain the advantages and disadvantages of water carriage system.

Ans. Following are the advantages and disadvantages of water carriage system.

a. **Advantages of Water Carriage System**

1. It is hygienic method because all the excremental matters are collected and conveyed by water only and no human agency is employed for it.
2. There is no chance of any nuisance on the street.
3. Less area is required for the treatment works.
4. Sewage after proper treatment can be used for various purposes.
5. It does not depend on manual labor except in the case of cleaning of sewer, when required.
6. The usual water supply is sufficient and no additional water is required in water carriage system.
7. As only one sewer is laid, therefore it occupies less space in the crowded lanes.
8. There are no chances of outbreak of epidemic because flies and other insects do not have direct access to the sewage.

b. **Disadvantages of Water Carriage System**

1. This system is very costly as the initial cost is high.
2. The maintenance of the system is also costly.
3. During monsoon, large volumes of the sewage are to be treated where as very small volume is to be treated in the remaining period of the year.

Question 11

Differentiate between water carriage system and conservancy system.

(CSVTU Nov -Dec 2008)

Ans. **Comparison of Conservancy and Water Carriage System**

	Conservancy System	*Water-Carriage system*
1.	Very cheap and initial cost.	It involves high initial cost.
2.	Due to foul smell from the latrines, they are to be constructed away from the living room; building cannot be constructed as	As there is no foul smell, latrines remain clean and neat hence are constructed with rooms.

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	compact units.	
3.	The aesthetic appearance of the city cannot be increased.	Good aesthetic appearance of the city can be obtained.
4.	For burying of excremental matter large area is required.	Less area is required as compared with the conservancy system.
5.	Excrete is not removed immediately hence its decomposition starts before its removal, causing nuisance of smell.	Excreta is immediately removed with water, no problem of foul smell or hygienic trouble.
6.	Storm water is carried in usually surface drains hence no problem of pumping the storm water.	Sewage is treated before disposing off, it may are may not require pumping it depends on the town.
7.	The quantity of waste liquid reaching the disposed point is less, hence it can be disposed of without any treatment.	Large quantity of sewage highly polluted in nature it requires its treatment before disposal. So it is costlier in operation and maintenance.
8.	This system is fully dependent on the human agency. In case of strike by the sweepers, there is danger of insanitary condition in the city, which may cause spreading of disease.	As on human agency is involved in this system, there is no such problem as in case of conservancy system.
9.	As sewage is disposed of without any treatment, it may pollute the nature water courses.	Sewage is treated up to required degree of sanitation.

1.5 System of Sewerage

Question 12

Describe briefly the various commonly adopted sewerage systems.

(CSVTU Nov -Dec 2010)

Or

Describe the various systems of sanitation giving their advantages and disadvantages. Considering the water shortage in townships and cities, what are the modifications you would suggest for better functioning of the system?

(CSVTU April-May 2010) (CSVTU Nov -Dec 2009)

Or

Discuss the relative merits of separate and combined system of sewage.

(CSVTU April-May 2011)

Ans. The system of sewerage can be divided into following types.

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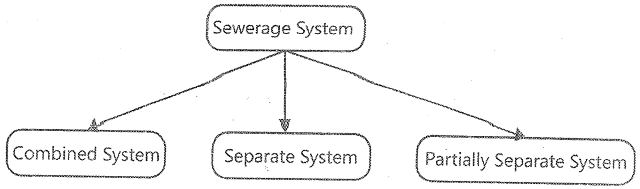


Fig. 1.2

(a) Combined System

The combined system provides only one sewer to carry both the foul sewage as well as the rain water. The sewage and rain water are carried to the sewage treatment plant, before its final disposal. This is provided on the ground that the street washing are as impure as sewage itself so care should be taken that it has to be properly treated that it enters the natural stream.

Advantages of Combined System:

1. The system requires only one set of sewers. Hence the maintenance costs are reduced.
2. The sewers are of large size therefore chances of their choking are rare, also it is easy to clean them.
3. The strength of sewage is reduced by dilution.
4. This is relatively simple system of collection of sewage and also in this system house plumbing is economical.

Disadvantages of Combined System:

1. The cost of construction is very high because of large dimension of the sewers to be constructed at sufficient depth to receive the sewage from the basement.
2. Because of large size of sewer, their handling and transportation is difficult.
3. Initial cost is high as compare to separate system..
4. During heavy rain, the overflowing of sewers will endanger the public health.
5. If the whole sewage is to be disposed of by pumping, it is uneconomical.
6. In congested areas, it is easy to play one large sewer than to smaller sewers.

(b) Separate System

When the domestic and industrial sewage are taken in one set of sewers whereas storm and surface water are taken in another set of sewers, it is called separate system. In the separate system, if a portion of storm water is allowed to enter in sewers carrying sewage, and the remaining storm water flows in separate set of sewers, it is called partially separate system. If rain fall is heavy and it is for short time, it is better to provide separate system because in combined system self-cleaning velocity will not be available for most of the period of the years.

Advantages of separate system

Following are the Disadvantage of separate system:

1. The sewage flow in separate sewer, there for the quantity to be treated is small which rebuilt in economical design of treatment works.
2. Separate system is cheaper than combined system, because only sanitary sewage flows in closed sewers and the storm water which is unfoul in nature can be taken

through open gutters or drains, whereas both types of sewage is to be carried in closed sewer in case of combined system.

3. During disposal if the sewage is to be pumped, the separate system is cheaper.
4. There is no fear of stream pollution.

Disadvantages of separate system:

Following are the disadvantage of separate system:

1. Generally self-cleaning velocity is not available due to small quantity of sewage therefore flushing is required at various points.
2. There is always risk that storm water may enter the sanitary sewer and cause over flowing of sewer and heavy load on the treatment plant.
3. As two sets of sewers are laid therefore its maintenance cost is more.
4. In busy lanes, laying of two sewer is difficult which also cause great inconvenience to the traffic during repairs.

(c) **Partially Separate System :**

Sewers are designed as sanitary sewer but sufficient excess capacities are provided to carry a part of storm discharge also .In this type the initial washings from the drainage area i.e. a part of storm water are included in the sewers. When the quantity of the storm water further exceeds the permissible capacities the excess is diverted into natural water course.

Advantages of Partially Separate System

1. As it is an improvement over the separate system, economical and reasonable size of the sewers are required.
2. The storm water eliminates the chances of sewer choking.
3. The work of house plumbing is reduced.
4. No flushing is required, because the quantity of sewage is increased as small portion of storm water is allowed to enter in sanitary sewage.

Disadvantages of Partially Separate System

1. There are possibilities of overflow, requiring storm overflows.
2. In dry weather self cleaning velocity may not be developed.
3. If the diversion of storm water is not done at proper time, then it may create unnecessary trouble both in the treatment plant and in the sewers.

Question 13

Explain conditions which are favorable to the combined system.

(CSVTU, April-May 2011)

Ans. **Following are the conditions favorable to the combined system:**

1. **Restriction of space:** when the space available for laying the sewer is restricted it is desirable to lay a combined sewer.
2. **Even Rainfall:** If the rainfall is even than the combined sewer can be used.
3. **Pumping Requirement:** When it is necessary to pump domestic or sanitary sewage, industrial sewage or storm water the combined system can be used.
4. **Conversion of existing storm water sewer:** If existing storm water sewer may be converted into combined sewer, then combined system may be preferred.

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Question 14

Explain conditions which are favorable to the separate system.

(CSVTU, April-May 2011)

Ans. **Following are the Conditions favorable to the separate system:**

1. **Uneven Rainfall:** When the rainfall is uneven, then it becomes economical to adopt separate system.
2. **Time of laying sewer:** If the sewers are to be laid before the area is developed, it is desirable to adopt separate system.
3. **Subsoil Conditions:** If the subsoil is hard, then the combined system is very difficult to be laid therefore separate system is desirable.
4. **Gradient of sewer:** If it is not possible to lay sewer at suitable gradients, there is a danger house. Under such circumstances, it is desirable to adopt separate system.

1.6 Considerations for the Type of System

Question 15

What are the points to be considered before selecting the type of collection system?

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

1) The separate system requires laying of two sets of conduits whereas in combined system only one bigger size conduit is required.
2) Laying of two separate conduits may be difficult in the congested streets.
3) In combined system sewers are liable for silting during non-monsoon season, hence they are required to be laid at *steeper gradients*. Steeper gradients for the sewers may require more number of pumping stations, particularly for flat terrain, which may make the system costly.
4) Large quantity of wastewater is required to be treated before discharge in case of combined system. Hence, large capacity treatment plant is required.
5) In separate system, only sewage is treated before it is discharged in to natural water body or used for irrigation. No treatment is generally given to the rainwater collected before it is discharge in to natural water body.

Question 16

State with reasons why in a country like India the partially combined system of sewage collection suits the best. *(CSVTU, April-May 2013)*

Or

What type of sewage system will you recommend for the cities of Chattisgarh? Explain your choice giving suitable reason. *(CSVTU, Nov-Dec 2010)*

Ans. As in combined system only one set of the sewer is laid for carrying both liquid waste from community and storm water. This is generally adopted in India because

1) Self cleansing velocity can be easily achieved.
2) This system requires only one set of sewer so the operating and maintenance cost is very low.
3) Also the rainfall in India is uneven.

4) As space available for laying of the sewer is restricted so combined system is adopted.
5) It combines the advantages of both combined systems and separate systems.
6) The entry of storm water avoids silting in sewers.
7) The problem of disposing storm water from houses is simplified.

1.7 Patterns of Collection Systems

Question 17

Describe in brief the patterns of collection of stream and waste water.

(CSVTU April-May 2009)

Ans. The pattern of the collection system mainly depends on the following factors.

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

There are various patterns of the systems, but the following are most commonly used.

1. Perpendicular Pattern
2. Interceptor Pattern
3. Radial Pattern
4. Fan Pattern
5. Zone Pattern

1. **Perpendicular Pattern** - In this pattern, sewers carrying storm water are laid in such a way to seek the shortest possible path to the natural water course. The shortest possible path to the natural water course can be obtained if the sewers are laid perpendicular to them. It is suitable for the separate system and partially separate system in which the water can be directly disposed off without any treatment. It is not suitable for the combined system.

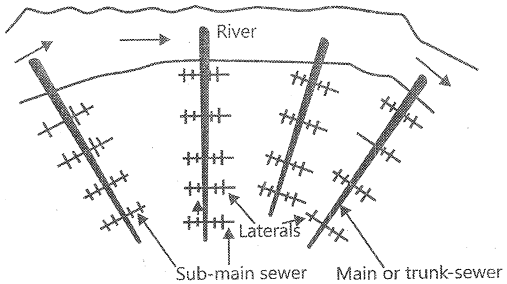


Fig. 1.3 Perpendicular Pattern

2. **Interceptor Pattern** - This pattern is an improvement over the perpendicular pattern. In this pattern the sewer are intercepted by large size sewers, which are laid along the water carrying sewage to a common point, where it can be disposed off with or without treatment. If the quantity of storm water is very large, overflows should be provided as shown in the figure, allowing the excessive sewage to spill over into natural water course through outlet which are existing before the interception.

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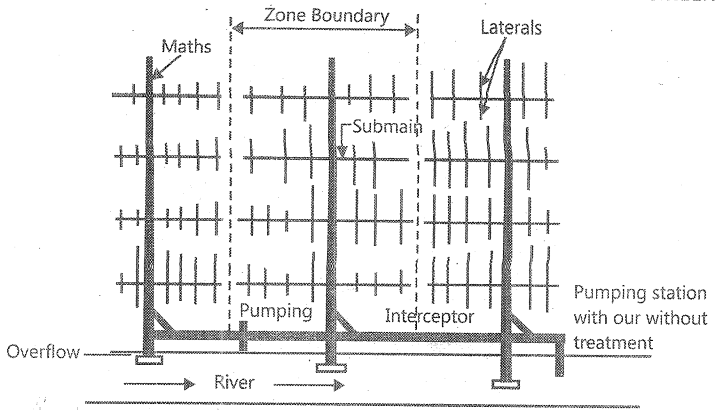


Fig. 1.4 Interceptor Pattern

3. **Radial Pattern** - This type of pattern can be employed if the sewage is to be disposed off on land around the town. In this pattern large numbers of outlets are provided. The sewers are laid radially outwards from the center of the city, therefore this is called as radial pattern.

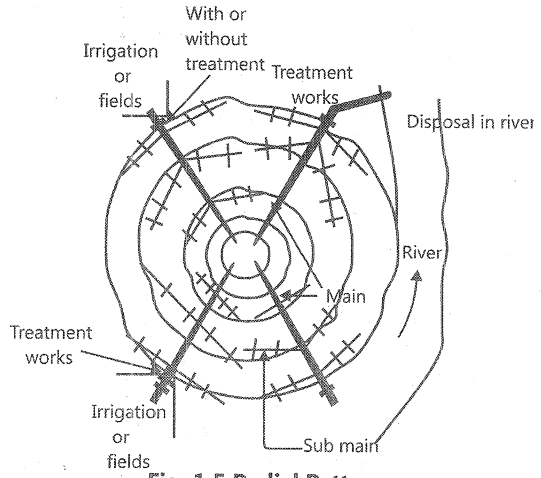


Fig. 1.5 Radial Pattern

4. **Fan Pattern** - If the city is situated near the river, which is on one side of it only, the sewer can be laid in such a way that the whole sewage flows to a common point where one treatment plant can be located. In this pattern no of converging main sewers are laid which forms a fan like shape. The only advantage of this pattern is being a single unit of treatment work. But the diameter of the sewer increases as the sewage moves, due to which the diameter of the main trunk is very large, increasing the overall cost of this pattern.

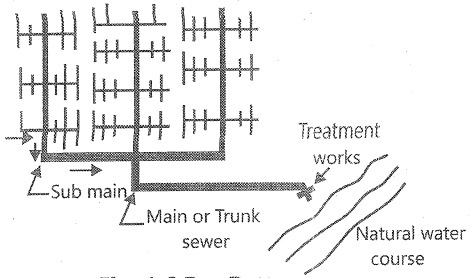


Fig. 1.6 Fan Pattern

5. **Zone pattern:** In the interceptor pattern only one single large size intercepting sewer is used to collect and convey the entire sewage, due to which it is overloaded. This overloading can be removed by providing more number of interceptors of each zone. This type of pattern is most suited to sloppy areas as hills than flat areas.

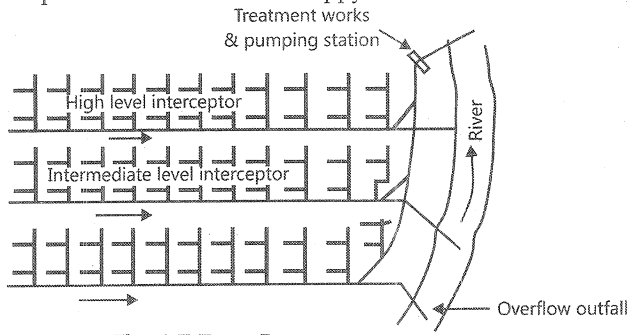


Fig. 1.7 Zone Pattern

1.8 Quantity estimation of storm sewage

Question 18

Enlist the factors affecting the Quantity of Storm Water.

Ans. **Following are the factors affecting the quantity of storm water.**

The surface run-off resulting after precipitation contributes to the storm water. The quantity of storm water reaching to the sewers or drains is very large as compared with sanitary sewage.

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

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

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1.9 Methods for Estimation of Quantity of Storm Water

Question 19

What are the different methods for determining the quantity of storm water?

Ans. Following are the different methods for determining the quantity of storm water.

1. Rational Method
2. Empirical formulae method

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

Rational Method

Storm water quantity can be estimated by rational method as below:

Storm water quantity, $Q = C.I.A / 360$

Where,

Q = Quantity of storm water, m^3/sec
C = Coefficient of runoff
I = intensity of rainfall, mm/hour, and
A = Drainage area in hectares

OR

$Q = 0.278\ C.I.A$

Where, Q is m^3/sec; I is mm/hour, and A is area in square kilometer.

Question 20

Give various empirical formulae for determining storm water flow in sewers, explaining their applicability. *(CSVTU April-May 2012)*

Ans. The empirical formula is based on the experience and experiments on various conditions such as nature of surface area, intensity of rainfall, impermeability and the topography of the concerned area.

The following empirical formulas are generally used.

(a) **Inglis formula**

$$Q = \frac{123100\ A}{\sqrt{A + 10.36}}$$

Where, Q = Storm water in liter/sec
A = Area in km^2

This formula was devised for the old Bombay presidency.

(b) **Fanning's formula**

$$Q = 3125\ A^{5/8}$$

Q = Runoff in lit/sec
A = Area in km^2

(c) **Talbot's formula**

$$Q = 87000\ A^{1/4}$$

(d) **Ryve's formula**

$$Q = 15\ CA^{2/3}$$

Where, C = constant and its value varies from 450 to 675. This formula is suited for conditions prevailing in South India.

(e) **Dicken's formula**

$$Q = 14\ CA^{3/4}$$

Where, C= const and its value varies from 250 to 1600. 250 = for larger area; 1600 = for smaller area; this formula is suited for conditions prevailing in North India.

(f) **Burkli – Ziegler formula**

$$Q = 296\ CIA\sqrt[4]{\frac{S}{A}}$$

Where, Q = Runoff in lit/sec
C = Constant depends on nature of ground surface.
= Varies between 0.5 – 0.90; average ≈ 0.7
I = Maximum rate of rainfall in mm/hr
A = Area in hectares.
S = Slope in m per 100 meth length of sewer

(g) **McMath's formula**

$$Q = 292\ CIA\sqrt[5]{\frac{S}{A}}$$

Where, Q = Runoff in lit/sec
C = Constant depends on nature of ground surface.
= Varies between 0.5 – 0.90; average ≈ 0.7
I = Maximum rate of rainfall in mm/hr
A = Area in hectares.
S = Slope in m per 100 meth length of sewer

The value of C varies from 0.3 to 0.9. This formula is generally used for local conditions of St. Louis.

(h) **Metcalf and Eddy formula**

$$Q = 28.316\left[\frac{25000}{2.471\,A + 125} + 15\right]$$

This formula is adopted for storm occurring in small areas.

Question 21

Explain the term time of concentration.

Ans. **Time of Concentration:** The period after which the entire catchment area will start contributing to the runoff is called as the *time of concentration*.

a) The rainfall with duration lesser than the time of concentration will not produce maximum discharge.

b) The runoff may not be maximum, even when the duration of the rain is more than the time of concentration. This is because in such case, the intensity of rain reduces with the increase in its duration.

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c) The runoff will be maximum, when the duration of rainfall is equal to the time of concentration and is called as *critical rainfall duration*. The time of concentration is equal to sum of inlet time and time of travel.

Time of concentration = Inlet time + time of travel

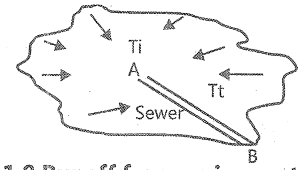


Fig. 1.8 Runoff from a given catchment

1.10 Variation in the quantity of sewage

Question 22

Write a short note on the variation of the sewage flow.

Ans. The sewage flow like the water supply flow is not constant, it varies with every hour of the day, every day of the season and every season of the year. The designer is concerned with the both maximum and minimum rate of flow. The sewer should be so designed that it can take maximum load. At the same time, they should be laid on such longitudinal gradient that there are no deposits in the sewer at the minimum flow. Both the maximum and minimum flows are expressed as percentage of the average rate of flow. The variations in the flow may be due to several factors such as habits of the people, working hours of the office, climatic conditions, timings of the water supply, type of industries etc. hourly variations are because of varying rate of water consumption at different hours of the day. Sewers are designed for carrying maximum hourly flow running 3/4 th full.

Maximum Daily flow = 2 × Average daily flow
Maximum hourly flow = 1.5 × Maximum Daily flow
Maximum hourly flow = 3 × Average Daily flow

Question 23

What are self cleansing velocity, scouring and limiting velocity?
Or
What do you understand by self cleaning velocity? *(CSVTU, April-May 2009)*

Ans. **Self cleansing velocity:** The minimum velocity at which the sewer will keep itself clean over a wide variation in discharge is known as self cleansing velocity. It depends upon the size of particles present in sewage and their specific gravity.

Scouring velocity: The minimum velocity to cause the scouring of the suspension of the solids heavier than the sewage or liquid is known as scouring velocity. The self cleaning velocity will depend on scouring action of the flowing sewage.

Limiting velocity: The maximum permissible velocity which does not cause any wear of contact surface and does not make the surface rough is known as limiting velocity. Above this, limiting velocity scouring will take place.

Question 24

Why maximum and minimum velocities are essential to be maintained in the sewer?

Ans. The sewage must flow in the sewer at all the times with velocity sufficient to keep it in suspension. The velocity shall neither be too small nor be very great.

If too small, the suspended matter gets settled down in the sewer because of sudden loss of transporting power of flow. Since transporting power of flow varies as sixth power of velocity, any fall in the velocity of flow would cause a big drop in the transporting power of sewage flow. If the velocity is too great, the suspended matter is likely to erode the material of sewer. Hence, the maximum and minimum velocities are essential to be maintained in the sewer.

1.11 Shield's Expression for Self Closing Velocity

Question 25

Derive an expression for shield self cleansing velocity. Also derive an expression for proportionate area, velocity and HMD. *(CSVTU, Nov-Dec 2011)*

Ans. Self cleansing velocity may be defined as *that velocity, at which solid particles will remain in suspension, without setting at the bottom of the sewer.* The self cleansing property is dependent on the scouring action of the flowing sewage. According to shield, the velocity required to transport water borne solids is the self cleansing velocity which can be determined from the following figure.

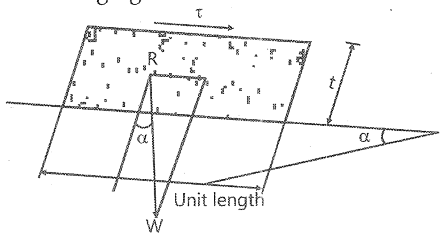


Fig. 1.9

Consider a layer of sediment of unit length, unit width and thickness t, deposited at the invert of the sewer. Let the slope of the sewer be α .The water flowing in the sewer will exert a force, on the sediment in the direction of flow which tends to move the sediment. This force is called as *drag force* or *tractive force* (τ) and is given by

$$\tau = wRS \quad \cdots (1)$$

Where,

τ = Tractive force/Drag force
R = Hydraulic mean depth
S = Slope of sewer
w = Unit weight of water at prevailing temperature

The motion of the sediment is opposed by the frictional resistance, F. When the sediment is just on the point of moving, the frictional resistance is given by the expression,

$$F = W \sin\theta \quad \ldots (2)$$

Where , W = Effective weight of the sediment

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θ = Angle of internal friction of sediment.

The weight of sediment of unit length and unit width is given by,

$$W = w_{sub} \times 1 \times 1 \times t \quad \ldots (3)$$

Where , w_{sub} = submerged unit weight of sediment

The submerged unit weight of sediment is given by,

$$w_{sub} = w\left[\frac{G_s - 1}{L + e}\right]$$

$$= w\,[(G_s - 1)\ (1 - n\,] \quad \ldots (4)$$

G_s = Specific gravity of sediment
e = Void ratio of sediment deposit
n = Porosity of sediment deposit

Putting the value of w_{sub} is equation no (3)
We get,

$$W = w\,[(G_s - 1)(1 - n)]t \quad \ldots (5)$$

Substituting the value of W in equation

$$F = w\,(G_s - 1)(1 - n)\,t \times \sin\alpha \quad \ldots (6)$$

When the sediment is just on the point of moving,

$$\tau = F$$

$$wRS = w\ (G_s - 1)(1 - n)\,t \sin\alpha$$

$$S = \frac{1}{R}(G_s - 1)(1 - n)\,t \sin\alpha$$

Putting $(1 - n)\sin\alpha = k$

Where, k is the important characteristic of sediment, to be determined by experiments, we get

$$S = \frac{k}{R}(G_S - 1)t \quad \ldots (7)$$

For a single layer of grains, the volume per unit area, i.e., t becomes a function of diameter of grains d_s as the individual grains exposed to drag friction.

$$S = \frac{k}{R}(G_S - 1)\,d_S \quad \ldots (8)$$

Equation (8) gives the invert slope at which the velocity will be self cleansing.
From Chezy's formula, we have

$$V = C\sqrt{RS}$$

Denoting $V = V_S$ as self cleansing velocity and substituting the value of S from equation (8),

$$V_S = C\sqrt{R} \times \sqrt{\frac{k}{R}(G_s - 1)} \times d_s$$

$$V_S = C\sqrt{k\,.(G_s - 1) \times d_S} \quad \ldots (9)$$

In order to determine the Chezy's constant C, Darcy–Weishbach formula equation of head loss H_f is used,

$$H_f = \frac{fLV^2}{2gD}$$

Where, D = pipe diameter

$$\therefore \quad S = \frac{H_L}{L} = \frac{f V^2}{2gD}$$

Now, $$V = C\sqrt{R.S}$$

$$\therefore \quad C\sqrt{R} = \frac{V}{\sqrt{S}} = \sqrt{\frac{2gD}{f}}$$

For circular pipes, running full

$$R = D/4$$

$$C\sqrt{\frac{D}{4}} = \sqrt{\frac{2gD}{f}}$$

$$C = \sqrt{\frac{8g}{f}} \qquad \ldots (10)$$

Substituting the value of C, in equation (9)

$$V_S = \sqrt{\frac{8\beta}{f}(G_s - 1)\, g d_S} \qquad \ldots (11)$$

Where,

V_S = Self cleansing velocity

β = Characteristics of solids flowing. In the sewage, in suspension

β = 0 · 04 for initiating scour of clean grit to 0.8 for full removal of sticky grit. Actual magnitude of k has to be found from experiments.

G_s = Specific gravity of sediments flowing in the sewage. It may range from 2.65 for inorganic sediments to 1.2 to you organic sediments .

g = Gravitational acceleration constitution

d_S = Diameter of solid parcticles to be carried by the liquid.

Question 26

Enlist the various empirical formula used in the design of sewer.

Ans. Design of sewer is done on the basis of the following hydraulic empirical formulae:

1. Chezy's formula
2. Manning's formula
3. Hazen and Williams formula
4. Bazins formula
5. Kutters formula
6. Bruges formula

1. **Chezy's Formula**: Chezy's gave the following formula.

$$V = C\sqrt{RS} \qquad \ldots (1)$$

Where, V = velocity of flow (m/sec)

S = slope of the sewer

R = hydraulic mean radius

R = (A/P)

A= area of cross section(m^2)

P= wetted perimeter

C = Chezy's constant

The Chezy's constant C is very complex in nature and depends on several factors, such as roughness of inner surface of sewer, hydraulic mean radius, size and shape of sewer slope etc. Generally the value of C is found out by Kutter's formula or Bazin's formula. Knowing the velocity of flow V from eqn. (1), the channel section is designed by the following general formula

$$Q = A \times V$$

Where Q = discharge in m^3/sec.

2. **Kutter's formula:** Kutter gave the following expression for Chezy's coefficient C,

$$C = \frac{23 + \frac{0.00155}{S} + \frac{1}{N}}{1 + (23 + \frac{0.0155}{S})\frac{N}{\sqrt{R}}}$$

Where, R = Hydraulic mean radius

S = slope of the sewer

N = Rugosity coefficient the value of which depends upon the nature of inside surface of the sewer.

For the cement concrete pipes of diameter 600 mm and above, a value of N = 0.013 may be adopted.

3. **Bazin's Formula**: Bazin (1897) gave the following formula for chezy's constant.

$$C = \frac{157.6}{1.81 + \frac{k}{\sqrt{R}}}$$

Where, k = Bazin's constant

4. **Manning's formula:** Manning(1890) gave the following expression for the velocity of flow. This is widely used in India as well as U.S.A.

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

where, V = velocity of flow (m/sec)

S = slope of the sewer

R = hydraulic mean radius

R = (A/P)

N = Rugosity coefficient the value of which depends upon the nature of inside surface of the sewer.

5. **Crimp and Burge's Formula**: This formula is commonly used in England.

$$V = 83.47\, R^{2/3} S^{1/2}$$

6. **Hazen and William's Formula**: Allen Hazen's and G.S. William's (1902) gave the following formula which is generally used for flow under pressure.

$$V = 0.85\, CR^{0.63} S^{0.54}$$

Question 27

Explain the various methods of sewer testing.

Ans.

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The various tests are applied to check the straightness of sewer. The drains are usually tested in sections between successive chambers and the vertical pipes are tested. Following are the tests which are commonly employed.

1. *Air test*
2. Coloured water test
3. Hydraulic test
4. Smell test
5. Smoke test

1. **Air test** - This is applied for the underground and vertical pipes. The particular section is selected and the plugs are provided at the upper and lower ends. The air is forced in the pipe by suitable equipment such as pump. The leaky joints are found out by applying soap solution. The escape of the air from the leaky joints will form bubbles which are visible. These joints are then repaired.
2. **Coloured water test** - When the coloured water is allowed to flow from one point to other point of the drain, it will come out through the leaky joints. Thus, the leakage can be detected and the suitable remedies may be applied to remove it from the joints.
3. **Hydraulic Test** - This is most common test which is applied for water tightness of the joints in underground drains. The sewers are tested by plugging the upper end with a provision for an air outlet pipe with stop cock. The water is filled through a funnel connected at the lower end provided with a plug. After the air has been expelled through the air outlet, the stop cock is closed and water level in the funnel is noted after 30 minutes and the quantity of water required to restore the original water level in the tunnel is determined. The pipe line under pressure is then inspected while the funnel is still in position. There shall not be any leaks in the pipe or the joints, though small sweating on the pipe surface is permitted. Leakage in 30 minutes determined by measuring the replenished water in the funnel shall not exceed 15 ml in the smaller diameter and 60 ml in the larger dia. per cm dia. of pipe for 100 mm length. My sewer or part there of that does not meet the test shall be emptied and repaired or relaid as required and tested again. For concrete, R.C.C. and asbestos cement pipes of more than 600 mm dia, the quantity of water inflow can be increased by 10% for each additional 100 mm of pipe dia. For brick sewers, regardless of their diameter, the permissible leakage of water shall not exceed 10 m3/24 hours per km length of the sewer. 3. Smoke test. Smoke test is carried out for drainage pipes located in buildings. The smoke is produced by burning oil waste tar paper etc. in the combustion chamber of a smoke machine. The pipes are approved gas-tight by the smoke test conducted under pressure of 25 mm of water, maintained for 15 minutes after all trap seals have been filled with water.
4. **Smell Test** - This is similar to the air test but in this case the air is mixed with some smelling gas which can be easily recognized. Such air is allowed to pass through the drain. The escape of air from leaky joints is detected by small and such joints are then repaired.

5. **Smoke Test** - This is similar to air it except that smoke is introduced in the drain instead of air. This test is generally applied for detecting leakage in existing drains.

Question 28

Write a short note on different types of materials used for the sewer construction.

Ans. The following materials are used for sewers.

1. **Asbestos Cement Sewers**

These are manufactured from a mixture of asbestos fibers, silica and cement. Asbestos fibers are thoroughly mixed with cement to act as reinforcement.

These pipes are available in size 10 to 100 cm internal diameter and length up to 4.0 m. These pipes can be easily assembled without skilled labor with the help of special coupling, called 'Ring Tie Coupling' or Simplex joint. The pipe and joints are resistant to corrosion and the joints are flexible to permit 12°deflection for curved laying. These pipes are used for vertical transport of water. For example, transport of rainwater from roofs in multistoried buildings, for transport of sewage to grounds, and for transport of less foul sullage i.e., wastewater from kitchen and bathroom.

Advantages

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

Disadvantages

1. These pipes are structurally not very strong.
2. These are susceptible to corrosion by sulphuric acid. When bacteria produce H2S, in presence of water, H2SO4 can be formed.

2. **Plain Cement Concrete Pipes or Reinforced Cement Concrete Pipes**

Plain cement concrete (1: 1:5: 3) pipes are available up to 0.45 m diameter and reinforcement cement pipes are available up to 1.8 m diameter. These pipes can be cast in situ or precast pipes. Precast pipes are better in quality than the cast in situ pipes. The reinforcement in these pipes can be different such as single cage reinforced pipes, used for internal pressure less than 0.8 m; double cage reinforced pipes used for both internal and external pressure greater than 0.8 m; elliptical cage reinforced pipes used for larger diameter sewers subjected to external pressure; and hume pipes with steel shells coated with concrete from inside and outside. Nominal longitudinal reinforcement of 0.25% is provided in these pipes.

Advantages of concrete pipes

a. Strong in tension as well as compression.
b. Resistant to erosion and abrasion.
c. They can be made of any desired strength.
d. Easily molded, and can be in situ or precast pipes.
e. Economical for medium and large sizes.

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f. These pipes are available in wide range of size and the trench can be opened and backfilled rapidly during maintenance of sewers.

Disadvantages

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

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

3. **Vitrified Clay or Stoneware Sewers**

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

Advantages

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

Disadvantages

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

4. **Brick Sewers**

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

5. **Cast Iron Sewers**

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

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6. **Steel Pipes**

These are used under the situations such as pressure main sewers, under water crossing, bridge crossing, necessary connections for pumping stations, laying pipes over self supporting spans, railway crossings, etc. They can withstand internal pressure, impact load and vibrations much better than CI pipes. They are more ductile and can withstand water hammer pressure better. These pipes cannot withstand high external load and these pipes may collapse when negative pressure is developed in pipes. They are susceptible to corrosion and are not generally used for partially flowing sewers. They are protected internally and externally against the action of corrosion.

7. **Plastic sewers (PVC pipes)**

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

8. **High Density Polyethylene (HDPE) Pipes**

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

Question 29

Explain the following sewer appurtenances with the aid of sketch.

1. *Drop manhole*
2. *Street Inlet*
3. *Flushing tank*
4. *Lamp hole*
5. *Ventilating shafts*
6. *Storm water regulator*

Ans.

1. **Drop Manholes:** When it is uneconomical or impracticable to arrange the connection with 60 cm of invert of the sewer and manhole, then a vertical shaft is constructed outside the manhole chamber through which the sewage of branch sewer is allowed to enter the manhole as shown in the figure. Such manholes which drop the level of invert of the incoming sewer by providing a vertical shaft are called drop manholes. The main purpose

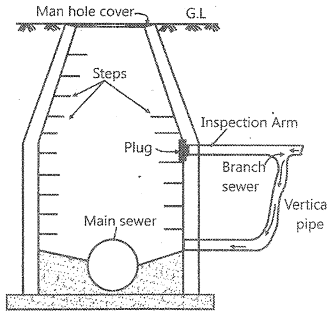


Fig. 1.10 Drop manhole

of drop manhole is to avoid the splashing of sewage on the man working and on the masonry work.

A plug is provided at the point where the branch sewer, if prolonged straight intersects with the vertical wall of the man hole. The prolonged length of the branch sewer, beyond the vertical pipe serves as the inspection arm, after opening the plug it can be used for inspecting the branch sewer.

2. **Flushing Tank:** A flushing tank is a device or an arrangement, which is made to hold and then to throw water in to the sewer for the purpose of flushing it. When the gradients of the sewers are flat and the velocity of sewage is very low, the suspended matter of the sewage starts settling in the bed of the sewer and causes clogging of sewer lines. At such places where self cleaning velocity is not available, flushing tanks are provided to flush the sewers. Two types of flushing tanks are used.
   i. Hand operated flushing tank
   ii. Automatic flushing tank.

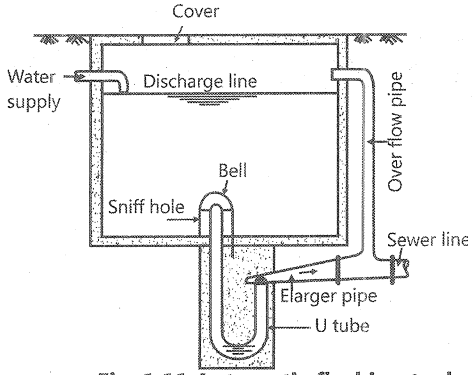


Fig. 1.11 Automatic flushing tank

3. **Lamp hole:** A lamp hole is an opening or hole constructed in a sewer for the purpose of lowering a lamp inside it. It consists of vertical stoneware or concrete pipes which are connected to the sewer line through a tee junction. The pipes are surrounded by concrete to make them stable. At the ground level, the manhole cover with frame is provided to make is provided to take up the load of traffic. The lamp hole is provided to achieve the following objects.

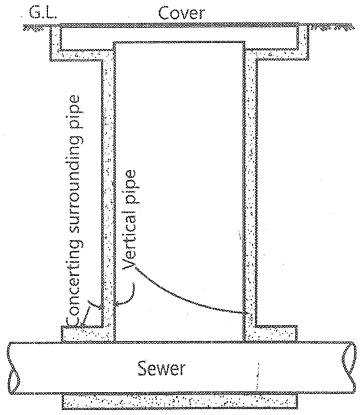


Fig. 1.12 Lamp hole

   i. The lamp hole assists in examining the sewer length between the adjacent manholes. An electric lamp is inserted in the lamphole and the light of the lamp is observed from the manholes if the sewer length is unobstructed, the light of lamp will be seen.

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   ii. If the cover at the top of lamp hole is perforated, the ventilation of the sewer is achieved and such a lamp hole is also known as *fresh air inlet*.

4. **Street inlets:** A street inlet is an opening through which storm water and surface wash flowing along the streets are admitted and conveyed to the storm water sewer or combined sewer by means of pipes. These are placed at the roads, gutters, generally at street junctions. At the street junctions, inlets should be placed in such a way that the storm water does not flow across any of the streets or flood the cross walks causing interference with the traffic.
   a. **Curb inlet:** An opening is provided in the road in the curb for the entrance of storm water.
   b. **Gutter inlet:** These are placed directly below the road gutter and the storm water directly enters from the top.
   c. **Combined gutter and curb inlet:** In this type of the inlet, storm water enters from both gutter and curb.
   d. **Catch basins or catch pits:** Catch basins or catch pit is a structure in the form of a chamber which is provided along the sewer line to admit clear rain water free from silt, grit debris etc in to the combined sewer. The catch basins are adopted for the combined sewerage system.

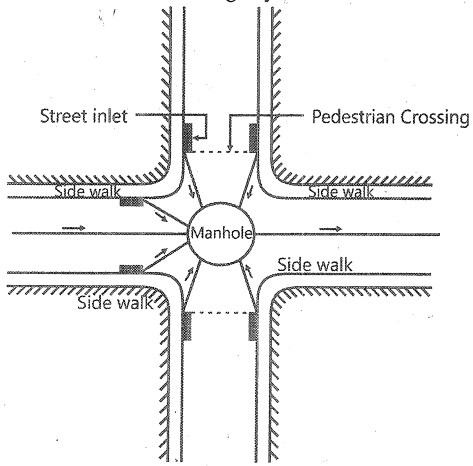


Fig. 1.13 Street Inlet

4. **Ventilating shafts:** It is a vertical shaft provided in the sewer line to remove foul gases from it and to provide fresh air to the workers working in manholes. It may be R.C.C or cast iron 15-25cm in diameter with a cowl provided at the top. The height of ventilating shaft should be more than the roof of the tallest building in the neighborhood.

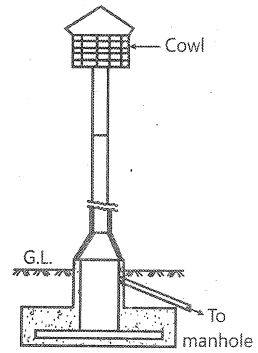


Fig. 1.14 Ventilating Shaft

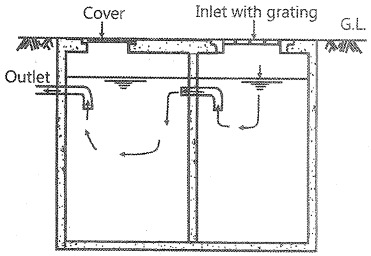


Fig. 1.15 Oil and Grease Trap

5. **Grease and oil traps:** These are the traps or chamber which is provided on the sewer line to exclude grease and oil from sewage before it enters the sewer line. The grease and oil being light in weight and can float on the surface of sewage. Hence if outlet draws the sewage from the lower level, the grease and oil are excluded. Thus the outlet level is near the bottom of the chamber and the inlet level is near the top of the chamber. These are generally provided near the sources contributing grease and oil to the sewage. They are located at the places like automobile repair workshop, grease and oil producing industries, garages, kitchens of hotels etc.

   The grease and oil should be removed from the sewage as their presence adds to the possibilities of explosions in sewer. Also it sticks to the sides of sewer and consequently capacity of sewage is reduced.

6. **Inverted siphons:** These 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. They are constructed when a sewer crosses a stream or deep cut or road or railway line. To clean the siphon pipe sluice valve is opened, thus increasing the head causing flow. Due to increased velocity deposits of siphon pipe are washed into the sump, from where they are removed.

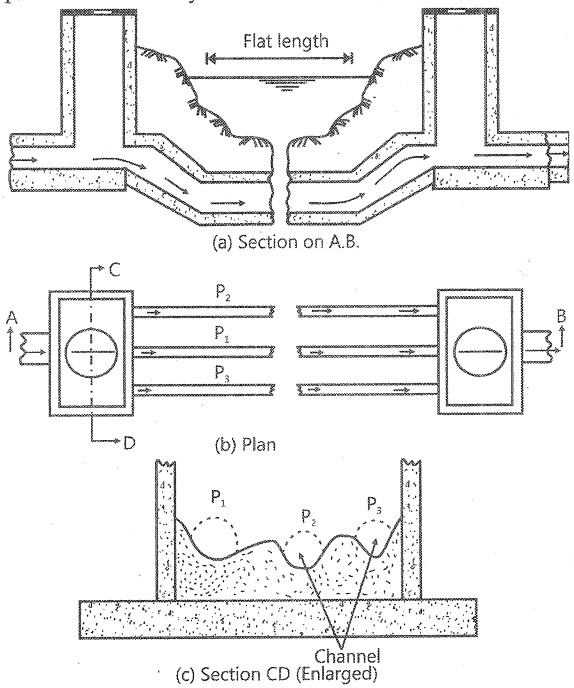


Fig. 1.16 Inverted Siphon

Question 30

What are the factors to be considered while selecting material for the construction of sewer?

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Ans. Following are the factors to be considered while selecting material for the construction of sewer.

1. **Resistance to corrosion**

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

2. **Resistance to abrasion**

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

3. **Strength and durability**

   The sewer pipe should have sufficient strength to withstand all the forces that are likely to come on them. Sewers are subjected to considerable external loads of backfill material and traffic load, if any. They are not subjected to internal pressure of water. To withstand external load safely without failure, sufficient wall thickness of pipe or reinforcement is essential. In addition, the material selected should be durable and should have sufficient resistance against natural weathering action to provide longer life to the pipe.

4. **Weight of the material**

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

5. **Imperviousness**

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

6. **Economy and cost**

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

7. **Hydraulically efficient**

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

1.12 Shapes of Sewer

Question 31

With the help of neat sketches, describe the various section of sewer.

Ans. Sewers are generally circular pipes laid below ground level, sloping continuously towards the outfall. These are designed to flow under gravity. Shapes other than circular are also used. They are as follows:

a. Standard Egg-shaped sewer
b. Horse shoe shaped sewer
c. Parabolic shaped sewer
d. Semi-elliptical section
e. Rectangular shape section
f. U-shaped section

g. Semi-circular shaped sewer
h. Basket handled shape sewer

a. **Standard Egg-shaped sewer:** Standard egg-shaped sewers, also called as *ovoid shaped sewer,* and *new or modified egg-shaped sewers* are used in combined sewers. These sewers can generate self cleansing velocity during dry weather flow. Horse shoe shaped sewers and semi-circular sections are used for large sewers with heavy discharge such as trunk and outfall sewers. Rectangular section is used for conveying storm water. U-shaped section is used for larger sewers and especially in open cuts. Other sections of the sewers have become absolute due to difficulty in construction on site and non availability of these shapes readily in market.

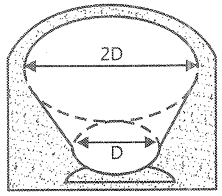


Fig. 1.17 Standard Egg shaped sewer

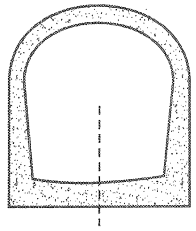


Fig. 1.18 House shoe

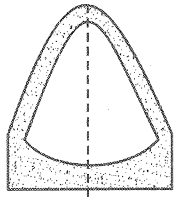


Fig. 1.19 Parabolic

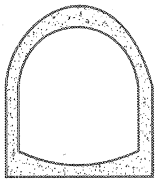


Fig. 1.20 Semi-elliptical

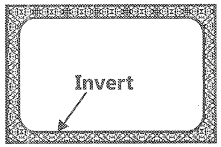


Fig. 1.21 Rectangular

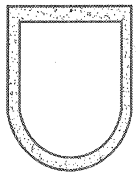


Fig. 1.22 U-shaped

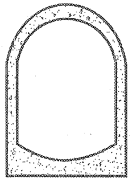


Fig. 1.23 Semi circular

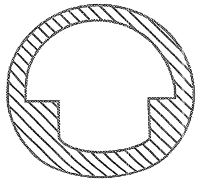


Fig. 1.24 Basket handle shaped

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b. **Horse shoe shaped sewer:** It is used for the construction of large sewers with heavy discharge such as trunk and outfall sewer. Such a section is also suitable when the available head room for the construction of sewer is limited. The invert of the sewer may be flat, circular or parabolic. Its top is semicircular with sides inclined or vertical. Its height is more than its width. It is mostly used for constructing sewers in tunnel.

c. **Parabolic shape sewer:** The upper arch of the sewer takes the form of a parabola. The sewer with parabolic section is suitable for carrying comparatively small quantity of sewage and it is found to be economic in construction. The invert of the sewer may be flat, elliptical or parabolic.

d. **Semi elliptical section:** The semi elliptical section is adopted for the soft soil as it is more stable .The section is not suitable for carrying small quantity of sewage and is generally adopted for the sewers having diameter greater than 1.8 m or so. This section possesses good hydraulic properties except at low depth.

e. **Rectangular shape** section: The rectangular or box type section of sewer is stable and it is easy to construct. It is sometimes used to work as storage tank.

f. **U- shaped section:** This U shaped section may have true shape of letter U or a small trench of U-shape can be set up in large section of sewer. The trench is known as *cunette* and such arrangement is adopted for a combined sewer having predominant flow of storm water. The true U- shaped sewers are easy to construct especially in an open cut. The invert may be in the form of semicircular arch or even flat. The sides are vertical and the top is flat.

g. **Semi circular shaped sewer:** The semicircular section gives a wider base at bottom and hence it becomes suitable for constructing large sewers with less available head room.

h. **Basket Handle shaped:** In this type of sewer the upper portion of the sewer has got the shape of basket handle as shown in figure. The bottom portion is narrower in width than the upper portion. It carries small discharge through the bottom narrow portion and during monsoon combined sewage is carried through full section. It is generally not used in present.

Question 32

Write short note on
(i) Storm Water Regulator
(ii) Hand operated flushing tank
(iii)Automatic flushing Tank

Ans.

(i) **Storm Water Regulator**

Storm water regulators are constructed in the combined sewerage system. They permit the diversion of the excess storm water into nearby stream. Thus, if a combined sewer is designed for 3-times the dry weather flow, the excess quantity of sewage after this limit is crossed is diverted to the natural stream or river. The excess sewage will mainly consist of storm water and therefore will not be foul in nature. This reduces the load on the treatment units or pumping stations.

Types of storm water regulator.

a. Leaping weir

b. Overflow weir
c. Siphon spillway.

(ii) **Hand operated flushing tank**

The working of the hand operated flushing tank can be explained as follows.

1. At the end of the nose, pipe may be connected to the nearest fire hydrant and another end is placed in the manhole to achieve flushing operation.
2. The outlet end of the manhole is closed by suitable arrangement such as sluice valve on gate. Therefore, the sewage starts collecting at the manhole and when the sufficient head gate is opened the flushing action begins.

(iii) **Automatic flushing Tank**

In this tank, the flushing action is achieved automatically at regular intervals. The entry of the water is so regulated that the tank is just filled up to the discharge point in a period equal to the flushing interval. The excess water is drained out with the help of an overflow pipe.

The working of automatic flushing tank is as follows:

1. The water level stand up to the level x-y in U tube.
2. As the water level rises in the tank above the sniff hole, the air is caught and compressed in the bell portion.
3. The compressed air exerts pressure on the surface and hence the water goes down in the longer arm of U-tube.
4. Ultimately the stage is reached when the water level arm reaches upto the bend portion. At this stage, some compressed air is released through the shorter arm of U-tube and the water enters the bell.
5. This is so adjusted that the discharge line is just reached at this stage and the head of the water above the bell becomes greater than that in the shorter arm of U-tube. The siphonic action gets started and the water is discharged into the sewer through the enlarged pipe.
6. The siphonic action continues until the water level in tank falls upto the sniff hole. The air then enters the bell portion through the sniff hole and it breaks the siphonic action.
7. The water level in the two arms of U-tube again assumes the position x-y and the process is repeated.

1.13 Sewer Appurtenances *(CSVTU, Nov-Dec 2011)*

Sewer system requires various types of appurtenances for their proper functioning and maintenance.

Question 33

What is the importance of providing man holes in a sewerage line? Explain the construction and working of drop man hole with sketch. *(CSVTU, Nov-Dec 2010)*

Or

Why are the manholes required and where are these provided? Explain the construction of one with sketch. *(CSVTU, April-May 2010) (CSVTU, Nov-Dec 2009)*

Ans. **Manholes:** A manhole is defined as the construction made to connect the ground level with the hole or opening made in the sewer line so that a man can easily, conveniently

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and safely enters through it and carries out the usual maintenance operation. As far as the sewer are laid straight. At every change of alignment, gradient or diameter of sewer, manholes are constructed for giving access into the sewer for inspection, cleaning, repair and maintenance. Manholes are masonry or R.C.C. chambers which are constructed at the top of sewer. These are fitted with suitable cast iron covers at their top.

A manhole consists of

1. A Working chamber
2. An access shaft
3. A strong cover on the top flush with the road level

The lower portion of a deep manhole is known as *working chamber*. It provides a working space to carry out the cleaning and an inspection of the sewer line. The access shaft provides an access to the working chamber. At the top of the manhole, the manhole cover of cast iron or R.C.C is provided to cover the opening.

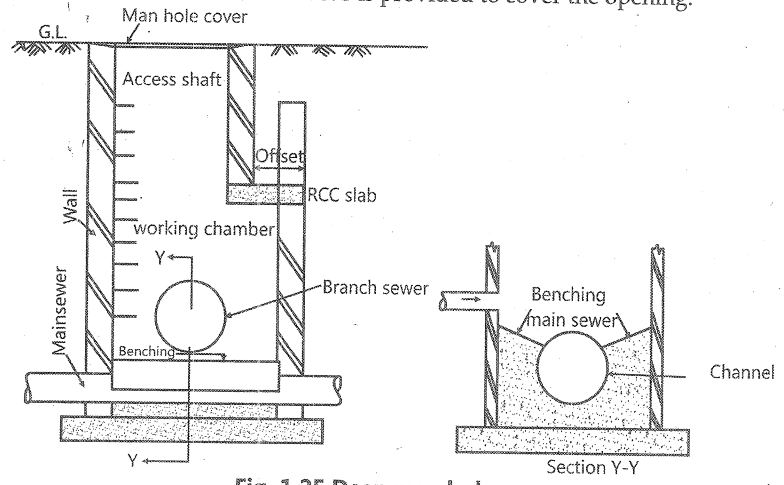


Fig. 1.25 Deep man hole

Question 35

Explain the classification of manhole.

Ans. According to the depth, the manholes are classified as shallow manhole, medium manhole and deep manhole.

1. **Shallow manhole:** It is about 750 mm – 900 mm in depth and it is constructed at the beginning of branch sewer or at places where the traffic is low. It is also known as inspection chamber and it is provided with a light cover at its top.
2. **Medium Manhole:** It is about 1500 mm in depth and it is constructed of 1000 x 1000 mm or 800 mm x 1000 mm in size. It is rectangular or square in shape and its section is not reduced. It is provided with heavy cover at its top.
3. **Deep Manhole:** This is deeper having depth more than 1500 mm. The size is correspondingly increased but the size in upper portion is reduced and an offset

constructed either in bricks arch or cement concrete is provided. It also contains facility to go down up to its bottom and it is provided with heavy cover at its top.

Question 36

Write a short note on construction of sewers.

Or

Explain in detail the complete procedure for laying sewers.

Ans. Laying of sewers involving the following steps.

1. **Setting out alignment and gradient of sewers** – In any sewerage scheme, setting out of alignment is carried out starting from the tail end and proceeding towards upward. First sewer lines are marked along the designed layout routes on ground and pegs at 15-20 m intervals are fixed and temporary benchmarks are established. For good gravity flow of sewage, the sewers are laid to the correct alignment and gradient setting the position and levels sewers accurately. This process is completed with the help of suitable boning rods, sight rails and dumpy levels. The sight rails are horizontal boards. It varies in sizes of timber piece 15 cm x 5 cm cross section.

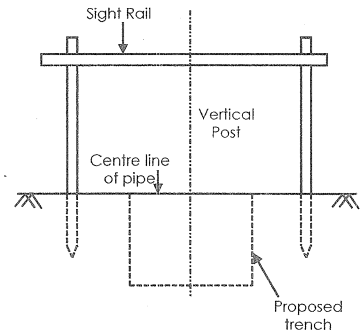


Fig. 1.26 Layout of sewers by using sight rules rails and boning rods

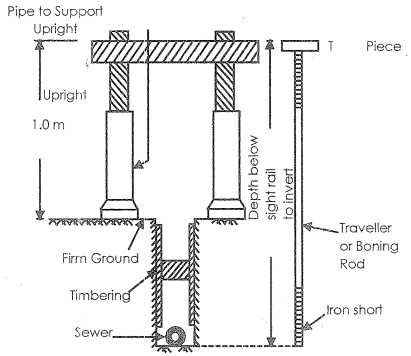


Fig. 1.27 Layout of sewers with the help of sight rails and boning rods.

2. **Excavation of trenches** – Trenches are excavated manually or mechanically. The width of trench depends upon the diameter of the sewer and the depth of sewer line below the ground level. For large sewers the width of trench is equal to the external diameter of sewer is 10-15 cm. For doing the proper accommodation of socket end of pipe some deeper excavations have to be done.
3. **Timbering of trenches** – In case of loose soil, the sides will collapse and hence shoring and strutting is necessary. This is also necessary to prevent caving to reduce danger to workman. (Fig. 1.28)

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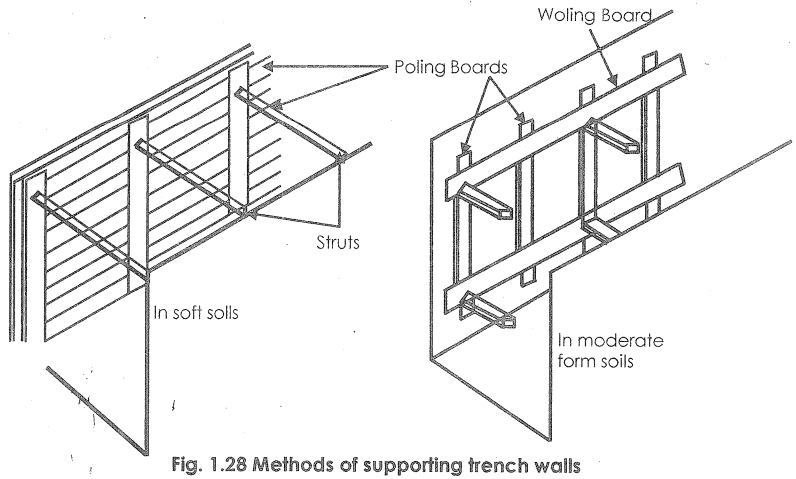


Fig. 1.28 Methods of supporting trench walls

4. **Laying of pipe** – Before laying the pipes they should be inspected to ensure that they should not have any cracks or defects. Small sided pipes may be placed by the pipe layers manually but heavier pipes may be lowered into trenches by means of ropes. Sewers should be laid on concrete bedding so that weight of pipe may be distributed uniformly. The levels of the invert of sewers are checked by means of a boning rod or by traveller. The boning rod is a shoe at bottom.
5. **Dewatering of trenches** – As trench becomes wet and muddy due to water table and construction of sewer becomes difficult. Dewatering is done by pumping.
6. **Jointing in laying of sewer** – Normally, the sewers are laid with their socket end upgrade for ease in jointing.

1.14 Pumping of Sewage

Question 37

Explain the circumstances for pumping of sewage.

Ans. **Pumping of sewage:**

In the sewerage system, at some places sewage cannot flow under the gravitational force, then it is to be lifted. Under the following conditions, it becomes necessary to lift the sewage.

1. If some portion of the town is low lying and the sewage cannot flow by gravity into mains and sub mains, the entire sewerage system in that area is laid at the required low level and the sewage is pumped from lower branch up to the main sewer line.
2. When basements are provided in the building the sewage is pumped to the sewer line.
3. If a ridge intervenes, sometimes it is economical to pump the sewage, instead of providing a tunnel.
4. When the land is flat and it is not possible to get self cleansing velocity the sewers are laid at the required slope and after some interval they are allowed to flow under gravity.

5. At the treatment plants to rise it up to the plant for treatment.
6. At the outfall while disposing it of it is required to be pumped if the level of the water course is higher than the outlet of the sewer.

Question 38

What are the difficulties to be faced during the pumping of sewage?

Ans. The sewage pumping is not simple similar to the water pumping due to the following reasons:

a) Sewage has foul characteristics.
b) Sewage contains suspended and floating matters which clogs the pumps.
c) Sewage contains organic and inorganic wastes which act upon the parts of the pump and cause their corrosion and erosion.
d) Sewage contains disease bacteria which may cause health hazard to the workers.
e) The rate of sewage flow is continuously varying and the pumping rate is to be adjusted accordingly.
f) Larger size sump well cannot be constructed, otherwise the organic matters present it the sewage will settle in the bottom and produce foul smell as well as choking of the lamp well.

1.15 Types of Pumping Stations

Question 39

Explain the different types of pumping stations.

Ans. While the term pumping station covers all types of pumping of sewage or storm water, the term life station is restricted to lifting of sewage across a very short distance and discharging it into another sewer. Pumping stations are provided with two separate wells; wet wells for receiving the incoming sewage and dry wells for installing the pumps. The wet and dry well may be of any of the following types:

1) Circular with central dry and peripheral wet well.
2) Rectangular with dry and wet wells adjacent to each other.
3) Circular with a dividing wall to separate the dry and wet well.

The rectangular wells require thicker walls to withstand the pressure of the lateral soil, subsoil water and sewage, therefore not recommended for larger sizes. These may be provided only when availability of space is the deciding factor.

Question 40

What points should be kept in mind while locating the site of pumping station? What are requirements of sewage pump? Describe in brief. *(CSVTU, April-May 2009)*

Ans. **Location of Pumping Station**

The following points should be considered while locating the site of pumping station.

1. The topographical conditions of the city should be thoroughly studied to locate the best site of pumping station.
2. If the quantity of sewage is very large, the site should be near the point of disposal or at such place where during emergencies, the sewage can be directly disposed off.

3. The site should be such that during flood, it should not be flooded with river water or seepage from the ground.
4. Provision should be made to pump all the sewage which will be received during worst conditions of rains.

Requirement of sewage pump:

The following are the requirement of good sewage pumps.

1. It can pump the sewage up to the required elevation.
2. It should be reliable.
3. It should be cheap in initial cost and maintenance.
4. It should require less space for maintenance.
5. It should not make more noise during working.
6. It should not require high skill in its maintenance and operation.
7. It should not be corroded by the organic and inorganic wastes of the sewage.
8. It should be able to pump the required quantity of sewage even in emergency period.
9. It should not clog due to the suspended and floating solids moving in the sewage.

1.16 Hydraulic Elements of a Circular Sewer

Question 41

Write a short note on wet well.

Ans. **Wet well:**

The sewage from the city is received at pumping station in a tank known as sump or wet well. The capacity of wet well is such that it can store D.W.F of at least of two hours which is the maximum period during which the pump can be repaired or replaced.

The wet well is an underground masonry or R.C.C chamber, placed at such a level that sewage from the trunk sewer can flow into it by gravity only. The tank may be rectangular, ring shaped, circular in shape in the plan. Mostly circular wet wells are used, the bottom of which is given a 1:1 slope towards a central pit where the end of suction pipe of the pump is placed. The depth of the well mainly depends upon the depth of the incoming sewage inlet. The main storage inside the well should be free fall which will avoid the surcharging and back flow inside the incoming sewer. Guide pipes filled with flats, switches of motors, cables of electric motors, sewage level indicators are installed inside the wet well at suitable places. Gate valves should be fitted on the incoming sewer lines to stop the sewage flow during the inspection, repair and cleaning of wet well etc. In the top of wet well manholes with the ladders are provided for its cleaning, inspection and maintenance. The overflow weirs and the bypass arrangements are also provided in the wet wells for diverting the sewage during emergency floods.

(a) Circular Section of Sewer Running Full

Let D be the internal diameter of the circular sewer.

Area of cross section,

$$A = \frac{\pi}{4} D^2$$

Wetted perimeter $P = \pi D$

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Hydraulic Mean Depth, HMD, R

$$R = \frac{A}{P}$$

$$= \frac{\pi/4D^2}{\pi D} = \frac{D}{4}$$

(b) Circular Section Running Partially Full

Now, for a circular section running partially full as shown in fig. 1.29,

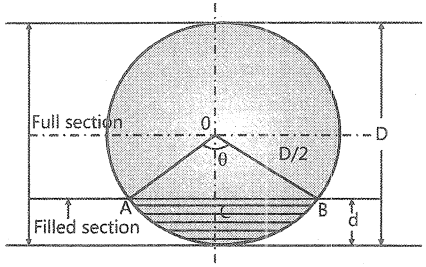


Fig. 1.29

Let

a = Area of cross section
p = Wetted perimeter
r = Hydraulic mean Depth (H. M. D)
v = Velocity of flow

Central angle is given by

$$\cos\frac{1}{2}\theta = 1 - 2d/D$$

(1) Depth d:

$$d = \frac{D}{2} - \frac{D}{2}\cos\frac{\theta}{2}$$

$$= \frac{D}{2}\left(1 - \cos\frac{\theta}{2}\right)$$

Proportional Depth

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

(2) Proportional Area:

$$a = \frac{\pi}{4}D^2 \times \frac{\theta}{360^\circ} - \frac{D}{2}\cos\frac{\theta}{2}\cdot\frac{D}{2}\sin\frac{\theta}{2}$$

$$a = \frac{\pi D^2}{4}\left[\frac{\theta}{360} - \frac{\sin\theta}{2\pi}\right]$$

Proportional Area

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

(3) Hydraulic Mean Depth

$$\mu = \frac{a}{p} = \frac{\frac{\pi D^2}{4}\left[\frac{\theta}{360} - \frac{\sin\theta}{2\pi}\right]}{\pi D \frac{\theta}{360^\circ}}$$

$$\mu = \frac{D}{4}\left[1 - \frac{360\sin\theta}{2\pi\theta}\right]$$

Proportional hydraulic mean Depth:-

$$\frac{\mu}{R} = \left[1 - \frac{360^\circ\sin\theta}{2\pi\theta}\right]$$

(4) Proportional Velocity

Velocity of flow is given by

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

Where n = Manning's rugosity coefficient applicable for partial flow condition

Proportional velocity $= \frac{v}{V}$

$$= \frac{N}{n}\left[\frac{\mu}{R}\right]^{2/3}$$

If

$$\frac{N}{n} = 1.0, \quad \text{then } \frac{v}{V} = \left[\frac{\mu}{R}\right]^{2/3}$$

$$= \left[1 - \frac{360^\circ\sin\theta}{2\pi\theta}\right]^{2/3}$$

(5) Proportionate Discharge

$$q = a \times v$$

Taking

$$\frac{n}{N} = 1.0, \text{ we have}$$

Proportionate Discharge $= \frac{q}{Q} = \frac{a.v}{A.V}$

$$\frac{a.v}{A.V} = \frac{a}{A} \times \left(\frac{\mu}{R}\right)^{2/3}$$

$$\frac{q}{Q} = \left[\frac{\theta}{360} - \frac{\sin\theta}{2\pi}\right]\left[1 - \frac{360\sin\theta}{2\pi\theta}\right]^{2/3}$$

$$= \frac{\theta}{360}\left[1 - \frac{360\sin\theta}{2\pi\theta}\right]^{5/3}$$

For variable values of $\frac{n}{N}$

$$\frac{q}{Q} = \frac{N}{n}\left[\frac{a}{A}\right]\left[\frac{\mu}{R}\right]^{2/3}$$

1.17 Design of Sewer

Question 42

Calculate the velocity of flow in a sewer of diameter 1.0m. The sewer is laid at a gradient of 1 in 500.What will be the discharge through this sewer when the sewer is running half full. Take N =0.012

Ans.

S = 1 in 500
d = 1.0 m
N = 0.012

$$A = \frac{1}{2}\frac{\pi}{4}d^2$$

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$$A = \frac{1}{2}\frac{\pi}{4} \times 1^2$$

$$A = 0.3926\ m^2$$

$$R = \frac{A}{p}$$

$$= \frac{d}{4}$$

$$\left(\frac{1}{4}\right) = 0.25\ m$$

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

$$= \frac{1}{0.012} \times (0.25)^{2/3} \times \left(\frac{1}{500}\right)^{1/2}$$

$$= \frac{1}{0.012} \times 0.395 \times 0.0447$$

$$V = 1.472 m/sec$$

$$Q = A \times V$$

$$= 0.3926 \times 1.472$$

$$Q = 0.58\ m^3/sec$$

Question 43

Determine the velocity of flow in a circular sewer of diameter 1200m, laid on a slope of 1 in 700 flowing full.

Ans. Manning's formula

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

$$R = \frac{A}{P} = \frac{d}{4} = \frac{1.2m}{4}$$

$$R = 0.3m.$$

$$n = 0.013$$

$$S = 1 \text{ in } 700$$

$$V = \frac{1}{n} R^{\frac{2}{3}} S^{\frac{1}{2}}$$

$$V = \frac{1}{0.013} \times (0.3)^{\frac{2}{3}} \times \left(\frac{1}{700}\right)^{1/2}$$

$$V = \frac{1}{0.013} \times 0.4463 \times 0.0377$$

$$V = 1.297\ m/sec$$

Question 44

A 40 cm diameter sewer is to flow at 0.3 depth, on a grade ensuring a degree of self cleansing equivalent to obtained at full depth, at a velocity of 80 cm/sec. Find,

(1) The required velocity

(2) Associated grade

(3) Rate of discharge at this depth *(CSVTU, April –May 2012)*

Ans. Given,

$$V = 0.8m/sec$$

$$D = 0.4m$$

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$$d = 0.3m$$

Assuming $N = 0.014$

Proportionate Area $= 0.252$

Proportionate Hydraulic mean Depth $= 0.684$

For sewer running full

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

$$R = \frac{D}{4} = \frac{0.4}{4} = 0.1m$$

$$0.8 = \frac{1}{0.014} (0.1)^{2/3} S^{1/2}$$

$$S = 0.0027 \cong \frac{1}{370}$$

$$Q = A.V$$

$$= \frac{\pi}{4} \times D^2 (0.8)$$

$$= 0.1005\ m^3/sec$$

For partial depth self cleansing flow at 0.4 depth $\frac{d}{D} = 0.4$

Also

$$\frac{a}{A} = 0.252 \text{ and } \frac{\mu}{R} = 0.684$$

Now,

$$\frac{S_s}{S} = \frac{R}{\mu} = \frac{1}{0.684} = 1.462$$

$$S_s = 1.462 \times 0.0027 = 0.00395$$

$$= \frac{1}{253.3}$$

Also, $$\frac{V_s}{V} = \frac{N}{n}\left[\frac{\mu}{R}\right]^{\frac{1}{6}} = 1 \times (0.684)^{\frac{1}{6}}$$

$$= 0.9387.$$

$$V_s = 0.9387 \times 0.8 = 0.751\ m/sec$$

And,

$$\frac{q_s}{Q} = \left[\frac{N}{n}\right]\left[\frac{a}{A}\right]\left[\frac{\mu}{R}\right]^{\frac{1}{6}}$$

$$= 0.252 \times 0.9387$$

$$\frac{q_s}{Q} = 0.2365$$

$$q_s = Q \times 0.02365$$

$$= 0.0237\ m^3/sec$$

Question 45

A sewer in a district has a population of 10,000 and the average rate of supply is 200 lpcd. Determine the diameter and the grade for a circular sewer to carry sanitary sewage at non scouring velocity running half full. Take N = 0.013.

Ans.

$$Q = 10,000 \times 200$$

$= 2 \times 10^6$ liter/day

$$Q_{avg} = \frac{2 \times 10^6}{10^3 \ 24 \ \times 3600}$$

$Q_{avg} = 0.0231 m^3/sec$

Assuming

$Q_{max} = 2.5 \times Q_{avg}$

$= 2.5 \times 0.0231$

$= 0.05787 \ m^3/sec$

Now we have to design sewer running half full at 0.5 proportionate depth.

Proportionate discharge

$$\frac{q}{Q} = 0.5$$

$q = 0.5Q$

$= 0.5 \times 0.05787$

$= 0.028935 \ m^{3/sec}$

Proportionate hydraulic depth

$R = 1.0$

For circular sewer,

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

$D = 4R$

Area of sewer $= \frac{\pi}{4} D^2$

$A = 12.566 \ m^2$

Proportionate Area $= \frac{a}{A} = 0.5$

$a = 0.5A$

$= 0.5 \times 12.566$

$a = 6.283 \ m^2$

Velocity of flow $(v) = \frac{Q}{A} = \frac{0.05787}{12.566}$

$= 0.0046$

Proportionate velocity

$v = 0.0046 \times 1.0$

$v = 0.0046$ m/sec

Now using Manning's formula

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

$$S^{\frac{1}{2}} = \frac{v}{\frac{1}{n} R^{\frac{2}{3}}}$$

$$= \frac{0.0046}{\frac{1}{0.013} \times (1)^{\frac{2}{3}}}$$

$S^{1/2} = 0.0000598$

$S = 3 \times 10^{-9}$

Question 46

A 30 cm diameter sewer having an invert slope of 1 in 150 was flowing full. What would be the velocity of flow and discharge? (n =0.013) Is the velocity self cleansing? What would be the velocity and the discharge, when the same is flowing 0.2, 0.6 and depth? *(CSVTU, Nov-Dec 2011)*

Ans. Given,

$d = 30$ cm

$$S = \frac{1}{150}$$

$n = 0.013$

(a) According to Manning's formula

$$V = \frac{1}{n} R^{\frac{2}{3}} S^{\frac{1}{2}}$$

$$R = \frac{A}{P}$$

$$A = \frac{\pi}{4} D^2$$

$P = \pi D$

$$\therefore \quad R = \frac{\pi}{4} D^2 \div \pi D$$

$$= \frac{\pi \ D^2}{4} \times \frac{1}{\pi D}$$

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

Where, D is diameter of sewer

$$S = \frac{1}{150}$$

$$\therefore \quad V = \frac{1}{n} \times R^{\frac{2}{3}} \times S^{\frac{1}{2}}$$

$$= \frac{1}{n} \times \left(\frac{D}{4}\right)^{\frac{2}{3}} \times S^{\frac{1}{2}}$$

$$= \frac{1}{0.013} \times \left(\frac{0.30}{4}\right)^{\frac{2}{3}} \times \left(\frac{1}{150}\right)^{\frac{1}{2}}$$

$$= 0.17631 \times \frac{1}{0.013} \times 0.08164$$

$V = 1.1073$m/sec

Since the velocity is greater than 0.45 m/sec which is theoretical value for self cleansing velocity.

∴ Sewer can be termed as self cleansing velocity at full flow

$Q = A \times V$

$$= \frac{\pi}{4} \times D^2 \times V$$

$$= \frac{\pi}{4} \times 0.3^2 \times 1.1073 = 0.07827 m^3/sec$$

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Question 47

A 60 cm diameter sewer is to discharge 0.07 cumecs at a velocity as self cleansing as a sewer flowing full at 0.85 m/sec. Find the depth, velocity of flow and required slope? N = 0.015. *(CSVTU, Nov – Dec 2011)*

Ans. For sewer running full,

$$V = \frac{1}{N} R^{2/3} S^{1/2} \quad \ldots (1)$$

Here,

$$N = 0.015$$
$$V = 0.85 \text{ m/sec}$$
$$R = \frac{D}{4} = \frac{0.6}{4} = 0.15 \text{ m}$$

$$\therefore \quad 0.85 = \frac{1}{0.015} (0.15)^{2/3} \times S^{1/2}$$
$$S = 0.00204 = \frac{1}{490.2}$$
$$Q = A.V$$
$$= \frac{\pi}{4} \times D^2 \times 0.85$$
$$= \frac{\pi}{4} \times (0.6)^2 \, 0.85$$
$$Q = 0.2403 \text{ m}^3$$

For partial depth self cleansing flow,

$$q_s = 0.07 \text{ m}^3$$
$$\frac{q_s}{Q} = \frac{0.07}{0.2403} = 0.2913$$

But

$$\frac{q_s}{Q} = \left[\frac{N}{2}\right] \left[\frac{a}{A}\right] \left[\frac{r}{R}\right]^{1/6}$$

Also

$$\frac{a}{A} = \frac{\theta}{360} - \frac{\sin\theta}{2\pi}$$
$$= \frac{\theta}{360} \left[1 - \frac{360 \sin\theta}{2\pi\theta}\right]$$

and

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

$$\therefore \quad \frac{q_s}{Q} = \frac{N}{n} \times \frac{\theta}{360} \left[1 - \frac{360\sin\theta}{2\pi\theta}\right] \times \left[1 - \frac{360 \sin\theta}{2\pi\theta}\right]^{1/6}$$

Now,

$$0.2913 = \frac{1 \times \theta}{360} \left[1 - \frac{360^\circ \sin\theta}{2\pi\theta}\right]^{7/6}$$

Solving above equation by trial and error method, we get

$$\theta = 143.5^\circ$$
$$\frac{d}{D} = \frac{1}{2} \left[1 - \cos\frac{\theta}{2}\right]$$
$$= 0.3434$$

and

$$\frac{r}{R} = \left[1 - \frac{360 \sin\theta}{2\pi \times \theta}\right]$$
$$= \left[1 - \frac{360 \sin 143.5}{2\pi \times (143.5)}\right]$$
$$= 0.7624$$

Now,

$$\frac{V_S}{V} = \frac{N}{n} \left[\frac{r}{R}\right]^{1/6}$$
$$\frac{V_S}{V} = 1 \, [0.7624]^{1/6}$$
$$\frac{V_S}{V} = 0.9558 \text{m/sec}$$

and

$$\frac{S_S}{S} = \left[\frac{R}{\mu}\right] = \frac{1}{0.7624} = 1.3116$$
$$S_S = 1.3116 \times 0.00204$$
$$= 0.00268$$
$$S_S = \frac{1}{373.7}$$

Question 48

The surface on which the rain falls consist of roofs and pavements 40% ($c_1 = 0.80$); lawns and gardens 60% ($c_2 = 0.20$). Calculate the coefficient of runoff. If the total area of the district is 2 hectare and intensity of rainfall is 50mm. What is the rate of runoff of the district?

Ans. The total area consists of roofs and pavement and lawns and gardens.

Let the area of roofs and pavement BE a_1 and lawns and gardens be a_2 having impermeability factor as i_1 and i_2.

∴ Total impermeability factor

$$I = \frac{a_1 i_1 + a_2 i_2}{a_1 + a_2}$$
$$a_1 = 40\% \text{ of } A$$
$$= 0.4 \, A$$
$$i_1 = 0.80$$
$$A_2 = 60\% \text{ of } A$$
$$i_2 = 0.20$$
$$I = \frac{a_1 i_1 + a_2 i_2}{A}$$
$$= \frac{0.4A \times 0.80 + 0.6A \times 0.20}{A}$$
$$I = \frac{0.32A + 0.12A}{A}$$
$$I = 0.44$$

Now, using rational formula

$$\therefore \quad Q = \frac{CIA}{360}$$
$$\therefore \quad Q = \frac{0.44 \times 2 \times 50}{360}$$
$$Q = 0.122 \text{m}^3/\text{sec}$$

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Question 49

The following data is available regarding various types of area and the corresponding impermeability factors of town:

S. no.	Types	% Area	Impermeability
1	Roofs	15 %	0.9
2	Pavements	20 %	0.8
3	Lawn, Gardens, Vegetation	40 %	0.15
4	Unpaved	15 %	0.20
5	Wooded	10 %	0.05

Determine the average coefficient of runoff. If the total area of the district is 20 hectares, determine the maximum intensity of 50 mm/hour having frequency of once in five years. Use rational formula.

(CSVTU, April – May 2011)

Ans. The average impermeability factor I_{av} is given as

$$I_{av} = \frac{\sum A.I}{\sum A}$$

Where

$$A_1 I_1 = (0.15\,A)\,0.9 = 0.135A$$
$$A_2 I_2 = (0.20A)\,0.8 = 0.160A$$
$$A_3 I_3 = (0.40A) \times 0.15 = 0.060A$$
$$A_4 I_4 = (0.15\,A) \times 0.20 = 0.030A$$
$$A_5 I_5 = (0.10A) \times 0.05 = 0.005A$$
$$\sum A.I = [0.135 + 0.160 + 0.060 + 0.030 + 0.005]\,A$$
$$= 0.390A$$
$$I_{av} = \frac{0.390A}{A} = 0.39$$

The storm discharge can be calculated as follows

$$Q = \frac{A\,.\,I\,.\,R_i}{360}\ m^3/sec$$

R_i = intensity of rainfall in mm/hour
= 50 mm/hour

I = Average Impermeability Factor = 0.39

A = Catchment Area in hectares
= 20 hectares

$$Q = \frac{20 \times 0.39 \times 50}{360}$$
$$= 1.08\ m^3/sec$$
$$Q = 1080\ litres/sec$$

Question 50

For a circular sewer and a rectangular sewer to be hydraulically equivalent, find the relation between the depth of rectangular sewer and diameter of circular sewer. Take the width of rectangular sewer as 1.5 times the depth. Assume that only three sides of the rectangular sewer are wetted. *(CSVTU, April-May 2011)*

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Ans. **a) Rectangular section**

Let D = Height of rectangular section

Width = B = 1.5D

$$A = D \times 1.5\,D = 1.5D^2$$
$$P = D + 1.5\,D + = 3.5\,D$$
$$R = \frac{1.5D^2}{3.5D} = 0.4286\,D$$
$$Q = A \times V = A \times \frac{1}{N} R^{2/3} S^{1/2}$$
$$= (1.5D^2) \times \frac{1}{N} \times (0.4286D)^{2/3} \times S^{1/2} \quad ...(1)$$

b) For circular section

Let d = diameter

$$\therefore\ A = \frac{\pi}{4} d^2$$
$$P = \pi d$$
$$R = \frac{A}{P}$$
$$= \frac{\pi d^2}{4\pi d}$$
$$= \frac{d}{4}$$

Now,
$$Q = A \times V = A \times \frac{1}{N} R^{2/3} S^{1/2}$$
$$Q = \frac{\pi}{4} d^2 \times \frac{1}{N} \times \left(\frac{d}{4}\right)^{2/3} \times S^{1/2}$$
$$= 0.3117\,d^{8/3} \frac{S^{1/2}}{N} \quad ...(2)$$

For two sewers to be hydraulically equivalent Q, N and S are the same.

∴ From equation (1) *and* (2),

$$0.8527\,D^{8/3} = 0.3117\,d^{8/3}$$
$$\therefore\ \left(\frac{D}{d}\right)^{8/3} = 0.3655$$
$$\frac{D}{d} = 0.6856$$
$$D = 0.6856d$$

Question 51

Determine the size of circular sewer for a discharge of 1:2 cumecs running half full. Assume a grade of 1 in 2000 and rugosity coefficient as 0.013. (CSVTU, Nov –Dec 2010)

Ans. Given,

$$\frac{d}{D} = 0.5$$
$$\therefore\ d = 0.5D$$
$$\cos\frac{\theta}{2} = 1 - 2\frac{d}{D}$$
$$\cos\frac{\theta}{2} = 0$$

$$\frac{\theta}{2} = \cos^{-1} 0$$

$$\frac{\theta}{2} = 90^\circ$$

$$\theta = 90 \times 2$$

$$= 180^\circ$$

$$\sin 180^\circ = 0$$

Proportionate Area

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

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

$$= \frac{\pi}{4} \times D^2\left[\frac{\theta}{360} - \frac{\sin\theta}{2\pi}\right]$$

$$= \frac{\pi}{4} D^2\left[\frac{180}{360} - 0\right]$$

$$= \frac{\pi}{4} D^2\left[\frac{1}{2}\right]$$

$$a = \frac{\pi}{8} D^2$$

Wetted perimeter:-

$$P = \pi D \frac{\theta}{360}$$

$$P = \pi \times D \times \frac{180^\circ}{360^\circ} = \frac{\pi D}{2}$$

$$r = \frac{a}{p}$$

$$r = \frac{\pi D^2}{8} \div \frac{\pi D}{2} = D/4$$

Now,

$$q = \frac{1}{N} \times a \times r^{2/3} \times S^{1/2}$$

$$q = 0.5 m^3$$

$$0.5 = \frac{1}{0.015} \times \frac{\pi}{8} \times D^2 \left(\frac{D}{4}\right)^{\frac{2}{3}} \times (0.0001)^{1/2}$$

$$D^{8/3} = 4.8128$$

$$D = 1.80 \text{ m}$$

Question 52

Design the section of circular sewer from the following data:

Area to be served	*= 150 hectares.*
Population of locality	*= 50,000*
Maximum permissible velocity	*= 3.2m/sec*
Time of entry	*= 5min.*
Time of flow	*= 20minutes.*
Rate of water supply	*= 270 liter/ day /capita.*
Impermeability factor	*= 0.45*

(CSVTU, April -May 2009)

Ans. Quantity of water supply

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$$= \frac{50{,}000 \times 270}{24 \times 3600}$$

$$Q = 156.25 \text{ lit/sec.}$$

Assuming the maximum discharge as 1.5 times the average

$$Q_{max} = 1.5 \times 156.25$$

$$= 234.375 \text{ lit/sec}$$

$$= 0.234 \text{ m}^3/\text{sec}$$

Storm Water:

Time concentration = 5 +20

= 25 minutes

Now, Intensity of rainfall,

$$i = \frac{760}{t + 20}$$

$$= \frac{760}{25 + 20}$$

$$= \frac{760}{45}$$

$$= 16.89 \text{ mm/hr}$$

$$i = 168.9 \text{ cm/hr}$$

Again using rational formula

$$Q = \frac{C\,i\,A}{360}$$

$$= \frac{0.45 \times 16.89 \times 1.50}{360}$$

$$= 3.167 \text{m}^3/\text{sec}$$

∴ Combined Discharge

$$= (0.2234 + 3.167)$$

$$= 3.401 \text{ m}^3/\text{sec.}$$

Also,

$$Q = A.V$$

$$A = \frac{Q}{V}$$

$$= \frac{3.167}{3.2}$$

$$= 0.99 \text{ m}^2$$

$$\text{Area} = \frac{\pi}{4} d^2$$

$$d = \sqrt{\frac{4 \times \text{Area}}{\pi}}$$

$$= \sqrt{\frac{4 \times 0.2}{\pi}}$$

$$D = 1.123 \text{ m}$$

Provide a circular sewer of diameter 1.15m. *Ans.*

Question 53

A population of 30,000 is residing in a town having an area of 60 hectares. If the average coefficient of runoff for this area = 0.60 and the time of concentration of the design rain is 30 min. Calculate the discharge for which the sewer of a proposed combined system will be designed for the town in question. Make suitable assumptions where needed. *(CSVTU, Nov-Dec 2008)*

Ans. Assuming that the water is supplied at 120liters/ capita /day.

Assuming Quantity of sewage will be 80% of the water supplied.

$$\therefore \quad Q_{Sewage} = \frac{80}{100} \times 120 \times 30{,}000 \ \frac{liter}{day}$$

$$= 2.88 \times 10^6 \ \frac{liter}{day}$$

$$Q_{Sewage} = 2880 \ m^3/day.$$

$$Q_{Sewage} = \frac{2880}{24 \times 3600}$$

$$Q_{Sewage} = 0.033 m^3$$

Now, assuming the maximum sewage discharge to be three time the average.

∴ Maximum Sewage Discharge

$$Q_{max} = 3 \times 0.033$$

$$Q_{max} = 0.1 \ m^3/sec$$

The storm water discharge can be computed using rational formula.

$$Q_p = \frac{1}{36} k \times p_c \times A$$

Using

$$p_c = \frac{100}{T + 20} = 20 m/hr$$

$$Q_p = \frac{1}{36} \times 0.60 \times 2 \times 60 \text{ cumecs}$$

$$= 2 \ m^3/sec$$

Hence, the total peak discharge for which the sewers of the combined system should be designed

$$= Q_{max\ (Sewage)} + \text{Maximum storm run off}$$

$$= 0.1 + 2.0$$

$$= 2.1 \ m^3/sec$$

The total peak discharge = 2.1 m^3 /sec. *Ans.*

Question 54

A main sewer is designed to carry sewage of a township spread over an area of 80 sq km with an average population of 200 persons per hectare. The average Rate of waste water flow can be taken as 300 Lpcd and the maximum flow is 50% in excess of the average. Calculate the discharge for which the sewer is to be designed and find the diameter of the sewer with sewer running half full. Take n = 0.02 and available scope as 1 in 1000. *(CSVTU, April-May 2010)*

Sol.

Total population = $80 \times 10^2 \times 200 = 1600000$

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Average flow $= 1600000 \times 300$ lit/day

$= 480 \times 10^6$ lit/day

$$= \frac{480 \times 10^6}{10^3 \times 24 \times 3600}$$

$= 5.56 \ m^3/sec$

Now, $Q = A \times V$

When the sewer runs half full

$d = 0.5 D$ and $\theta = 180°$

$$a = \frac{1}{2} \frac{\pi}{4} D^2 = \frac{\pi}{8} D^2$$

$$P = \pi D \frac{\theta}{360}$$

$$= \pi D \frac{180}{360}$$

$$= \frac{\pi D}{2}$$

$$R = \frac{A}{P}$$

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

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

$$V = \frac{1}{0.02} \times \left(\frac{D}{4}\right)^{2/3} \times \left(\frac{1}{1000}\right)^{1/2}$$

$$Q = A \times V$$

$$5.536 = \frac{\pi D^2}{4} \times \frac{1}{0.02} \times \left(\frac{D}{4}\right)^{2/3} \times \left(\frac{1}{1000}\right)^{1/2}$$

$$= 0.787 \times \frac{1}{0.02} \times \left(\frac{D}{4}\right)^{4/3} \times 0.3968 \times 76.92$$

$$5.56 = 1201.03 \ D^{\frac{4}{3}}$$

$$4.629 \times 10^{-3} = D^{4/3}$$

$$D = 0.0177 \ m$$

Question 55

A main sewer is designed to carry the swage of a township spread over an area of 44 sq. km with an average population of 200 persons per hectare. The average rate of waste water flow can be taken as 250 lpcd and maximum flow is 50% in excess of average. Calculate the discharge of the sewer with running half full. Take n = 0.013 and available slope as 1 in 1000. *(CSVTU, Nov-Dec 2009)*

Sol.

Total population $= 44 \times 10^2 \times 200$

$= 880000$

Average flow $= 880000 \times 250$ lit / day

$= 220 \times 10^6$ lit/day

$$= \frac{220 \times 10^6}{10^3 \times 24 \times 3600}$$

$= 2.546\ m^3/sec$

Now $Q = A \times V$

When the sewer runs half full

$d = 0.5\ D$ and $\theta = 180°$

$$a = \frac{1}{2}\frac{\pi}{4}D^2 = \frac{\pi}{8}D^2$$

$$P = \pi D \frac{\theta}{360}$$

$$= \pi D \frac{180}{360}$$

$$= \frac{\pi D}{2}$$

$$R = \frac{A}{P}$$

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

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

$$V = \frac{1}{0.013} \times (D/4)^{2/3} \times \left(\frac{1}{1000}\right)^{1/2}$$

$\therefore$ $Q = A \times V$

$$2.546 = \frac{\pi D^2}{4} \times \frac{1}{0.013} \times \left(\frac{D}{4}\right)^{2/3} \times \left(\frac{1}{1000}\right)^{1/2}$$

$\therefore$ $D^{4/3} = 3.361$

$D = 2.48$ m

Question 56

Determine the size of circular sewer for a discharge of 6000 Lps running half fall. Assume S = 0.0001 and N = 0.015. *(CSVTU, April-May 2013)*

Ans.

$$\frac{d}{D} = .5$$

$q = 600$ lit/sec

$b = 0.0001$

$N = 0.015$

For sewer running half full

$$\frac{q}{Q} = 0.5$$

$$Q = \frac{q}{0.5}$$

$$= \frac{600}{0.5}$$

$= 1200$ lit/sec

$= 1.2\ m^3/sec$

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

But $Q = A \times V$

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$\therefore$ $$Q = \frac{\pi}{4} \times D^2 \times \frac{1}{N} \times R^{2/3 \times 5} S^{1/2}$$

Again $$R = \frac{A}{P}$$

$$= \frac{\pi}{4} D^2 \div \pi D$$

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

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

$$1.2 = \frac{\pi}{4} D^{8/3} \times \frac{1}{0.015} \times \left(\frac{1}{0.0001}\right)^{1/2}$$

$$D^{8/3} = \frac{1.2 \times 0.015 \times 4 \times 2.52 \times 100}{\pi}$$

$D^{8/3} = 5.78$

$D = (5.78)^{3/8}$

$D = 1.93$m

$\therefore$ The diameter of the sewer = 1.93m

Question 57

A main sewer is to be designed to carry the combined flow of waste water and storm water of a township spread over an area of 12 Sq. Km with an average population of 250 persons per hectare. The average rate of waste water flow can be taken as 250 lpcd and the maximum flow is 100% in excess of the average together with the rainfall equivalent of 15mm in 24 hrs all of which is runoff. Calculate the discharge for which the sewer is be designed and find the diameter of sewer with sewer running half full. Take n = 0.012 & available slope as 1 in 1000. *(CSVTU, April-May 2013)*

Sol. Total population

$= (12 \times 10^2)$ha $\times$ 250 person/ha

$= 300000$ ha

Average flow $= 300000 \times 250$

$= 750 \times 10^5$ lit/day

$$= \frac{75 \times 10^6}{24 \times 60 \times 60} \times \frac{1}{1000}$$

$= 0.868\ m^3$

Maximum sewage flow $= 2 \times 0.868$

$= 1.736\ m^3/sec$

Storm water flow $= 12 \times 10^6 \times \frac{15}{1000} \times \frac{1}{24 \times 60 \times 60}$

Total flow for the combined sewer

$Q = 1.736 + 2.083$

$Q = 3.82\ m^3/sec$

Now, $$V = \frac{1}{n} \times R^{2/3} \times S^{1/2}$$

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

$$\therefore \quad V = \frac{1}{0.012} \times \left(\frac{D}{4}\right)^{2/3} \times \left(\frac{1}{1000}\right)^{1/2}$$

$$Q = A \times V$$

$$3.82 = \frac{\pi}{4} \times D^2 \times \frac{1}{0.012} \times \left(\frac{D}{4}\right)^{2/3} \times \left(\frac{1}{1000}\right)^{1/2}$$

$$3.82 = \frac{\pi}{4} \times D^{8/3} \times \frac{1}{0.015} \times \left(\frac{1}{1000}\right)^{1/2}$$

$$D^{8/3} = \frac{3.82 \times 0.015 \times 4}{\pi \times 0.0316}$$

$$D = 1.368\text{m}$$

Question 58

The BOD of sewage incubated for one day at 30°C has found to be 100 mg/L. What will be 5-day 20°C BOD. Assume k = 0.12 (Base 10) at 20°C. **(CSVTU, Nov-Dec 2012)**

Ans. $y_1(30°C) = 100$ mg/L

$y_5 =$? at 20°C

1. $k_{30} = k_{20}\theta^{(T-20)}$

$= 0.12\ (1.047)^{30-20}$

$= 0.12 \times 1.5829$

$k_{30} = 0.1899$

2. $y_1 = 100$ mg/L

$y = L_0(1 - 10^{-kt})$

$y_1 = L_0(1 - 10^{-0.19\times1})$

$100 = L_0(1 - 10^{-0.19})$

$100 = 0.354\ L_0$

$L_0 = 282.264$m g/L

3. $y_5 = L_0(1 - 10^{-kt})$

$y_5 = 282.264(1 - 10^{-0.189\times5})$

$y_5 = 250.226$ mg/L

Question 59

5 Day 20°C BOD of a waste water is 150 mg/L. What would be 8 day 15°C BOD? Assume k = 0.23 at 20°C.

Ans. Given

y_5 at 20°C $= 150$ mg/L

$y_B =$? at 154°C

$k_{20} = 0.23$

$k_{15} = k_{20}(\theta)^{T-20}$

$= 0.23(1.047)^{15-20}$

$k_{15} = 0.1828$ mg/L

$y_5 = L_0(1 - 10^{-kt})$

$150 = L_0(1 - 10^{-0.23\times5})$

$150 = L_0(0.929)$

$L_0 = 161.42$ mg/L

$y_8 = L_0(1 - 10^{-kt})$

$= 161.42\ (1 - 10^{-0.1823\times8})$

$y_8 = 155.85$ mg/L

The 8 day 15°C BOD is 155.85 mg/L.

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CSVTU, APRIL-MAY 2013

(a) *What do you understand by the 'Conservancy System' and 'Sewerage System'?* 2

Ans. ***Refer Question 8 Unit - 1***

(b) *A main sewer is to be designed to carry the combined flow of waste water and storm water of a township spread over an area of 12 sq. km. with an average population of 250 persons per hectare. The average rate of waste water flow can be taken as 250 lpcd and the maximum flow is 100% in excess of the average together with the rainfall equivalent of 15 mm in 24 hours, all of which are runoff.*

Calculate the discharge for which the sewer is to be designed and find the diameter of the sewer with sewer running half-full. Take n = 0.012 and available slope as 1 in 1000. 7

Ans. ***Refer Question 57 Unit - 1***

(c) *Sate with reasons why in a country like India the partially combined system of sewage collection suits best.* 7

Ans. ***Refer Question 16 Unit - 1***

(d) *Derive the hydraulic elements of a circular sewer running partially full. Determine the size of a circular sewer for a discharge of 500 lps running half full. Assume S = 0.0001 and N = 0.015.*

Ans. ***Refer Question 41, 56 Unit - 1***

CSVTU, NOV-DEC 2012

(a) *What do you understand by DO sag curve?* 2

Ans. ***Refer Question 17 Unit - 4***

(b) *Derive the first stage BOD equation.* 7

Ans. ***Refer Question 7 Unit - 2***

(c) *The BOD of sewage incubated for one day at 30°C has found to be 100 mg/l. What will be the 5-day 20°C BOD? Assume K = 0.12 (Base 10) at 20°C.* 7

Ans. ***Refer Question 58 Unit - 1***

CSVTU, APRIL-MAY 2012

(a) *Term used to indicate the wash basin waste water:* 2

(1) *Sullage*

(2) *Sewage*

(3) *Night Soil*

(4) *Garbage*

Ans. ***Refer Question 1 Unit - 1***

(b) *Describe the conditions for satisfactory disposal of sewage.* 7

Ans. ***Refer Question 3 Unit - 1***

(c) *Give various empirical formula for determining storm water flow in sewers, explaining their applicability.* 7

Ans. ***Refer Question 20 Unit - 1***

(d) A 40 cm diameter sewer is to flow at 0.3 depth on a grade ensuring a degree of self cleansing equivalent to that obtained at full depth at a velocity of 80 cm/sec. Find: 7

(i) The required velocity

(ii) Associated grade

(iii) Rate of discharge at this depth

Ans. **Refer Question 44 Unit - 1**

CSVTU, NOV-DEC 2011

(a) (i) List 6 sewer appurtenances. **Refer Question 29 Unit - 1**

(ii) Zero specific gravity of sewage is: **Refer Question 2 Unit - 1**

(1) Zero (2) Equal to 1 (3) > 1 (4) < 1 2

(b) A 30 cm dia. sewer having an invert slope of 1 in 150 was flowing full. What would be the velocity of flow and discharge? (n = 0.013). Is the velocity self cleansing? What would be the velocity and the discharge when the same is flowing 0.2, 0.6 and depth?

Ans. **Refer Question 46 Unit - 1**

(c) Derive the expression for shield self cleansing velocity? Also derive expression for proportionate area, velocity and HMD. 7

Ans. **Refer Question 25 Unit - 1**

(d) A 60 cm diameter sewer is to discharge 0.07 cumecs at a velocity as self cleansing as a sewer flowing full at 0.85 m/sec. Find the depth and velocity of flow and the required slope? N = 0.015. 7

Ans. **Refer Question 47 Unit - 1**

CSVTU, APRIL-MAY 2011

(a) Define the term sullage. 2

Ans. **Refer Question 1 Unit - 1**

(b) Discuss the relative merits of separate and combined system of sewage and give the conditions favourable for the adoption of each one of them. 7

Ans. **Refer Question 12 Unit - 1**

(c) The following data is available regarding various types of area and corresponding impermeability factors of a twon: 7

	Type	% Area	Impermeability coefficient
1.	Roofs	15%	0.9
2.	Pavements	20%	0.8
3.	Lawns, Gardens Vegetation	40%	0.15
4.	Unpaved	15%	0.20
5.	Wooded	10%	0.05

Determine the average coefficient of runoff. It the total area of the district is 20 hectares, determine the maximum storm water flow for a rainfall intensity of 50 mm/hour having a frequency of once in five years. Use rational formula.

Ans. **Refer Question 49 Unit - 1**

(d) For a circular sewer and a rectangular sewer to be hydraulically equivalent, find the relation between the depth of rectangular sewer and diameter of circular sewer. Take the width of rectangular sewer as 1.5 times the depth and assume that only three sides of the rectangular sewer are wetted. 7

Ans. **Refer Question 50 Unit - 1**

CSVTU, NOV-DEC 2010

(a) What is importance of quantity of sewage? 2

Ans. **Refer Question 7 Unit - 1**

(b) Describe briefly the various commonly adopted sewerage systems? What type of sewerage system will you recommend for cities of Chhattisgarh? Explain your choice giving suitable reasons. 7

Ans. **Refer Question 12 Unit - 1**

(c) What is the importance of providing man holes in a sewerage line? Explain the construction and working of drop manhole with sketch.

Ans. **Refer Question 33 Unit - 1**

(d) Determine the size of a circular sewer for a discharge of 1:2 cumecs running half full. Assume a grade of 1 in 2000 and rugosity coefficient as 0.013. 7

Ans. **Refer Question 51 Unit - 1**

CSVTU, APRIL-MAY 2010

(a) How the amount of sewage is estimated? 2

Ans. **Refer Question 6 Unit - 1**

(b) Describe the various systems of sanitation giving their advantages and disadvantages. Considering the water shortage in townships and cities, what are the modifications you would suggest for better functioning of the system? 7

Ans. **Refer Question 8 Unit - 1**

(c) Why are the manholes required and where are these provided? Explain the construction of one with sketch. 7

Ans. **Refer Question 33 Unit - 1**

(d) A main sewer is to be designed to carry the sewage of a township spread over an area of 80 Sq km with an average population of 200 persons per hectare. The average rate of waste water flow can be taken as 300 ipcd and the maximum flow is 50% in access of the average. Calculate the discharge for which the sewer is to be designed and find the diameter of the sewer with sewer running half-full. Take n = 0.02 and available slope is 1 in 1000. 7

Ans. **Refer Question 54 Unit - 1**

CSVTU, NOV-DEC 2009

(a) What do you mean by hygienic conditions? 2

Ans. **Refer Question 5 Unit - 1**

(b) Describe the various systems of sanitation giving their advantages and disadvantages. Considering the water shortage in townships and cities, what are the modifications you would suggest for better functioning of the system? 7

Ans. **Refer Question 8 Unit - 1**

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(c) *Why are manholes required and where are these provided? Explain the construction of one with sketch.* 7

Ans. ***Refer Question 33 Unit - 1***

(d) *A main sewer is to be designed to carry the sewage of a township spread over an area of 44.sq.km, with an average population of 200 persons per hectare. The average rate of wastewater flow can be taken as 250 ibcd and the maximum flow is 50% in excess of the average. Calculate the discharge for which the sewer is to be designed and find the diameter of the sewer with sewer running half-full. Take n = 0.013 and available slope as 1 in 1000.* 7

Ans. ***Refer Question 55 Unit – 1***

CSVTU, APRIL-MAY 2009

(a) *What do you understand by self cleansing velocity?* 2

Ans. ***Refer Question 23 Unit - 1***

(b) *Describe in brief the patterns of collection of stream and waste water.* 7

Ans. ***Refer Question 19 Unit - 1***

(c) *What point should be kept in mind while locating the site of pumping station? What are requirement of sewage pump; describe in brief.* 7

Ans. ***Refer Question 40 Unit - 1***

(d) *Design the section of circular sewer from following data:* 7

(i) *Area to be served = 150 hectares*
(ii) *Population of locality = 50,000*
(iii) *Maximum permissible velocity = 3.2 m/s*
(iv) *Time of entry = 5 minutes*
(v) *Time of flow = 20 minutes*
(vi) *Rate of water supply = 270 litre/day/capita*
(vii) *Impermeability factor = 0.45.*

Ans. ***Refer Question 52 Unit – 1***

CSVTU, NOV-DEC 2008

(a) *Define Sewerage.* 2

Ans. ***Refer Question 1 Unit - 1***

(b) *Differentiate between water carriage system and conservancy system.* 7

Ans. ***Refer Question 11 Unit - 1***

(c) *A population of 30,000 is residing in a town having an area of 60 hectares. If the average co-efficient of run off for this area is 0.60 and time of concentration of the design rain is 30 minutes, calculate the discharge for which the sewers of a proposed combined system will be designed for town in question. Make suitable assumption where needed.* 7

Ans. ***Refer Question 53 Unit - 1***

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Unit - 2

Characteristics of Sewage
Sewage Treatment
Primary Treatment Systems

2.1 Sewage Characteristics

Characterization of wastes is essential for an effective and economical waste management programme. It helps in the choice of treatment methods, deciding the extent of treatment, assessing the beneficial uses of wastes and utilizing the waste purification capacity of natural bodies of water in a planned and controlled manner. While analysis of waste in each particular case is advisable; the data from other cities may be utilized during initial stage of planning.

Domestic sewage comprises of spent water from kitchen, bathroom, lavatory, *etc.* The factors which contribute to variations in characteristics of the Domestic sewage are daily per capita use of water, quality of water supply and the type, condition and extent of sewerage system, and habits of the people. Municipal sewage, which contains both Domestic and industrial wastewater, may differ from place to place, depending upon the type of industries and industrial establishment. The important characteristics of sewage are discussed here.

Question 1

Discuss various physical properties of sewage. *(CSVTU April – May 2009)*

Ans.

Physical Characteristics of Sewage

Following are the important physical characteristics of the waste water:

(i) **Temperature**

Generally, the temperature of the waste water is higher than that of water supply due to addition of warm water from the households and industries. The observations of temperature of sewage are useful in indicating *solubility of oxygen*, which affects transfer capacity of aeration equipment in aerobic systems, and rate of biological activity. Extremely low temperature affects adversely on the efficiency of biological treatment systems and on efficiency of sedimentation. In general, under Indian conditions, the temperature of the raw sewage is observed to be between 15 to 35° C at various places in different seasons.

(ii) **Colour**

Fresh Domestic sewage has a slightly soapy and cloudy appearance depending upon its concentration. As time passes, the sewage becomes stale, darkening in color, more or less black with a pronounced smell due to microbial activity. The color of industrial waste water depends on the chemical process used in the industries. Industrial waste water when mixed with the domestic sewage may also add color to it.

(iii) **Odour**

The fresh sewage has musty odour which is normally not offensive but as the time passes, the sewage becomes stale and it begins to give offensive odour. Within 3-4 hours, all the oxygen present in the sewage gets exhausted and it starts emitting offensive odour of hydrogen sulphide gas and other sulphur compounds produced by anaerobic microorganisms.

(iv) **Solids**

Though sewage contains only about 0.1 percent solids, the rest being water, still the nuisance caused by the solids cannot be overlooked, as these solids are highly putrescible and therefore needs proper disposal. The sewage solids may be classified into dissolved solids, suspended solids and volatile suspended solids. Knowledge of the volatile or organic fraction of solid, which decomposes, becomes necessary, as this constitutes the load on biological treatment units or oxygen resources of a stream when sewage is disposed by dilution. The estimation of suspended solids, both organic and inorganic, gives a general picture of the load on Sedimentation and grit removal system during sewage treatment. Dissolved inorganic fraction is to be considered when sewage is used for land irrigation or any other reuse is planned.

(v) **Turbidity**

The turbidity of the waste water depends on the quantity of solid matters present in the suspension state. Turbidity is the measure of light emitting properties of waste water and Turbidity test is used to indicate the quality of waste discharges with respect to colloidal matter.

The normal sewage is usually turbid and it contains some matter which can be easily identified, when the sewage is fresh. Such matter includes fecal matter or night soil, pieces of paper, cigarette ends, grease, and fruit skins, soaps, match sticks, vegetable debris etc.

Question 2

Discuss various chemical characteristics of sewage.

Ans.

Chemical Characteristics of Sewage

The nature of the fresh sewage and treated or purified sewage is alkaline. The nature of stale sewage is acidic. In addition to solids and liquids, sewage also contains various gases such as hydrogen sulphide, methane, ammonia and carbon dioxide. Industrial sewage may possess unusual chemical properties.

(i) **Total Dissolved Solids**

Dissolved solids result mainly because of prolonged contact of water with the salts of different catchments. They may be of organic or inorganic origin. Inorganic substances are minerals and metals. Decay products of vegetable and animal origin give rise to organic matter. Dissolved salts may produce colour, taste and odour of which some are objectionable. Distilled water or rain water free from dissolved solids is preferred for industrial operations as steam production and manufacturing of soft drinks. Domestic water should be colourless, odourless but of agreeable taste. Presence of dissolved

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solids alone gives taste. However a concentration greater than 500 to 1000 mg/*l* of dissolved salts may give rise to bitter taste and laxative effect.

(ii) **The pH:**

pH is *potential Hydrogen* i.e., the negative logarithm of hydrogen ion concentration. It is an important quality parameter of both waters and wastewaters. The hydrogen ion concentration expressed as pH, is a valuable parameter in the operation of biological units. The pH of the fresh sewage is slightly more than the water supplied to the community. However, decomposition of organic matter may lower the pH, while the presence of industrial wastewater may produce extreme fluctuations. Generally, the pH of raw sewage is in the range 5.5 to 8.0.

(iii) **Fluoride:**

It is an ingredient of igneous and sedimentary rocks. Fluoride is rarely found in appreciable quantities in surface waters but appears in certain ground waters. Concentrations of approximately 1 mg/*l* in drinking water help to prevent dental cavities in children (*dental carries*). During the formation of permanent teeth, fluoride combines chemically with tooth enamel resulting in harder and stronger teeth that are more resistant to decay. Excessive intakes of fluoride can result in discolouration of enamel of teeth called *mottling* (Dental Fluorosis). Excessive dosages of fluoride can also result in fluorosis of bones and other skeletal abnormalities (Skeletal Fluorosis).

(iv) **Chloride Content:**

Concentration of chlorides in sewage is greater than the normal chloride content of water supply. The chloride concentration in excess than the water supplied can be used as an index of the strength of the sewage. The daily contribution of chlorides averages about 8 gm per person. Based on an average sewage flow of 150 LPCD, this would result in the chloride content of sewage being 50 mg/L higher than that of the water supplied. Any abnormal increase should indicate discharge of chloride bearing wastes or saline ground water infiltration, the latter adding to the sulphates, which may lead to excessive generation of hydrogen sulphide.

(v) **Nitrogen:**

The principal nitrogen compounds in domestic sewage are proteins, amines, amino acids and urea. Ammonia nitrogen in sewage results from the bacterial decomposition of these organic constituents. Nitrogen being an essential component of biological protoplasm, its concentration is important for proper functioning of biological treatment systems and disposal on land. Generally, the domestic sewage contains sufficient nitrogen, to take care of the needs of the biological treatment. For industrial wastewater if sufficient nitrogen is not present it is required to be added externally. Generally, nitrogen content in the untreated sewage is observed to be in the range of 20 to 50 mg/L measured as TKN.

(vi) **Phosphorus:**

Phosphorus is contributing to domestic sewage from food residues containing phosphorus and their breakdown products. The use of increased quantities of synthetic detergents adds substantially to the phosphorus content of sewage. Phosphorus is also an essential nutrient for the biological processes. The concentration of phosphorus in

domestic sewage is generally adequate to support aerobic biological wastewater treatment. However, it will be matter of concerned when the treated effluent is to be reused. The concentration of PO_4 in raw sewage is generally observed in the range of 5 to 10 mg/L.

(vii) **Toxic Metals and Compounds:** Some heavy metals and compounds such as chromium, copper, cyanide, which are toxic may find their way into municipal sewage through industrial discharges. The concentration of these compounds is important if the sewage is to treat by biological treatment methods or disposed off in stream or on land. In general these compounds are within toxic limits in sanitary sewage. However, with receipt of industrial discharges they may cross the limits in municipal wastewaters.

(viii) **Inorganic Salts:**

Inorganic salts, which are present in most industrial wastes as well as in natural soils, render the water hard and make it undesirable for industrial, municipal and agricultural use. Salt laden waters deposit scales on municipal water distribution pipelines result in increase resistance to flow and lower the overall capacity of the pipes. Salts of nitrogen and phosphorous promote the growth of microscopic plant life (algae) resulting in *eutrophication* of lakes.

(ix) **Acids and Alkalies:**

Acids and alkalies discharged by chemical and other industrial plants make a stream undesirable not only for recreational uses as swimming and boating, but also for propagation of fish and other aquatic life. High concentrations of mineral acids lower the pH well below 4.5. Similarly extreme alkalinity causes eye irritation to swimmers.

(x) **Organics:**

Most natural organics consist of the decay products of organic solids, while synthetic organics are usually the result of industrial wastewater discharges or agricultural runoffs.

(xi) **Fats, Oil and Grease:**

Fats and oils are the third major component of food stuffs. The term "grease" as commonly used, includes the fats, oils, waxes and other related constituents found in wastewater. Fats and oils are compounds (esters) of alcohol or glycerol with fatty acids. Fats and oils are contributed to domestic sewage in butter, vegetable fats and oils. Fats are also commonly found in meats, in seeds, in nuts and in certain fruits. Oils reach the sewer in considerable volumes from soap manufacturing units, from garages and street washes. These interfere with biological action of microbes and cause maintenance problem of sewers and treatment plants.

(xii) **Dissolved Oxygen:**

The living organisms are dependent upon oxygen in one form or another to maintain the metabolic processes that produce energy for growth and reproduction. All the gases of atmosphere dissolve in water to some degree. Both nitrogen and oxygen are poorly soluble. The solubility of atmospheric oxygen in fresh waters ranges from 14.6 mg/*l* at 0°C to about 7.6 mg/*l* at 30°C at 1 atmospheric pressure. Dissolved salts of water reduce the solubility of oxygen so also impurities in water.

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Question 3

Discuss various biological characteristics of sewage.

Ans.

Biological Characteristics of Sewage

The sewage contains bacteria and other living micro organisms such as algae, Fungi, protozoa etc. The bacteria are present in sewage in large number and depending upon their nature, they may be classified as pathogenic and non pathogenic bacteria .The Pathogenic bacteria are harmful and they are responsible for causing diseases. The sewage obtains such bacteria from the discharge of the person and animals suffering from various diseases. The non pathogenic bacteria are harmless. Depending upon their action bacteria divided into three categories, namely aerobic bacteria, anaerobic bacteria and facultative bacteria.

(i) **Bacteria:**

The word bacteria come from the Greek word meaning "rod" or "staff" a shape characteristic of most bacteria. Bacteria are single cell microorganisms, usually colourless and are the lowest form of plant life capable of synthesizing protoplasm from the surrounding environment. In addition to the rod shape (*bacilli*), bacteria may also be spherical (*cocci*), comma shaped (*vibrio*), or spiral shaped (*spirilla*). Gastrointestinal disorders are common symptoms of most diseases transmitted by waterborne pathogenic bacteria.

(ii) **Viruses:**

Viruses are the smallest biological structure known to contain all the genetic information necessary for their own reproduction. It is the demarcation between living and non-living objects. Viruses require a host to live and to multiply. Waterborne viral infection usually involves disorders of the nervous system rather than those of the gastrointestinal tract. Waterborne viral pathogens are *Poliomyelitis* (Polio) and *infectious hepatitis* (yellow jaundice).

(iii) **Protozoa:**

The lowest form of animal life, protozoa is unicellular organisms more complex in their functional activity than bacteria or viruses. Protozoal infections are usually characterized by gastrointestinal disorders as amoebic dysentery.

Question 4

Explain the procedure of determination of total solids, suspended solids, and settle able solids for a waste water sample. How will you separate the organic and inorganic part of these solids? *(CSVTU, April –May 2010) (CSVTU, Nov –Dec 2009)*

Or

State and describe four important tests that may be carried out to know the characteristics of sanitary sewage. *(CSVTU Nov- Dec 2008)*

Or

Write the formula for determination of:

(i) Total Solids

(ii) Total Volatile Solids *(CSVTU, April –May 2012)*

Ans. Total solids of waste water are defined as all the matter that remains as residue on the evaporation to 103°C to 105 °C. The total solids may exist in the three different forms.

1. Suspended solids
2. Colloidal solids
3. Dissolved solids

Suspended solids are those which can be filtered out on a filter paper. Suspended solids may be divided into:

1. **Settleable Solids:** Settleable Solids are those which settle to the bottom of cone shaped container, called imhoff cone in 2 hr period.
2. **Non Settleable solids**

Determination of Total solids and Volatile Solids

Total solids in the given sample of the waste water can be determined as follows.

1. Take the initial dry weight of the crucible let it be (W_1).
2. Take the known volume (V) of the well mixed sample in the crucible.
3. Place the crucible in the oven at 103°C for 24 hrs, in constant temperature oven.
4. Cool the dish in the desiccators and determine its weight as (W_2).
5. Ignite the dish at 600^0 c in a muffle furnace, for 30 miniatures.
6. Cool the dish in the desiccators and determine its weight as (W_3).

The Total solids can be determined by using the formula

Total Solids

$$T_S = \frac{(W_2 - W_1)}{V} \times 100 \text{ mg/}l$$

Total Volatile Solids

$$V_S = \frac{(W_2 - W_3)}{V} \times 100 \text{ mg/}l$$

Determination of Suspended (non-filterable) solids:

1. Take the initial dry weight of the crucible let it be (W_1).
2. Take a known volume (V) of sample and filter it through a watt's man filter no 44.
3. Place the filter paper in the oven at 103°C for 24 hrs.
4. Weigh the residue left in the filter paper let the weight be (W_2).
5. Ignite the crucible at 600^0 c in a muffle furnace, for 30 miniatures.
6. Cool the dish in the desiccators and determine its weight as (W_3).

Suspended(non-filterable) Solids =

$$= \frac{(W_2 - W_1)}{V} \times 100 \text{ mg/}l$$

Suspended(non-filterable) Volatile Solids =

$$= \frac{(W_2 - W_3)}{V} \times 100 \text{ mg/}l$$

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Determination of Settleable Solids:

Settleable solids can be determined easily with the help of an Imhoff cone. The capacity of the cone is 1 Liter and it is graduated up to 50 ml. Sewage is allowed to stand in this imhoff cone for a period of two years and the quantity of solids settled in the bottom of the cone then can be directly read out. However, for the more precision the amount of settelable solids the liquid from the cone should be decanted off and the settelable solids collected at the bottom of the cone should be dried and weighed.

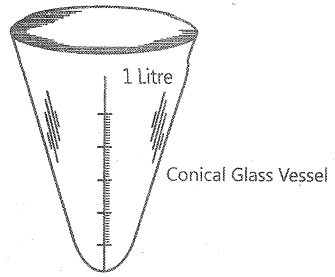


Fig. 2.1 IMHOFF CONE

2.2 Cycles of Decomposition

Question 5

Write a short note on

1. *Aerobic decomposition of sewage*
2. *Anaerobic decomposition of sewage:*

Ans.

1. Aerobic decomposition of sewage

The aerobic bacteria come into action when oxygen is available in plenty or when it is made available by the process of *putrefaction*. The aerobic decomposition of sewage is also known as *oxidation* and during this process the organic matter is broken up and oxidized to form the stable compounds. The end product of oxidation includes carbon dioxide, nitrates, sulphates etc.

Treatment units which works on the principle of aerobic decomposition is aeration tanks, contact beds, intermittent sand filters and oxidation pond. The anaerobic decomposition is orderly and inoffensive and it is practiced in all biological units of sewage treatment except the controlled decomposition of sewage sludge in sludge digestion tanks.

2. Anaerobic decomposition of sewage:

The fresh sewage contains some quantity of oxygen to the extent of about 2 to 5 parts per million. The aerobic bacteria react on organic matter present in sewage and the available oxygen is consumed by them. The anaerobic bacteria then start their function and attack on the complex organic compounds and convert them into solids, liquids and gases. The anaerobic decomposition is known as *putrefaction* and the end products of putrefaction are black residue called humus, ammonia, methane, hydrogen sulphide, carbon dioxide, nitrogen, hydrogen etc.

Treatment units which work on the principal of anaerobic decomposition are Septic tanks, Imhoff tanks and sludge digestion tanks. The anaerobic decomposition is

disorderly and offensive. This is much slower than aerobic decomposition and is also found to be inefficient with respect to energy conversion.

2.3 Oxygen Demand

As stated earlier, the presence of oxygen is essential for the livelihood of organisms. The aerobic action continues only till the oxygen is present in wastewater, and after that anaerobic action begins resulting in putrefaction. Thus, oxygen is demanded in wastewater for the oxidation of both inorganic as well as organic matter. Thus demand of oxygen may be expressed in the following ways

(i) Biochemical oxygen demand (BOD)
(ii) Chemical oxygen demand (COD)
(iii) Total oxygen demand (TOD)
(iv) Theoretical oxygen demand (Th.OD)

In addition to these, the amount of organic matter present may also be determined by the total organic carbon (TOC) test.

2.3.1 Biological Oxygen Demand

Question 6

Explain BOD and its significance in waste water treatment.

Or

Explain the biochemical oxygen demand. *(CSVTU, April-May 2013)*

Ans. *Biochemical oxygen demand (BOD) is defined as the amount of oxygen required by microorganisms to stabilize decomposable organic matter at a particular time and temperature.*

BOD test is widely used to determine the pollutional strength of domestic and industrial wastes in terms of the oxygen that they require to deliver end products as CO_2 and H_2O. The BOD test is essentially a bioassay procedure involving the measurement of oxygen consumed by living organisms (mainly bacteria) while utilizing the organic matter present in the waste as carbohydrates, proteins and fats.

The general range of BOD observed for raw sewage is 100 to 400 mg/L. The standard time and temperature for this test in London where the test was originated is 5 days and 20°C respectively. But in Indian condition this test is done at 37°C.

The organic matter in the sewage is classified in two groups.

1. Carbonaceous matter
2. Nitrogenous matter

In first stage, the carbonaceous matter is oxidized and in second stage, the nitrogenous matter is oxidized. The amount of oxidation is nearly 70% after 5 days and 90% after 10 days or nearly 98 % or total after 20 days.

Significance of BOD:

The presence of oxygen is necessary for the life of organisms. The aerobic action continues till the oxygen is present in the sewage. As the oxygen exhausts, the anaerobic action begins due to which foul smell starts coming. Therefore, indirectly the decomposable matters require oxygen, which is used by the organisms. Length of aerobic action can be increased in the beginning and the BOD is satisfied.

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Question 7

Deduce expression for first stage BOD. (CSVTU, Nov-Dec 2012)(CSVTU, April-May 2011)

Or

What is first stage BOD? *(CSVTU, April-May 2013)*

Ans. **First Stage BOD Formulation:**

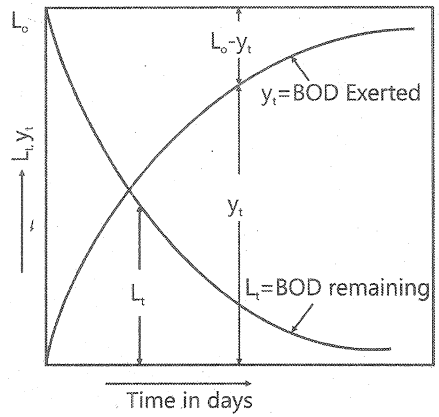


Fig. 2.2

At a given temperature, the rate at which the BOD is satisfied any time is directly proportional to the amount of organic matter present in sewage.

The exertion of BOD is considered to be first order reaction defined by

$$\frac{dL_t}{dt} = -k'.Lt \qquad \ldots (1)$$

Where, L_t = amount of first stage BOD remaining in the sample at any time t in mg/L.

k' = Rate constant is day^{-1}

t = Time in days

Integrating Eq. (1), from time t = 0 to time = t we get

$$\int \frac{dL_t}{L_t} = -k' \int dt$$

$$\text{Log}\ \frac{L_t}{L_o} = -k't$$

$$\frac{L_t}{L_o} = e^{-k't} \quad \text{OR} \quad \frac{L_t}{L_o} = 10^{-k't}$$

Where, $k = \frac{k'}{2.303}$

L_o = Oxygen equivalent of organic matter present in sewage in beginning

k = Deoxygenation constant or Base 10 constant

k' = Base *e* constant

The amount of BOD remaining at any time t is

$$L_t = L_o(10^{-kt})$$

Hence y_t, the amount of BOD exerted at any time t is given by

$$y_t = (L_o - L_t)$$

$$y_t = L_o [1 - 10^{-kt}]$$

The first stage BOD curve is as shown in Fig. 2.14. The ultimate first stage BOD can be obtained by substituting $t = \infty$ in above equation.

$$\therefore \quad y_t = L_o\left(1 - 10^{-k\infty}\right) = L_o$$

Therefore, we can say that the ultimate first stage BOD of a given wastewater is equal to the initial oxygen equivalent of the organic matter present in the sample of wastewater. The curve for first stage BOD is shown in fig. 2.2.

Question 8

What is second stage BOD? *(CSVTU, April-May 2013)*

Ans. As stated earlier, carbonaceous matter is oxidised in the first stage of biochemical reaction, while nitrogenous matter is oxidised in the second stage. Some of the autotrophic bacteria are capable of using oxygen to oxidize noncarbonaceous matter, such as ammonia to nitrites and nitrates. This second stage reaction is called *nitrification*. Thus, the nitrogenous oxygen demand caused by the autotrophic bacteria is called the second stage BOD. Fig. 2.3 shows the influence of nitrification on BOD curve.

It should be noted that at 20°C, the reproduction rate of nitrifying bacteria is very slow and it takes about 6 to 10 days to reach significant numbers and to exert a measurable oxygen demand. The interference caused by their presence can be eliminated by pretreatment of sample, such as pasteurization, chlorination or acid treatment. Alternatively, certain inhibitory agents (such as methylene blue, thiourea etc.) may be used.

Question 9

Draw BOD curve for a domestic waste water sample and explain various segments on it. *(CSVTU, April-May 2013)*

Ans. By comparing Figs. 2.2 and 2.3, it can be seen that the curve of Fig. 2.3 is nothing but the reciprocal of BOD remaining curve in Fig. 2.2. This is because the oxygen used in satisfying BOD is in direct ratio of the amount of organic matter oxidized, which means reciprocal of the curve of Fig. 2.2.

The portion AC of the curve of Fig. 2.3 represents the nitrification stage, which follows the carbonaceous stage, so that the BOD curve for the complete oxidation is represented by OAC.

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

The nitrogenous stage, or second stage, represents a combined carbonaceous plus nitrogenous demand, when organic nitrogen, ammonia, and nitrite are converted to nitrate. Nitrogenous oxygen demand generally begins after about 6 days. For some sewage, especially discharge from wastewater treatment plants utilizing biological treatment processes, nitrification can occur in less than 5 days if ammonia, nitrite, and nitrifying bacteria are present. In this case, a chemical compound that prevents nitrification should be added to the sample if the intent is to measure only the carbonaceous demand. The results are reported as carbonaceous BOD (CBOD), or as $CBOD_5$ when a nitrification inhibitor is used.

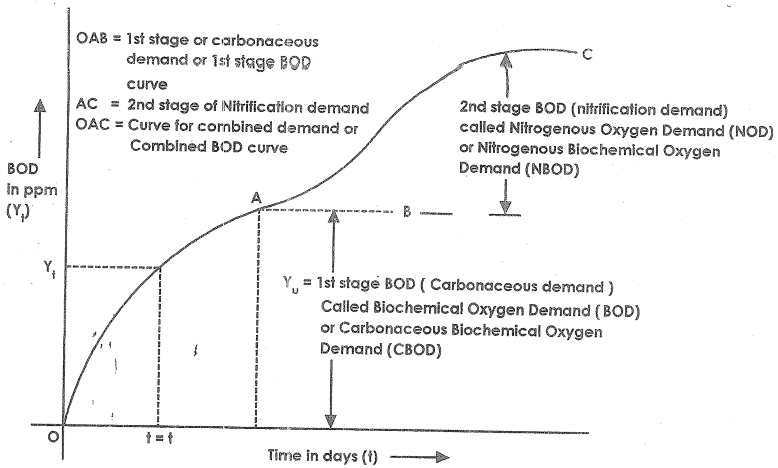


Fig. 2.3 Combined BOD Curve(First Stage and Second Stage)

Question 10

(i) Standard BOD_5 20°C when compared to ultimate BOD is about:

(1) 58% *(2) 68%*

(3) 78% *(4) 90%* *(CSVTU, Nov- Dec 2011)*

Ans. 68 %

(ii) Average BOD_5 of domestic sewage is

(1) 80 kg/d/p *(2) 8 kg/d/p*

(3) 0.08 kg/d/p *(4) 0.8 kg/d/p* *(CSVTU Nov- Dec 2011)*

Ans. 0.08 kg/d/P

Question 11

What is the standard BOD test?

Ans.

Estimation of BOD:

1. The most widely used parameter of organic pollution applied to both wastewater and surface water is the 5 day BOD (BOD_5) at 20°C.
2. BOD determination involves the measurement of the dissolved oxygen used by microorganisms in the biochemical oxidation of organic matter.
3. The reason is that BOD test results are now used (i) to determine the approximate quantity of oxygen that will be required to biologically stabilize the organic matter present (ii) to determine the extent of waste treatment facilities (iii) to measure the efficiency of the biological treatment processes.
4. In the standard BOD test, a small sample of the wastewater to be tested is placed along with dilution water in a BOD bottle (300 ml). The dissolved oxygen concentration of the mixture in the bottle is measured. The bottle is incubated for 5 days at 20°C and the

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dissolved oxygen concentration is measured again. The BOD of the sample is the decrease in the dissolved oxygen concentration values, expressed in mg/*l*; divided by the decimal fraction of the sample used.

Question 12

What are the limitations of BOD test?

Ans. Following are the limitation of BOD test.

1. If the sample of sewage contains toxic wastes, it should be given pretreatment before applying the BOD test.
2. It is essential to have a high concentration of the active bacteria present in the sample of sewage.
3. The effects of nitrifying organisms should be reduced before applying the test.
4. The test looses stoichiometric validity after the soluble organic matter present in the sample of sewage has been exhausted.
5. The test measures only the biodegradable organic.
6. The time required for the test is arbitrary and long.
7. For the BOD_5 test, the 5 day period may or may not correspond to the point where soluble organics matter present has been used.

2.3.2 Chemical Oxygen Demand

Question 13

Explain COD and its significance in waste water treatment. (CSVTU, April-May 2012)

Or

What do you understand by "chemical oxygen demand"? (CSVTU, April -May 2009)

Ans. The COD gives the measure of the oxygen required for chemical oxidation. It does not differentiate between biological ox disable and non oxidisable material. However, the ratio of the COD to BOD does not change significantly for particular waste and hence this test could be used conveniently for interpreting performance efficiencies of the treatment units. In general, the COD of raw sewage at various places is reported to be in the range 200 to 700 mg/L.

In COD test, the oxidation of organic matter is essentially complete within two hours, whereas, biochemical oxidation of organic matter takes several weeks. In case of wastewaters with a large range of organic compounds, an extra difficulty in using BOD as a quantitative parameter is that the rate of oxidation of organic compounds depends on the nature and size of its molecules. Small molecules are readily available for use by bacteria, but large molecules, colloidal and suspended matter can only be metabolized after preparatory steps of hydrolysis. It is therefore not possible to establish a general relationship between the experimental five-day BOD and the ultimate BOD of a sample, *i.e.*, the oxygen consumption after several weeks. For sewage (with k=0.23 d-1 at 20°C) the BOD_5 is 0.68 times ultimate BOD, and ultimate BOD is 87% of the COD. Hence, the COD /BOD ratio for sewage is around 1.7.

The ratio of BOD to COD is useful to assess the amenability of the waste for biological treatment. Ratio of the BOD to COD greater than or equal to 0.8 indicates the waste water is highly polluted and amenable to the biological treatment.

2.4 Relative Stability

Question 14

Define Relative Stability. (CSVTU, April-May 2011)

Ans. **Relative Stability:** Relative stability is defined *as the ratio of the oxygen available in the effluent to the total oxygen required to satisfy the first stage BOD. It is expressed as percentage of the total oxygen required, and can be expressed by the equation:*

Relative Stability

$$S = 100[1 - (0.794)^{t_{20}}]$$

$$S = 100[1 - (0.605)^{t_{37}}]$$

Where t_{20} and t_{37} are the number of days of incubation at 20°C and 37°C respectively.

2.5 Population Equivalent

Question 15

What is meant by population equivalent? How is it determined? (CSVTU, April -May 2012)

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

The strength of the industrial waste water/sewage is worked out as below:

[Standard BOD_5 of industrial sewage] = [Standard BOD_5 of Domestic sewage per capita per day] × [Population Equivalent]

The average Standard BOD_5 of Domestic sewage per capita per day is 0.08kg/day. Hence, if theBOD_5 of industrial sewage is worked out as 300kg/day then,

The Population Equivalent is given by

$$P_E = \frac{BOD_5 \text{ of industry in kg/day}}{BOD_5 \text{ value/capita/day}}$$

2.6 Biological Characteristics

Question 16

How are bacteria in sewage classified?

Ans. Bacteria are single -celled microorganism with rigid cell walls that take in soluble food and convert it to new cells. Bacteria may be classified according to type as (i) saprophytic bacteria, (ii) parasitic bacteria (iii) pathogenic bacteria and (iv) non-pathogenic bacteria. Saprophytic bacteria are beneficial to man, and obtain organic matter in solution from dead and decaying tissue in plants and animals. Parasitic bacteria live and multiply on or within the body of a living organism of a higher type. Pathogenic bacteria and pathogenic organism are capable of causing disease within the living organisms on which they subsist.

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According to the *oxygen need*, the bacteria may be classified as

(i) *Aerobic bacteria*, which needs oxygen to survive.
(ii) *Anaerobic bacteria*, which survives in the absence of oxygen.
(iii) *Facultative bacteria*, which can live or multiply with or without oxygen.

The bacteria of *excretal origin* can be classified as

(i) *The coli-aerogenes group*
(ii) *Clostridium Welchi*
(iii) *Faecal streptococci*

Coliaerogeneous Group: The intestines of men and warm blooded animals contain certain harmless bacteria which are excreted with faeces. These are numerous in sewage. These are known as *coliforms*. The *coliforms* group includes all of the aerobic and facultative anaerobic nonsporeforming, Gram-negative rod shaped bacteria that ferment lactose with production at 35° c of gas within 48 hours. The coliform group is comprised of two important species. *Escherichi coli (E-coli)* and *Aerobacteria aerogenes*. They are of advantage as indicators of water contamination.

Clostridium Welchi is a stout Gram-positive rod having elliptical sub-terminal spores. The organism is found in cultivated soils, sewage and polluted water. Intestines are its natural habitat where it causes non harm but assists digestion.

Faecal streptococci are found in human intestines. It is a Gram-positive coccus occurring in pairs or short chains. It grows in presence of bile salt and is capable of growing at temperatures as high as 45°C. However, they are not as numerous as E-coli in all normal cases. Hence test for faecal streptococci offers no advantage over the E-coli lest except in case of doubt.

The *coliforms* and the *E-coli* are normally used as indicator organisms since they are present in large numbers than pathogens. They also lend themselves to numerical evaluation as well as qualitative distinction. They are also identifiable by relatively simple analytical procedures, providing information quickly and economically. The usual procedure for determining the presence of coliforms consist of (i) presumptive (ii) the confirmed tests, and (iii) completed test.

There are two accepted methods for obtaining the number of coliforms organisms in the specimen:

(i) The coliforms index end
(ii) The most probable number (M.P.N). The most probable number (M.P.N) of coliform is defined as that bacterial density, which if it had been actually present in the sample under examination, would more frequently than any other, have given the observed analytical, result. Thus, MPN is not the absolute concentration of organism that are present but only a statistical estimate of that concentration.

Question 17

Write short note on:
(i) Aerobic Processes in bacteria

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Ans.

Anaerobic processes:

The work done by anaerobic bacteria, viz. decomposition of organic matter is called putrefaction and the result is called liquefaction, as the solid organic matter is dissolved by enzymes. Anaerobic bacteria oxidize organic matter utilizing electron acceptors other than oxygen. In carrying but their metabolic processes, they produce CO_2, H_2O, H_2S, CH_4, NH_3, N_2, reduced organics and more bacteria. A large part of the available energy appears in the form of end products, and hence cell production is low. Treatment units which work on putrefaction alone are septic tanks, Imhoff tanks, and sludge digestion tanks. The end products of an anaerobic fermentation are likely to be odorous. The production of a stable effluent is unlikely since wastes do not usually contain sufficient electron acceptors to permit complete oxidation.

Aerobic processes:

The work of the aerobic bacteria, i.e., combination with oxygen is called *oxidation*. Aerobic bacteria utilize free oxygen as an electron acceptor. The end products of aerobic activity are CO_2, H_2O, SO_4, NO_3, NH_3, and more bacteria. The bulk of the available energy finds its way into cell mass or heat, yielding a stable effluent which will not undergo further decomposition.

Though each of the above two *processes* work in the opposite direction, the former by splitting up and the latter by building up, there is co-ordination between the two processes. In the first stage, the anaerobic bacteria decompose complex organic matter into sample organic compounds while in the second stage; the aerobic bacteria oxidize them to form stable compounds.

Question 18

What do you mean by MPN of waste water? *(CSVTU, April –May 2010)*

Ans. The most probable number (M.P.N) of coliform is defined as that bacterial density, which if it had been actually present in the sample under examination, would more frequently than any other, have given the observed analytical, result. Thus, MPN is not the absolute concentration of organism that are present but only a statistical estimate of that concentration.

Question 19

A 2.5 ml of waste water sample is diluted to 200 ml of BOD test. The initial DO for the diluted sample is 7.8 mg/L and final DO after 5 day of incubation is 3.2 mg/L. Find out BOD of waste water.

Ans.

DO initial = 7.8 mg/L

DO final = 3.2 mg/L

$$\text{Dilution factor} = \frac{\text{Total volume of diluted sample}}{\text{Volume of raw sample}}$$

$$= \frac{250}{2.5} = 100$$

BOD = (DO initial – DO final) × Dilutionfactor

$= (7.8 - 3.2) \times 100$

$= 460$ mg/L

BOD of waste water is 460 mg/L.

Question 20

In a BOD test, 6 ml of waste water sample is mixed with 294 ml of dilution water. Dilution water contains 8.6 mg/L of DO. After 5 – day incubation at 20°c, the DO of mixture is found to be 5.4 mg/L. Calculate BOD of waste water. Assume that DO of the waste water is initially zero.

Ans. Volume of sample $(V_s) = 6$ ml

Volume of dilution water $(V_d) = 294$ ml

Volume of mix $(V_m) = 300$ ml

Constant of sample $(C_s) = 0$

Concentration of dilution water $(C_d) = 8.6$ mg/L

Concentration of mixture $(C_m) = Do_{initial} = DO_o$

Now, $V_m \times C_m = V_s \times C_s + V_d \times C_d$

$$C_m = \frac{V_s \times C_s + V_d \times C_d}{V_m}$$

$$= \frac{6 \times 0 + 294 \times 8.6}{300} = 8.428 \text{ mg/L}$$

Now, 5 day BOD

$$(BOD)_5 = [(Do(0)) - (Do(5))] \times \text{dilution factor}$$

$$= [8.428 - 5.4] \times \frac{300}{6}$$

$$(BOD)_5 = 151.4 \text{ mg/}l$$

The BOD is found to be 151.4 mg/l.

Question 21

In a 5 – day BOD test, a sample of sewage was diluted with water with a dilution factor of 100. If the content of dissolved oxygen in the beginning and end of test are 13 mg/L and 8 mg/L respectively, calculate the 5 – day BOD. Remark on nature of sewage.

Ans. 5 day BOD = Loss of oxygen in mg/L × dilution ratio

$= (13 - 8) \times 100$

$= 500$ mg/L

The sewage is strong and it requires heavy treatment before being disposed.

Question 22

Determine the ultimate BOD and 1 – day BOD for a sewage having 5 – day BOD at 20°C as 200 mg/L. Assume $k_{20} = 0.1/day$.

Ans. $y_t = L_o(1 - 10^{-kt})$

$y_5 = L_o(1 - 10^{-5k})$

$200 = L_o(1 - 10^{-5k})$

$\therefore \quad L_o = 292.5$ mg/L

Ultimate BOD $= 292.5$ mg/L

$y_t = L_o(1 - 10^{-kt})$

$y_1 = 292.5\,(1 - 10^{-1\times0.1})$

$y_1 = 60.16$ mg/L

The BOD is found to be 60.16 mg/l.

Question 23

The 5 – day BOD of the waste water sample at 20°C is 210 mg/L. Find out ultimate first stage BOD and also determine the 5 – day BOD of the same sample, if the incubation is done at 30°C. Assume the BOD rate constant as 0.23/day. (CSVTU, April-May 2010)

Ans. $k' = 0.23/day$

$y_5 = 210$ mg/l at 20°C

$\therefore \quad y_t = L_o(1 - e^{-k't})$

$210 = L_o(1 - e^{-0.23\times5})$

$L_o = 307.3$ mg/L

Ultimate first stage BOD

$(L_o) = 307.3$ mg/L

$k'_T = k'_{20}\,(\theta)^{T-20}$

Assuming $\theta = 1.047$

$k_{30} = 0.23(1.047)^{30-20}$

$k_{30} = 0.364/day$

Now, y_5 at 30°C

$y_5 = L_o(1 - e^{-k't})$

$= 307.3(1 - e^{-0.364\times5})$

$y_5 = 257.53$ mg/L

The ultimate first stage BOD is found to be 307.3 mg/l and 5 day BOD as 257.53 mg/l.

Question 24

Determine the ultimate BOD for a sewage having 5 day BOD at 20°C as 160 ppm. Assume the deoxygenation constant as 0.2 per day. Also determine the 2 day BOD of the sample.

Ans. Given:- $BOD_5 = 160$ ppm

$k = 0.2/day$

$L_o = ?$

Now, from the equation

$BOD_5 = y = L_o(1 - 10^{-kt})$

$y_5 = L_o(1 - 10^{-5k})$

$160 = L_o(1 - 10^{-5\times0.2})$

$160 = 0.9 \times L_o$

$L_o = 177.77$ mg/l

Again, $y_2 = L_o(1 - 10^{-2k})$

$= 177.77 \times (1 - 10^{-2\times0.2})$

$y_2 = 177.77 \times 0.6018 = 106.99$ mg/l

Question 25

The wastewater sample contains BOD_3 as 75 mg/l and reaction rate to base e as 0.345 per day, the amount of BOD remaining after 10 days is

(i) 3.12 mg/l

(ii) 3.45 mg/l

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(iii) 3.69 mg/l
(iv) 3.92 mg/l *(CSVTU, April-May 2013)*

Ans.

Here $k' = 0.345/day$

$y_3 = 75\ mg/l$

BOD remaining after 10 days=?

We know that

$$k = \frac{k'}{2.303}$$

$$k = \frac{0.345}{2.303}$$

$$k = 0.1498/day$$

$$y_t = L_o(1 - 10^{-k't})$$

$$y_3 = L_o(1 - 10^{-0.15\times3})$$

$$75 = L_o(1 - 10^{-0.45})$$

$$75 = L_o(1 - 0.355)$$

$$75 = L_o(0.645)$$

$$L_o = 116.331\ mg/l$$

$$y_{10} = L_o(1 - 10^{-0.1498\times10})$$

$$y_{10} = L_o(1 - 0.031676)$$

$$y_{10} = 0.9682\ L_o$$

It indicates 96.82 % of the ultimate BOD is utilized in 10 days and only 3.18 % is remaining unoxidised.

BOD remaining after 10 days

$$= \frac{3.18}{100} \times 116.31$$

$$BOD = 3.69\ mg/l$$

So the answer is *(iii)*.

Question 26

A sample of waste water has 4 day 20°C BOD value of 75% of the final. Find the rate constant (to the base 10) per day.

Ans. Given: $y_4 = 0.75\ L_o$

$k = ?$

$y_t = L_o(1 - 10^{-kt})$

$y_4 = L_o(1 - 10^{-4k})$

$0.75\ L_o = L_o(1 - 10^{-4k})$

$0.75 = (1 - 10^{-4k})$

$10^{-4k} = 1 - 0.75$

$-4k = \log(0.25)$

$-4k = -0.602$

$4k = 0.602$

$\mathbf{k = 0.151/day}$

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Question 27

Find the rate constant (to the base 10) at a temperature of 30°C if its value at 20°C is 0.12/day.

Ans. $k_{30} = ?$

$k_{20} = 0.12/day$

Now, from the equation

$$k_T = k_{20}\ (\theta)^{T-20}$$

Where, $\theta = 1.056$ as the temperature ranges between 20°C to 30°C

$$k_{30} = 0.12\ (1.056)^{30-20}$$

$$\mathbf{k_{30} = 0.207/day}$$

Question 28

The BOD_5 of a waste has been measured as 500 mg/L. If the rate constant $k' = 0.26/day$ (base e), what is the ultimate BOD of the waste? What proportion of BOD_u would remain unoxidised after 20 days?

Ans. $k' = 0.26/day$ (base e)

We know that, $k = \frac{k'}{2.303}$

$$k = \frac{0.26}{2.303}$$

$$k = 0.113/day$$

$$y_t = L_o(1 - 10^{-kt})$$

$$y_5 = L_o(1 - 10^{-5k})$$

$$500 = L_o(1 - 10^{-0.113\times5})$$

$$500 = L_o(1 - 0.2722)$$

$$500 = L_o(0.7277)$$

$$L_o = 687.06\ mg/L$$

Again, $y_{20} = L_o(1 - 10^{-0.133\times20})$

$$= L_o(1 - 10^{-2.26})$$

$$= L_o(0.9945)$$

$$= 0.9945\ L_o$$

This indicates that 99.45% of the ultimate BOD is utilized in 20 days and only 0.55% is left unutilized.

Question 29

Data from unseeded domestic waste water BOD test are: 5 ml of waste in 300 ml bottle, initial DO of 7.8 mg/L and 5 days D.O. equal to 4.3 mg/L. Compute
(i) The BOD
(ii) The ultimate BOD, assuming a k – rate of 0.10 per day.
(CSVTU, April-May 2011)

Ans. Given: Initial BOD = 7.8 mg/L

DO after 5 days incubation = 4.3 mg/L

∴ DO consumed in 5 days = 7.8 – 4.3

= 3.5 mg/L

Now, BOD_5 of the waste water

$$= \text{DO consumed by diluted sample} \times \left[\frac{\text{Vol. of diluted sample}}{\text{Vol. of undiluted sample}}\right]$$

$$= 3.5 \times \left[\frac{300 \text{ ml}}{5 \text{ ml}}\right]$$

$$= 210 \text{ mg/L}$$

$$y_5 = L_o[1 - 10^{-5k}]$$

$$210 = L_o[1 - 10^{-5\times0.10}]$$

$$210 = L_o[0.6837]$$

$$L_o = \frac{210}{0.6837}$$

$$\mathbf{L_o = 307.11 \text{ mg/L}}$$

Question 30

A 2% solution of a sewage sample is incubated for 5 days at 20°C. The depletion of oxygen was found to be 4 ppm. Determine the BOD of the sewage. What will be the 3 – day BOD of the sewage in summer when the temperature is 37°C? Take BOD rate constant (base 10) as 0.1 per day at 20°C.

(CSVTU, Nov-Dec 2009)(CSVTU, Nov-Dec 2010)

Ans.

$$\text{Dilution factor} = \frac{100}{\% \text{ of solution}} = \frac{100}{2}$$

Dilution factor = 50

Depletion of oxygen = 4 ppm

We know that, BOD = Depletion of oxygen × dilution factor

= 4 ppm × 50

BOD = 200 ppm

The BOD of the sewage is found to be 200 ppm. *Ans.*

The 3 – day BOD of the sewage in summer when the temperature is 37°C,

$$k_{37} = k_{20}\,\theta^{(T-20)}$$

$$= 0.1\,(1.056)^{37-20}$$

$$= 0.1 \times 2.5251$$

$$\mathbf{k_{37} = 0.2525/day}$$

Now, $BOD_5 = 200$ mg/L

$$y_5 = L_o[1 - 10^{-kt}]$$

$$200 = L_o[1 - 10^{-0.1\times5}]$$

$$200 = 0.6837\,L_o$$

$$\mathbf{L_o = 292.49 \text{ mg/L}}$$

Again, $y_3 = L_o(1 - 10^{-k_{37}\times3})$

$$y_3 = 292.49\,(1 - 10^{-0.2525\times3})$$

$$= 292.49\,[0.8252]$$

$$\mathbf{y_3 = 241.367 \text{ mg/L}}$$

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Question 31

The 5 day 20°C BOD of waste water is 210 mg/L. What will be the ultimate BOD? What will be the 10 – day BOD? Take the rate constant (natural log) as 0.23 per day.

Ans. Given: y_5 at 20°C = 210 mg/L

$y_{10} = ?$

$L_o = ?$

$k' = 0.23$/day

We know that $k = \frac{k'}{2.303}$

$$= \frac{0.23}{2.303} = 0.099/\text{day}$$

Now, $y_5 = L_o\,(1 - 10^{-kt})$

$$210 = L_o[1 - 10^{-0.99\times5}]$$

$$210 = L_o(0.6832)$$

$$L_o = 307.33 \text{ mg/L}$$

$$y_{10} = L_o\,(1 - 10^{-kt})$$

$$= 307.33\,(1 - 10^{-0.099\times10})$$

$$= 307.33 \times (0.8976)$$

$$\mathbf{y_{10} = 275.881 \text{ mg/L}}$$

Question 32

What will be 5 day 20°c BOD, if BOD of sewage incubated for a day at 30°C in 110 ppm? k_{20} =0.1. *(CSVTU, Nov-Dec 2008)(CSVTU, April-May 2009)*

Ans. Given:

y_1 at 30°C = 110 ppm

$k_{20} = 0.1$

y_5 at 20^0c = ?

$$k_{30} = k_{20}\,(\theta)^{T-20}$$

$$= 0.1\,(1.056)^{30-20}$$

$$\mathbf{k_{30} = 0.1724}$$

$$y_1 = L_o\,(1 - 10^{-kt})$$

$$= L_o\,(1 - 10^{-0.1724\times1})$$

$$1 = L_o \times 0.3277$$

$$L_o = 3.051 \text{ mg/L}$$

$$y_5 = L_o\,(1 - 10^{-kt})$$

$$= 3.051\,[1 - 10^{-0.1724\times5}]$$

$$= 3.051\,(0.8625)$$

$$\mathbf{y_5 = 2.631 \text{ Mg/L}}$$

Question 33

The 4 days 15°c BOD of a sewage sample is 200 mg/L. Draw a graph (in answer sheet only, no graph paper required) of a 5 day BOD as a function of a temperature in the range of 10°C to 30°C in step of 5°C. *(CSVTU, Nov-Dec 2011)*

Ans. y_4 at 15°C = 200 mg/L

Assuming $k_{20} = 0.1$

$$k_{15} = k_{20}(\theta)^{T-20}$$

Assuming $\theta = 1.047$

$$k_{15} = k_2 (1.047)^{T-20}$$
$$= 0.1 (1.047)^{15-20}$$
$$k_{15} = 0.79 \text{ /day}.$$
$$y_4 = L_o [1 - 10^{-kt}]$$
$$200 = L_o [1 - 10^{-0.079 \times 4}]$$
$$L_o = 386.89 \text{ mg/L}.$$
$$k_{10} = k_{20} (1.047)^{T-20}$$
$$= 0.1 (1.047)^{10-20}$$
$$k_{10} = 0.063/\text{day}$$
$$y_{10} = L_o [1 - 10^{-kt}]$$
$$= 386.89\ 1 - 10^{-0.063 \times 10}$$
$$y_{10} = 296.194 \text{ mg/L}.$$
$$k_{15} = 0.079 \text{ /day}.$$
$$y_{15} = L_o [1 - 10^{-kt}]$$
$$= 386.89 [1 - 10^{-0.079 \times 15}]$$
$$y_{15} = 361.621 \text{ mg/L}$$
$$k_{20} = 0.1/\text{day}.$$
$$y_{20} = L_o [1 - 10^{-kt}]$$
$$= 386.89 [1 - 10^{-0.1 \times 20}]$$
$$y_{20} = 383.0211 \text{mg/LL}$$
$$k_{25} = k_{20} [1.047]^{T-20}$$
$$= 0.1 [1.047]^{25-20}$$
$$k_{25} = 0.1258/\text{day}.$$
$$y_{25} = L_o [1 - 10^{-kt}]$$
$$= 386.89 [1 - 10^{-0.1258 \times 25}]$$
$$y_{25} = 386.61 \text{mg/L}.$$
$$k_{30} = k_{20} (1.047)^{T-20}$$
$$= 0.1 (1.047)^{30-20}$$
$$k_{30} = 0.1583/\text{day}.$$
$$y_{30} = L_o [1 - 10^{-kt}]$$
$$= 386.89 \times [1 - 10^{-0.1583 \times 30}]$$
$$y_{30} = 386.883 \text{ mg/L}.$$

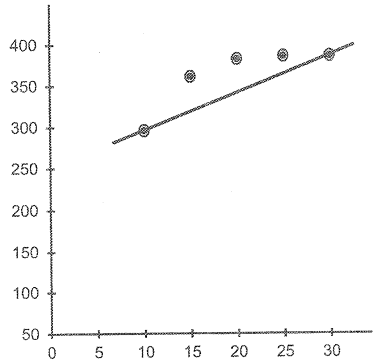


Fig. 2.15

Question 34

An analysis for solid is mode on waste water sample. Two hundred ml of sample is filtered through a fiber glass filter that has been pre-weighed at 0.133g. The filter and the residue is over carried until a constant mass of 0.229 g is reached. 100ml of the filtrate is placed in an evaporation dish whose mass has been determined to be 327.485g. The contents of the dish were evaporated to dryness and the total mass of the dish and solids is found to be 327.517g. Determine the total suspended solids and total dissolved solids. (CSVTU, Nov-Dec 2010)

Ans. Given:

Volume of sample (V) = 200ml.

Water of fiber glass filter = 0.138gm.

Water of residue left in a over = 0.229gm

$$\text{Total suspended solids} = \frac{0.229 - 0.138}{200}$$
$$= 0.091 \text{ gm/ml} = 0.091 \text{ mg/}l$$
$$\text{Total dissolved solids} = \frac{327.517 - 327.485}{100}$$
$$= \frac{0.032}{100}$$
$$= 3.2 \times 10^{-4} \times 1000$$

Total dissolved solids = 0.32mg/L

2.7 Treatment of Sewage

Question 35

Write a short note on treatment of sewage.

Ans. The object of the sewage treatment is to remove various contaminants present in sewage so as to produce an effluent and sludge which can be disposed off in the environment without causing health hazards or nuisance. In the sewage treatment there are three types of unit operations and process.

1. Physical Unit Operations
2. Chemical Unit process
3. Biological unit processes

Physical Unit Operations: Treatment methods in which the application of physical forces predominates are known as physical unit operations. Most of these methods are based on physical forces, e.g. screening, mixing, flocculation, sedimentation, flotation, and filtration.

Chemical Unit Processes: Treatment methods in which removal or conversion of contaminant is brought by addition of chemicals or by other chemical reaction are known as chemical unit processes, for example, precipitation, gas transfer, adsorption, and disinfection.

Biological Unit Processes: Treatment methods in which the removal of contaminants is brought about by biological activity are known as biological unit processes.

- This is primarily used to remove biodegradable organic substances from the wastewater, either in colloidal or dissolved form.
- In the biological unit process, organic matter is converted into gases that can escape to the atmosphere and into bacterial cells, which can be removed by settling.
- Biological treatment is also used for nitrogen removal and for phosphorous and sulphate removal from the wastewater.

The different treatment methods used in wastewater treatment plant are classified in three different categories as:

- *Primary Treatment:* Refers to physical unit operations.
- *Secondary Treatment:* Refers to chemical and biological unit processes.

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- *Tertiary Treatment*: Refers to combination of all three i.e., physical unit operations and chemical or biological unit processes, used after secondary treatment.

Question 36

What do you understand by waste water treatment?

Ans. The waste water treatment or sewage treatment is a broad term that applies to any process/operation or combination of processes and operations that can reduce the objectionable properties of water carried waste and render it less dangerous with the following.

1. Removal of suspended and floatable material
2. Treatment of biodegradable organics
3. Elimination of pathogenic organisms

Question 37

Explain the treatment systems employed for the waste water.

Ans. **Treatment Systems:** The type of combinations used from the available unit operations and process for treatment of particular waste water is known as the treatment systems. Normally the waste water plant is designed for either of the following treatment systems.

Types of the Treatment Process:

1. **Preliminary Treatment Process** :It mainly consist of removing the floating materials like branches of trees, rags, wood , paper etc. and also very heavy settelable inorganic solids. It helps in removing oil and grease from the sewage thereby reducing the BOD of the sewage by about 15 to 30 %. It is carried out by means of
   a) Screens - Removes floating paper, rags, clothes etc.
   b) Grit chambers- Removes Grit and sand
   c) Skimming tanks and Grease traps- For removing oil and greases.
2. **Primary Treatment Process:** These are used to remove large suspended organic solids which are generally done with the help of settling basins. The liquid effluent from the Primary treatment contains a large amount of suspended organic material and has a high BOD about 60% of the original. The organic solids separated out in the sedimentation tank are stabilized by anaerobic decomposition in a digestion tank or incinerated. The Residues are left for landfills.
3. **Secondary Treatment Process** : It involves further treatment of the effluent from the primary sedimentation tank which is accomplished by biological decomposition of organic matter either aerobically or anaerobically through the filters, aeration tank, Activated sludge process, oxidation ponds, aerated lagoons.
4. **Tertiary Treatment Process:** This treatment process removes the organic load left after the secondary process and particularly to kill pathogenic bacteria.

2.8 Methods of Sludge Processing and Disposal

Question 38

Draw the basic layout of a sewage treatment plant.

Ans. The basic layout of STP is shown in fig. below.



Sewage Treatment Plant

Question 39

Draw a waste water treatment flow diagram showing various treatment units. Clearly show the preliminary treatment, primary treatment and secondary treatment units on it. *(CSVTU, Nov-Dec 2012)(CSVTU, April-May 2010)*

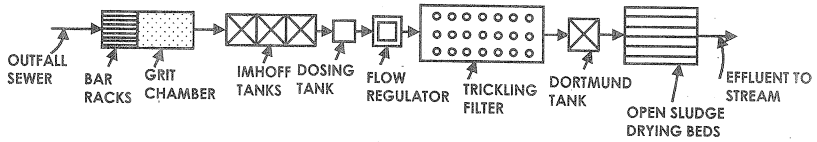
Or

Draw the flow diagram for an STP for a developed city. Explain the components.

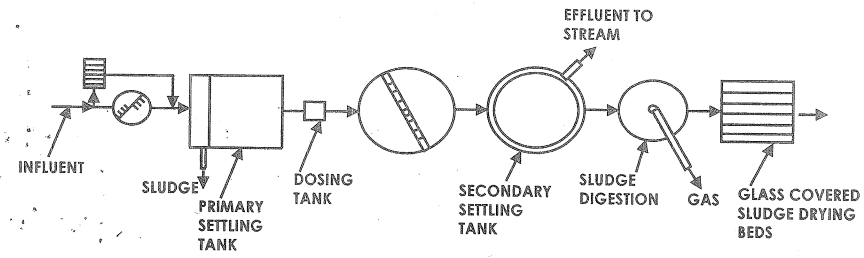
Ans. The raw sewage must be treated before it is discharged into the river stream. The extent of treatment required to be given depends not only upon the characteristics and quality of the sewage but also upon the source of disposal, its quality and capacity to tolerate the impurities.

The flow sheet of sewage treatment plant consist of unit operations such as screening, grit removal, and primary setting tank (PST)followed by a unit process of biological treatment such as activated sludge process (ASP) on trickling filter. The sludge removed from primary and secondary sedimentation tanks are digested anaerobically followed by drying of anaerobically digested sludge on sand drying beds.

The process flow sheet is as given in following figures.

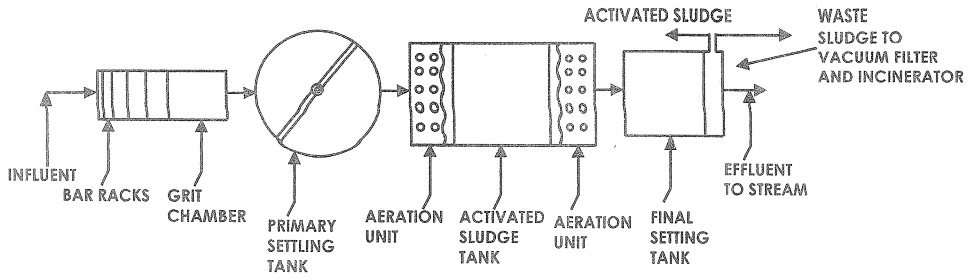


FLOW DIAGRAM OF SEWAGE TREATMENT PLANT CONFIGURATION I



FLOW DIAGRAM OF SEWAGE TREATMENT PLANT CONFIGURATION II

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FLOW DIAGRAM OF SEWAGE TREATMENT PLANT CONFIGURATION III

Question 40

What are the points to be considered while locating the site for sewage treatment plant?

Ans. Following points are to be considered while locating the site for sewage treatment plant.

1. The treatment plant should be located near to the point of disposal as possible.
2. Plant should be located on the downstream side of the city and sufficiently away from the water intake works.
3. The plant should not be much away from the town to so as to reduce the length of the sewer.
4. The site should not be close to the town, that it may cause difficulties in the expansion of the town and pollute the general atmosphere by smell and fly nuisance.
5. If the sewage is to be disposed off into the river or stream the sewage treatment plant should be located on the bank of the river.
6. If the sewage is to be disposed off by land disposal sewage treatment plant should be located near the land at such place from where the treated sewage can easily flow under gravitational forces towards the disposal point.

2.9 Primary Treatment of Sewage

Question 41

Write a note on application of various physical unit operation employed in waste water treatment.

Ans. The physical unit operation in which application of physical forces predominates consists of the following:

1. **Screening** :Removal of coarse and settleable solids by surface spraining
2. **Comminution** : Grinding of coarse solids.
3. **Flow equalization**: Equalization of flow and mass loadings of BOD and suspended solids.
4. **Mixing**: Mixing of chemicals and gases with waste water and maintaining solids in suspension.
5. **Flocculation**: Promotion of the aggregation of small particle into large particles.
6. **Sedimentation**: Removal of settleable solids and thickening of sludge.
7. **Floatation**: Removal of finally divided suspended solids and particles.

8. **Filtration**: Removal of fine residual suspended solids, after biological or chemical treatment.
9. **Micro screening**: Same as filtration also removes algae from stabilization pond efficiently.

Question 42

What is screening? Mention the objectives and types of screening.

Ans. Screening is the process of trapping and removing relatively coarser floating matter like pieces of paper, cloth, plastic, wood, fibers etc. This is done by allowing the waste water to flow through the screens. The screens are racks or gratings of mild steel bars with some clear openings in between. Screens should be preferably placed before the grit chambers.

Objective of Screening:

The main objective of screening is to remove coarser floating matter.

a) To reduce the load on the subsequent units.
b) To reduce the damage of the pumps.
c) To avoid the clogging and choking of smaller pipes.

Types of Screening:

Depending upon the size of opening the screens are classified as,

1. **Coarse Screen** - These are generally known as racks with the opening size > 50 mm. These helps in removing the large floating objects from the sewage. The material separated by the coarse screen usually consist of rags, wood, paper etc. which will not putrefy and may be disposed off by incineration, burial or dumping.

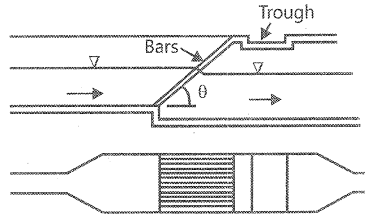


Fig. 2.3 Bar Screen

2. **Medium Screen** – these screens have opening size from 6 to 40 mm. They usually collect some quantity of organic material which may putrefy and become offensive and must therefore be disposed of by incineration, burial or dumping.
3. **Fine Screen** - Fine screens have perforations of 1.5 mm to 3 mm in size. The installation of these screen prove very effective and they remove 20% of solids from the sewage but these screens get clogged very often and thus need frequent cleaning. This screen reduces the load on subsequent units.

Question 43

Explain screen chamber with the help of neat sketch.

Ans. It consists of rectangular channel. Floor of the channel is normally 7 to 15 cm lower than the invert of the incoming sewer. Bed of the channel may be flat or made with desired slope. This channel is designed to avoid deposition of grit and other materials in to it. Sufficient straight approach length should be provided to assure uniform distribution of screenings over the entire screen area. At least two bar racks, each designed to carry peak flow, must be provided. Arrangement of stopping the flow and

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draining the channel should be made for routine maintenance. The entrance structure should have a smooth transition or divergence to avoid excessive head loss and deposition of solids (Figure 2.4). Effluent structure should be having uniform convergence. The effluent from the individual rack may be combined or kept separate as necessary.

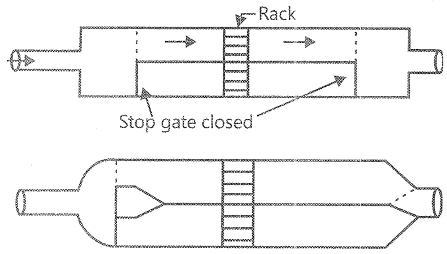


Fig. 2.4 Screen Chamber

Question 44

Write short notes on disposal of screening. *(CSVTU, April –May 2012)*

Ans.

Disposal of screening:

Following are the usual four methods adopted for the disposal of screening.

1. **Burial:** In this method the screenings are buried into the ground. This method is usually adopted for small works. The screening are sometime buried along with quick lime. The screening should be buried sufficiently deep to obtain complete decomposition and to avoid bad odour. Ordinarily a cover of about 300mm to 500mm depth of porous earth should be provided on the top of screening.
2. **Disintegration:** In this method, the screening is diluted first with water the dilution factor is being kept about 60-100.The diluted screening are then passed through disintegrators which break up the screening into small pieces. The flow from disintegrators is then diverted and it is then allowed to join the flow of sewage on the upstream of screens.
3. **Incineration:** It is the most effective method of disposal of screens. The screening is first dewatered either by pressing or centrifuging. In the pressing method the screening are stored in a cylinder and then a piston is worked to press the screenings. In centrifuging method the screenings are placed in the cylinder then the cylinder is rotated. The screenings after dewatering are then burnt in coal, gas, oil and furnaces at high temperatures..
4. **Fertilizer:** The screenings contain good fertilizing value with special precaution they may be used as fertilizer. It is not advisable to use the screening for crops which are consumed or eaten raw.

Question 45

Write design criteria for screen.

Ans. Screening is very first operation in sewage treatment plant and the sewage is passed through the screens so as to trap or remove the floating matter such as pieces of cloth, paper, wood, kitchen waste etc.

Design criteria for the screen

- Total area of the screens required may be found out by assuming a suitable velocity and determining the depth of submergence of screen at the time of this velocity.
- The velocity of flow should be kept reasonably constant and it may be taken as about 1 m/sec at an average flow of sewage.
- The slope of screens should be between 30°to60°.
- The maximum depth of screen should be about 1m.
- The detention period should be zero.
- The velocity of flow through the screen is to be assumed between 0.6 to 1.2 m/sec.
- The head loss can be computed as

$$h_L = 0.0729(V^2 - v^2)$$

Where,

V = Velocity of flow through the screen

v = Velocity of flow above the screen

Question 46

Design a bar screen for a peak average flow of 40MLD.

Ans.

$$Q = 40 \text{ MLD}$$

$$= \frac{40 \times 10^6}{10^3 \times 24 \times 60 \times 60}$$

$$Q = 0.463 m^3/sec$$

Assuming that the velocity through the screen is not allowed to exceed 0.8 m/sec

$$\therefore \quad Q = A.V$$

$$A = \frac{Q}{V}$$

$$= \frac{0.463}{0.8}$$

$$A = 0.5785 m^2$$

Now, providing bar screen having 1 cm width & placed at 5cm clear spacings.

The gross area of the screen required

$$= 0.5785 \times \frac{65}{36} = 0.7234 \text{ m}^2$$

Assuming that the bars are inclined at 45° to the horizontal, we have the gross area of screen required

$$= \frac{0.7234}{\sin 45}$$

$$= 1.023 \text{ m}^2$$

Now, velocity of flow above the screen

$$= 0.8 \times \frac{36}{45} = 0.64 \text{m/ sec}$$

Thus, we have V = 0.8 m/sec.

v=0.64m/sec.

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$$\therefore \quad h_L = 0.0729\,[V^2 - v^2]$$
$$= 0.0729\,[0.8^2 - 0.64^2]$$
$$= 0.0167 \text{ m.}$$
$$\approx 0.017\text{m}$$
$$\approx 1.7\text{cm}$$

This will be the head loss, if the screen is clean.

If the screen is half clogged,

$$V = 2 \times 0.8 = 1.6\text{m/sec}$$
$$h_L = 0.0729\,(1.6^2 - 0.64^2)$$
$$= 0.157\text{m} = 15.7\text{cm}$$

Question 47

Write short notes on Comminutor. *(CSVTU, April –May 2012)*

Ans. **Grinder or Comminutor:**

It is used in conjunction with coarse screens to grind or cut the screenings. They utilize cutting teeth (or shredding device) on a rotating or oscillating drum that passes through stationary combs (or disks). Object of large size are shredded when it will pass through the thin opening of size 0.6 to 1.0 cm. Provision of bye pass to this device should always be made. A comminutor consists of a vertical revolving drum screen with 6 mm to 10 mm slots. The coarse material is cut by cutting teeth and shear bars on the revolving drums as solids are carried past a stationary comb. The small sheared particles then pass through the slots of the drum out and of a bottom opening through an inverted siphon. The head loss across the comminutor depends upon screen details and flow, the normal values being on the order of 50 to 100mm. Another form of the comminutor consists of stationary semicircular screen and a rotating circular cutting disk. The grid intercepts the large solid particles whereas the smaller solids pass through the space between the grid and cutting disk.

Barminutor

A barminutor is another comminuting unit which is used for flow exceeding 50 mLd. It is a combined screening and cutting machine consisting of a bar screen of special design with small openings, along with rotating cutters comprising of a comminuting unit which travels up and down the screen cutting the retained solids.

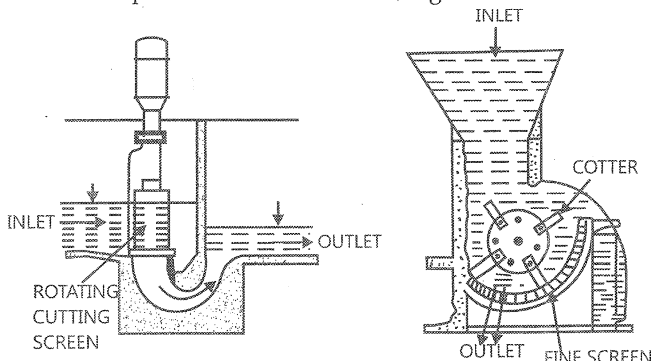


Fig. 2.5 Comminutors

Question 48

Write a short note on grit chamber.

Or

Explain the purpose of the grit chamber. *(CSVTU, Nov-Dec 2012)*

Ans. Grit chamber is the second unit operation used in primary treatment of wastewater and it is intended to remove suspended inorganic particles such as sandy and gritty matter from the wastewater.

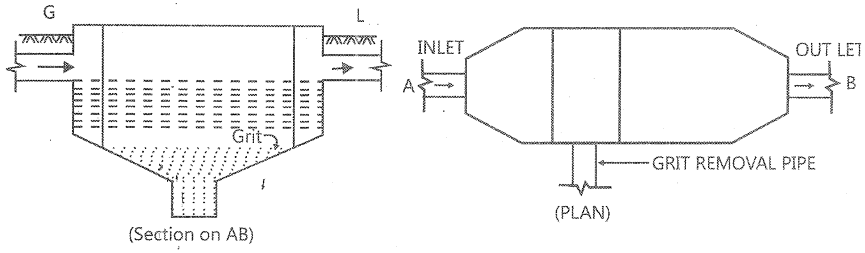


Fig. 2.6 Grit chamber with direct flow

The grit chamber is used to remove grit consisting of sand, gravel, cinder, or other heavy solids materials that have specific gravity much higher than those of the organic solids in wastewater. Grit chambers are provided to protect moving mechanical equipment from abrasion and abnormal wear; avoid deposition in pipelines, channel, and conduits; and to reduce frequency of digester cleaning. To remove the grit, the velocity of flow is decreased to such an extent that the heavier inorganic materials settle down at the bottom of the grit chamber and the lighter organic materials are carried forward for the further treatment.

Types of Grit Chamber:

1. **Rectangular Horizontal Flow Type:** It is the most commonly used type of grit chamber in which organic matter is not allowed to settle down with proper velocity control. It is designed to remove the particle of about 0.2 mm size or more. The length of the channel is normally governed by the depth required for specific settling velocity (critical velocity) and the type of velocity control device used.
2. **Detritus tank:** It is normally square type of grit chamber in which some amount of organic matter and fine suspended solids present in the waste water is allowed to settle down along with the grit by controlling the flow through velocity, however the organic matter is returned back to influent. Vertical sides of the tank are usually at the bottom to form a trough for collection of detritus, a mixture of grit and organic matter.
3. **Aerated Grit Chamber:** Excessive wear of grit handling equipment and necessity of separate grit washer can be eliminated by using aerated grit chamber. It is designed for typical detention time of 3 minutes at maximum flow. Grit hopper about 0.9 m deep with steeply sloping sides is located along one side of tank under air diffusers (Figure 2.7). The diffusers are located at about 0.45 to 0.6 m from the bottom. The size of particles removed will depend upon velocity of roll or agitation. The air flow rate can be easily adjusted to control efficiency and 100% removal of grit can be achieved.

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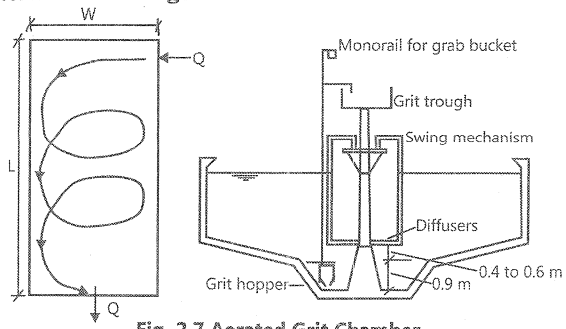


Fig. 2.7 Aerated Grit Chamber

Wastewater moves in the tank in helical path and makes two or three passes across the bottom of the tank at maximum flow (and more at less flow). Wastewater is introduced in the direction of roll in the grit chamber. The expansion in volume due to introduction of air must be considered in design. The aerated grit chambers are equipped with grit removal grab buckets, traveling on monorails over the grit collection and storage trough. Chain and bucket conveyers can also be used. Two grit chambers in parallel are used to facilitate maintenance. Typical design details for aerated grit chamber are provided below:

Depth: 2 to 5 m
Length: 7.5 to 20 m
Width: 2.5 to 7.0 m
Width to depth ratio: 1:1 to 5:1
Detention time at peak flow: 2 to 5 min (3 minutes typical)
Air supply m^3/m.min of length: 0.15 to 0.45 (0.3 typical)

2.10 Design of Grit Chamber

Question 49

What are the factors that govern grit chamber's design? *(CSVTU, Nov-Dec 2012)*

Or

What do you mean by overflow rate of a settling tank? *(CSVTU, Nov- Dec 2010)*

Or

What is detention period?

Ans. Design of grit chamber depends upon following factors:

1. **Settling Velocity**

   a. **For particles up to 0.1 mm (Laminar or Stream line Settling of particles)**

   Grit chamber may be designed by considering it as a sedimentation basin having discrete settling. The settling velocity for such a case is governed by the size and specific gravity of grit particles to he separated and the viscosity of the sewage. The size of separation based on the minimum size of grit to be removed is 0.2 mm although 0.15 mm is preferred for conditions where considerable amount of ash is likely to be carried by the sewage. The specific gravity may be as low as 2.4 but for design purposes, a value of 2.65 may be used. The settling velocity is given by Stoke's law, applicable for particles of diameter less than 0.1 mm:

$$v_s = \frac{g}{18}\left(\frac{\rho_s - \rho}{\mu}\right)d^2 \quad \ldots (1)$$

$$v_s = \frac{g}{18}\left(\frac{S_s - 1}{v}\right)d^2 \quad \ldots (2)$$

Where

v_s = Settling velocity(cm/sec)
d = Size of particle (cm)
μ = dynamic or absolute viscosity of liquid (centripoise)
$v = \frac{\mu}{\rho}$ = kinematic viscosity(centistokes)
ρ_s = mass density of liquid (gm/cm^3)
ρ = mass density of particles (gm/cm^3)
$S_s = \frac{\rho_s}{\rho}$ = Specific gravity of particles
g = acceleration due to gravity(cm/sec^2)

b. **For particles up to 0.1 mm (Turbulent Settling of particles)**

For particles of size more than 1 mm, the formula by Newton is used:

$$v_s = \sqrt{3.33g\left(\frac{\rho_s - \rho}{\rho}\right)d}$$

c. **For particles between 0.1 mm to 1 mm**

However, the grit particles lie between 0.1 mm and 1.0 mm. The zone of setting corresponding to this range of particles is called the *transition zone*. The relationship between settling velocity, size and density of particle, density and temperature of liquid, is given by Hazen's modified equation:

$$v_s = 60.6(S_s - 1)d\left(\frac{3t + 70}{100}\right)$$

v_s = Settling velocity in cm/sec
t = temperature of liquid (°C)

The settling velocity (*i.e.* rate of subsidence) of a particle in liquid medium is also denoted as *Hydraulic Subsidence Value (HSV)*.

2. **Over flow rate:** *It is the ratio of hydraulic loading per unit surface area of the tank. It is expressed in terms of m^3/ day/ m^2.*

The efficiency of grit removal can be expressed as the percentage removal of grit above a specified particle size. A grit chamber designed to remove 100% of grit particles of smallest size would also remove all grit particles larger than this. To obtain a 100% removal of the smallest size particles, it would be theoretically necessary for the detention time in the tank to equal the time required for the minimum sized particles to reach the tank bottom. It can be shown that the settling velocity v_s of the minimum sized particle is equal to the surface loading rate (Q/A), or overflow rate in order to obtain a theoretical 100% removal of particles.

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Diameter of Particles	Settling Velocity (cm/sec)		Overflow rate in an ideal grit chamber $m^3/d/m^2$	
	$S_s = 2.65$	$S_s = 1.20$	$S_s = 2.65$	$S_s = 1.20$
0.20	2.0	0.24	1700	210
0.18	1.8	0.22	1600	190
0.15	1.5	0.18	1300	160

Table above gives settling velocity of different size particles of specific gravity 2.65 (mineral matter) and 1.20 (organic matter) and corresponding overflow rates for 100% removal of these particles based on Hazen's modified equation.

The values given in Table should be corrected for any other temperature by the factor $\left[\frac{(3t+70)}{100}\right]$.

3. **Detention Period**

$$D_T = \frac{\text{Depth of water}}{\text{Settling Velocity}}$$

The detention period for grit chambers may vary from 30 to 90 seconds. A detention period of 60 seconds is usually adopted.

4. **Bottom scour and flow through velocity:**

The grit chamber efficiency is very much affected by the bottom scour. The scouring process itself determines the optimum velocity of flow through the grit chamber. The flow velocity should be enough to scour out the settled organic matter and reintroduce it into the flow stream. The critical velocity for scour may be calculated from the modified Shield's formula

$$v_c = 3 \text{ to } 4.5\sqrt{g(S_s - 1)d}$$

For a grit particle size of 0.2 mm, the formula gives critical velocity values of 17.1 to 25.6 cm/sec. In actual practice, a horizontal velocity of flow of 15 to 30 cm/sec is used at peak flows.

5. **Velocity control devices:**

The horizontal velocity of flow should be maintained constant at other flow rates also, to ensure that only organic solids and not the grit are scoured from bottom.

6. **Number of units:**

In case of manually cleaned grit chambers, atleast two units should be provided.

7. **Loss of head:**

Loss of head in a grit chamber may vary from 0.06 m to 0.6 m depending upon the device adopted for velocity control.

8. **Horizontal Velocity**

$$V_H = \frac{Q}{B.D}$$

V_H Should be greater than V_s.

2.11 Control of Velocity through Grit Chamber Using Proportional Flow Weir

Question 50

Explain the procedure of designing a grit chamber using a proportional weir.

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Ans. For proper functioning of the grit chamber, the velocity through the grit chamber should not be allowed to change inspite of the change in flow. One of the most satisfactory types of automatic control is achieved by providing a proportional Weir at the outlet. The shape of the opening between the plates of a Proportional Weir is made in such a way that the chamber depth will vary directly as the discharge, as a result of which the chamber velocity will remain constant for all flow conditions. The Fig. below shows the end view of the grit chamber with the above mentioned velocity control device: The flow through this weir, Q, can be given by the following formula:

$$Q = 1570 C_d \sqrt{2g \times w \times h^{3/2}}$$

In which, C_d = coefficient of discharge, 0.61 for symmetrical sharp edged weirs;

w = Width of the opening at height h in m.

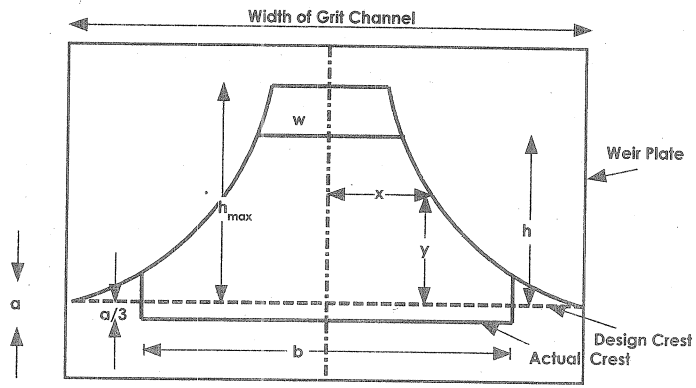
a and b are the dimensions of the weir as shown in the above figure, and

h'_a = Depth of flow above the actual crest level

$$h_{max} = \frac{Q_{max}}{V_H \times w}$$

The equation of curve forming on the edge of the weir is given by the formula

$$x = \frac{b}{2}\left(1 - \frac{2}{\pi}\tan^{-1}\sqrt{\frac{y}{a}}\right)$$



Proportional Flow Weir

Design Criteria of Grit Chamber Using Proportional Flow Weir

1. The design of the horizontal-flow grit chambers should be such that under the most adverse conditions, all the grit particles of size 0.2 mm or more in diameter will reach the bed of the channel prior to their reaching the outlet end.
2. The length of the channel will be governed by the depth required which is again governed by the settling velocity. A minimum allowance of approximately twice the maximum depth should be given for inlet and outlet zones. An allowance of 20%-50% of the theoretical length of the channel may also be given.
3. A width in between 1 m and 1.5 m may be assumed. The depth of flow is normally kept shallow. For total depth of the channel, a free board of about 0.3 m and a grit space of about 0.25 m should be provided.

4. For larger plants two or more number of grit chambers in parallel may be provided.
5. Detention time of 30 to 60 seconds is recommended in the grit chambers.

Question 51

Explain the purpose of grit chamber. Determine the dimensions (length × width × depth) and detention time for a grit chamber for a maximum waste water flow of 8000 m^3/day to remove particles having average settling velocity of 0.2 m/sec for a constant flow through velocity of 0.3 m/sec maintained by provision of proportional flow weir. (CSVTU, Nov-Dec 2012)

Ans. The purpose of grit chamber in the sewage treatment plant is to remove grit, sand and such other inorganic matter from sewage.

For this, the velocity of flow in grit chamber is decreased to such an extent that the heavier inorganic materials settle down at the bottom of grit chamber and lighter organic materials are carried fore for further treatment.

$$Q = 8000\ m^3/day$$
$$V_h = 0.3\ m/sec$$
$$V_s = 0.02\ m/sec$$
$$Q = 8000\ m^3/day$$
$$= 0.0926\ m^3/sec$$
$$A = \frac{Q}{V_h}$$
$$A = \frac{0.0926}{0.3}$$
$$A = 0.3086 m^2$$

Providing a depth of 1m, the width of the chamber is

$$B = \frac{A}{1}$$
$$= 0.3086\ m.$$

Provide a width of 0.35m.

The settling velocity $V_s = 0.02$ m/sec

$$\therefore \text{ Detention time } D_T = \frac{\text{Depth of chamber}}{V_s}$$
$$= \frac{1}{0.02}$$
$$= 50 secs.$$

Length of the tank $= V_h \times D_T$
$$= 0.3 \times 50$$
$$= 15m$$

Hence provide a grit chamber of length 15m width 0.35m and depth 1m.

Question 52

Design a rectangular grit – chamber from following data.
Flow of sewage = 55× 10^6 liters/day.
Specific gravity of grit = 2.70
Size of grit particle to be removed = 0.21 mm.
Viscosity of water = 1.0 × 10^{-2} cm^2/sec. (CSVTU, April-May 2011)

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Ans. Given,

Maximum flow = 55 × 10^6 lit /day
Specific gravity of grit particles = 2.70
Size of grit particle to be removed = 0.21mm.
Viscosity of water = 1.0 × 10^{-2} cm^2/sec

$$Q = \frac{55 \times 10^6}{10^{-6} \times 24}$$
$$= 2.29 \times 10^3\ cm^3/sec.$$

Now, using Stokes's law

Settling velocity

$$V_s = \frac{g}{18\mu}(\rho_s - \rho)\ d^2$$
$$V_s = \frac{981}{18 \times 1.0 \times 10^{-2}}(2.70 - 1)\left[\frac{0.21}{10}\right]^2$$
$$V_s = 4.09\ cm/sec.$$

Assuming the depth of grit chamber = 2.4 m.

$$D_T = \frac{2.4 \times 100}{4.09} sec = 58.7sec$$
$$\approx 1 \text{ minute.}$$

Quantity of sewage passing through one minute

$$= \frac{2.29 \times 10^3}{60} = 38.17\ m^3/min$$

C = Capacity of grit chamber

Now, capacity = A × depth

$$\text{suface area} = \frac{\text{capacity}}{\text{depth}}$$
$$= \frac{38.17}{2.4}$$
$$= 15.9 \text{ Sq. m}$$
$$\approx 16 \text{ Sq. m}$$

Providing three parallel grit chamber of size 1m×8.0m one will be cutting as standby and two will work at a time .The depth will be kept as 2.7m with 30cm as free board and 2.4m as effective depth

Check for horizontal velocity,

$$= \frac{Q}{B.D} = \frac{38.17}{2 \times 2.3}\frac{m}{min}.$$
$$= 7.952\ m/min$$
$$= 13.25 cm/sec.$$

Critical horizontal velocity,

$$V_s(c) = 40\sqrt{(\rho_s - \rho)d}$$
$$= 40\sqrt{(2.70 - 1)(0.21)}$$
$$= 23.9\ cm/sec$$

∴ The horizontal velocity is within the safe limits and the design is ok .

Question 53

Write a short note on sedimentation in sewage treatment. Classify it.

Ans. **Sedimentation:**

In a complete sewage treatment, the sedimentation is carried out twice once before the biological treatment (Primary sedimentation) and once after the biological treatment (secondary sedimentation). The purpose of the sedimentation of the sewage is to separate the settleable solids so that the settled sewage if discharged into the water course, does not form the sludge banks and when used for irrigation, does not lead to the excessive organic loading. It also reduces the organic load on the secondary treatment process.

Following are the different types of sedimentation

1. **Plain sedimentation:** When the impurities are separated from suspending fluid by action of natural forces alone, i.e. by gravitation and natural aggregation of settling particles the operation is called plain sedimentation.
2. **Sedimentation with coagulation (clarification):** When the chemicals or other substances are added to induce aggregation and settling of finely divided suspended matter, colloidal substances and large molecules the operation is called sedimentation with coagulation.
3. **Chemical precipitation:** When chemicals are added to throw dissolved impurities out of solution the operation is called chemical precipitation.
4. **Discrete particles:** A particle that does not alter its shape size and weight while settling or rising in the water is known as discrete particles.

Question 54

Explain various types of settlings. Differentiate unit processes and operations with proper examples. *(CSVTU, Nov- Dec 2011)*

Ans. **Types of Settling:** particles in the waste water may settle out of a suspension in the following four ways depending upon the concentration of suspension and the flocculating properties of the particles.

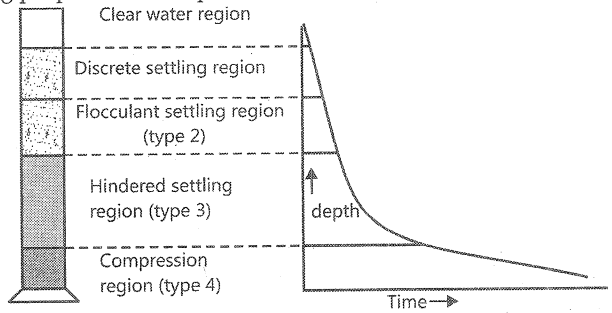


Fig. 2.8 Type of Settling

1. Type –I Sedimentation (Discrete settling)
2. Type –II Sedimentation (Flocculant settling)
3. Type –III Sedimentation (Hindered or Zone settling)
4. Type –IV Sedimentation (Compression settling)

Type –I **Discrete Settling:** This represents the sedimentation of discrete particles in a suspension of low solids concentration. This is also known as free settling since the particles have very less tendency to flocculate or coalesce upon contact with each other.

Type – II **Flocculant Settling:** This type of settling refers to the rather dilute suspensions of particles that coalesces or flocculate during sedimentation process. Due to flocculation, particles increases in mass and settle at a faster rate.

Type –III **Hindered or Zone Settling:** This type of settling refers to the flocculent suspension of intermediate concentration. Inter particle forces hold the particles together and hence the mass of the particles subside as a whole.

Type –IV **Compression Settling:** This type of settling refers to the flocculent suspension of very high concentration that actually comes in contact with each other resulting in the formation of the structure. Further settling will only occur due to compression of structure brought about due to the weight of the particles which are constantly being added to the structure.

Unit Operation: Treatment methods in which the application of physical forces predominates are known as physical unit operations. Most of these methods are based on physical forces, e.g. screening, mixing, flocculation, sedimentation, flotation, and filtration.

- *Intake* to bring in for treatment water of the best possible quality the source can provide.
- *Screening* to remove floating and suspended debris of a certain size.
- *Chemical mixing* with the water to allow suspended solids to coagulate into larger particles that settle more easily.
- *Coagulation,* a chemical water treatment method that causes small particles to stick together to form larger particles.
- *Flocculation* to gently mix the coagulant and water, encouraging large floc particle formation.
- *Sedimentation* to slow the flow so that gravity settles the floc.

Unit Process: Treatment methods in which removal or conversion of contaminant is brought by addition of chemicals or the use of the biological mass or microbial activities are known as unit process. e.g., Neutralization, Oxidation, Disinfection, Chemical Precipitation, Aerated Lagoon, Activated sludge process, Oxidation pond, Aerobic and anaerobic digesters.

- **pH Correction:** This method is used where wastes have high content of fats and grease, with high or low pH values, high in suspended solids which can be coagulated and settled.
- **Oxidation and Reduction:** removes some inorganic contaminants-iron, manganese, radium, etc.
- **Aeration:** Removes volatile organic chemicals (VOCs), *radon*, H_2S, and other dissolved *gases;* oxidizes iron and manganese.

Question 55

Explain the process of settling of discrete particle.

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Ans. **Settling of Discrete Particles:**

When a discrete particle is placed in a quiescent fluid, it will accelerate until the frictional resistance becomes equal to the impelling force acting on a particle. At this stage the particle attains a uniform terminal velocity and settles down with the constant velocity known as *settling velocity*.

This is also known as Type I settling. When the discrete particles are placed in a quiescent fluid, it will accelerate until a frictional resistance i.e., the drag force (f_D) becomes equal to the impelling force (f_i) outing on the particle. At this stage, the particles attain a uniform terminal velocity and settles down with a constant velocity known as *settling velocity*.

The impelling force (f_i) is equal to the effective weight of particle

$$f_i = (\rho_s - \rho)g.V \qquad \ldots (1)$$

Where,

ρ_s = Mass density of particle

ρ = Mass density of fluid

V = Volume of particle

$= \frac{\pi}{6}d^3$

Where d is the diameter of spherical particle.

(a) **Turbulent settling:**

The drag force (f_D) depends upon

(i) Dynamic viscosity (μ) of the fluid

(ii) Mass density (ρ) of the fluid

(iii) Shape and size of the particle

The drag force is given by the Newton's law,

$$F_D = C_D A \times \rho \times \frac{V_s^2}{2} \qquad \ldots (2)$$

Where,

C_D = Coefficient of drag

Now equating eq. (1) and (2) we get

$$F_D = F_i$$

$$(\rho_s - \rho) \times g \times V = C_D A \times \rho \times \frac{V_s^2}{2}$$

$$\therefore \quad V_s = \sqrt{\frac{4}{3}.\frac{g}{C_D} \times \frac{(\rho_s - \rho)d}{\rho}}$$

Or

$$V_s = \sqrt{\frac{4}{3}.\frac{g}{C_D}.(S_s - 1)d}$$

Where

S_s = Spelific gravity of the particles

Coefficient of drag C_D is related to the reynold's number R by the following relationship

- It R is between 0.5 to 10^4

$$\therefore \quad C_D = \frac{24}{R} + \frac{3}{\sqrt{R}} + 0.34$$

- For Reynolds no. (R) between 10^3 to 10^4

$$C_D \cong 0.4$$

- For R < 0.5

$$C_D = \frac{24}{R}$$

Where, $R = \frac{\rho V_s d}{\mu}$

Question 56

Explain the type-II settling adopted for the design of primary settling tank. *(CSVTU, Nov-Dec 2012)*

Ans. **Type II Settling flocculent setting**

This type of settling refers to rather dilute suspension of particles that coalesce or flocculate during sedimentation process due to which the mass of the particles increases and settling occurs at faster rate.

Type II setting can be analysed by a settling column test in which a suspension is placed in a long column land is allowed to settle under quiescent condition. Samples are withdrawn from this cylinder at several depths at several time intervals and the percentage removal is determined. The numerical value of percentage removal is located at the co-ordinate identifying the time and the depth of the sample and isoconcentration lines connecting points of equal removal are drawn.

Question 57

How and why the settling of solids in waste water treatment in primary settling tank is different than water treatment in plain sedimentation tank? *(CSVTU, April-May 2010)*

Ans. During plain sedimentation tank in waste water treatment plant, the settling is governed as zone II settling or flocculent setting where the particles coalesces and flocculates during the sedimentation process and thus results in increase of mass and then they settle at a faster rate.

However, the settling in plain sedimentation tank in water treatment is discrete settling or zone I settling. There is generally less concentration of solids and thus the particles have very less tendency to coalesce or flocculate upon each other.

Question 58

What type of settling governs the design of primary setting tank in wastewater treatment? Describe the settling column analysis carried out on a sample of wastewater. How the settling column analysis data is analyzed for the design of wastewater primary setting tank? *(CSVTU, Nov- Dec 2010)*

Or

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Describe the settling column test to determine the relevant data for the design of the PST. *(CSVTU, April-May 2013)(CSVTU, Nov-Dec 2012)*

Ans. Primary sedimentation tank is provided after grit removal in grit chamber, as the wastewater contains mainly lightweight organic matter which is settled in the primary sedimentation tank (PST). Due to involvement of many unknown parameters under such settling, the classical laws of sedimentation such as that applicable in grit removal are not applicable and this settling is called as *flocculant settling*.

Analysis of Flocculant Settling (Settling Column Test):

Settling column is used to determine the settling characteristics of the suspension of flocculant particles. A column with diameter of 15 cm and height of 3.0 m can give satisfactory results, with 5 to 6 ports provided over the height for sampling. The height of the tank should be ideally equal to side water depth of the settling tank for proper results.

The solution containing suspended solids should be added in the column in such a way that uniform distribution of solid particles occurs from top to bottom. Settling should takes place at quiescent conditions. It is important to maintain uniform temperature throughout the experimental column to avoid convection currents. At various time intervals, samples are withdrawn from the ports and analyzed for suspended solids. Percentage removal of solids is calculated for each sample analyzed and is plotted as a number (%) against time and depth. The curve of equal percentage removal is drawn between the plotted points.

The removal efficiency of the PST is given by the formula

Percentage removal = $\Delta h_1 \times (R_1 + R_2) / (h_5 \times 2) + \Delta h_2 \times (R_2 + R_3)/(h_5 \times 2) + \Delta h_3 \times (R_3 + R_4) / ((h_5 \times 2)) + \Delta h_4 \times (R_4 + R_5)/((h_5 \times 2))$

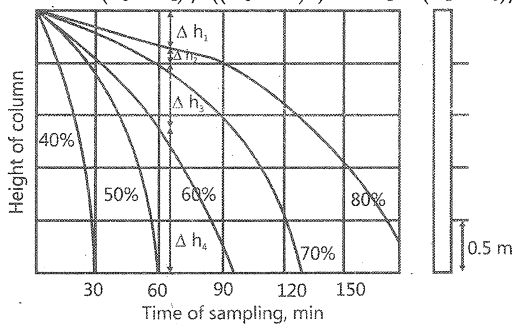


Fig. 2.9

In discrete settling, *overflow rate* is an important parameter. But in flocculant settling, in addition to overflow rate, other necessary design parameters are *depth, detention time* and *effluent weir flow rate*.

Question 59

Write a short note on Septic Tank.

Ans.

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Septic Tank:

In the rural areas and the fringe areas of the sub urban towns and also in case of isolated buildings and institutions like hostel, hospitals, hotels, school, residential colony, and underground sewerage system with complete treatment of sewage may neither be feasible nor economical.

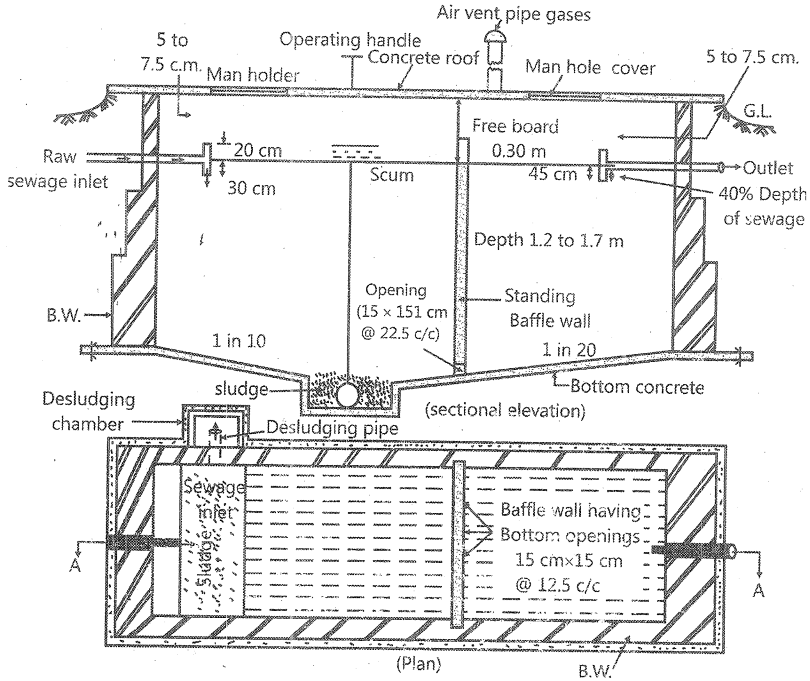


Fig. 2.13 Septic Tank

Under such conditions septic tank followed by subsurface disposal off effluent are provided. In areas having porous soil, this method gives satisfactory results. The location of septic tank should be as far as possible from the buildings and should not be located on the swampy areas prone to flooding. It is just like a plain sedimentation tank but in septic tank the biochemical reaction by anaerobic bacteria takes place. During the detention period the sewage is purified and the effluent is taken to soak pits for the disposal. The bad smells occur during the digestion period of the sludge and hence the septic tanks are provided with the cover at top.

Question 60

Explain the advantages and disadvantages of Septic Tank.

Ans. Following are the advantages and disadvantages Septic Tank.

Advantages:

1. It does not practically require any special attention or skilled supervision. It can be constructed very easily.
2. The cost is considerably reasonable as compare to the benefit it offers.

3. The performance of the properly constructed septic tank is very good. It can remove up to 90% of BOD and 80% of solids.
4. There is reduction in the volume of sludge as compare to sludge of plain sedimentation tank it is about 60% less in volume and 30 % less in weight.
5. The sludge effluent and scum obtained from the septic tank can be disposed off easily without causing any serious nuisance.
6. There is absence of any moving part.

Disadvantages:

Following are the disadvantages of septic tank:

1. If the tank is not properly functioning, the effluent is dark and foul smelling. It is even worse than the influent.
2. It requires excessive layers size for serving more persons.
3. The leakage of gases through the top of septic tank leads to air pollution.
4. The occasional removal of sludge leads to the maintenance cost and it is very tedious job.
5. The working of septic tank is unpredictable and non uniform.

Question 60

Explain the design aspects of the septic tank.

Ans. Following are the design aspects of septic tank:

1) **Capacity:** It is decided by taking into consideration the quality of flow and the detention time. It can also be designed on per capita basis which varies from 60-110 lit per person to be served by septic tank.
2) **Detention period:** It varies from 12-72 hours. Generally taken as 24 hours.
3) **Free board:** It should be about 400-600mm.
4) **Shape:** It is generally rectangular in shape. The ratio of length to width is about 2-4 hours.
5) **Disposal of effluent:** The effluent obtained from septic tank is highly odorous and therefore it should be properly discharged.
6) **Continued:** The effluents are generally disposed either in soak pits or soak wells.
7) **Soak pit:** A soak pit is a hollow circular pit. The total depth of soak pit varies from 1.2m to 1.8m. The effluent falls in the pit and is allowed to be soaked or absorbed into surrounding soils. The pits may be kept empty or filled with brick bats.
8) **Soak well:** It is similar to the soak pit except that it is large in size. The depth is about 3m or so. This is popular method of disposal of septic tank effluent. Explain the design of oxidation pond.
9) **Detention period:** It should be at least 7days and preferable 2 to 6 weeks.
10) **Area Required:** It varies with the climatic conditions of locality generally 250-1000 persons per hectare.
11) **Organic loading:** It varies from 150-300kg/ha/day.

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Question 62

Design the dimension of septic tank for a small colony of 150 persons provided with an assured water supply form municipal head work at a water of 120lit/person/day. Assume any data you may need. *(CSVTU, Nov-Dec 2008)*

Ans. Assuming that the whole quantity of water appears as sewage.

$\therefore$

$$Q = 150 \times 120$$
$$Q = 1800 \text{liters/day.}$$
$$Q = 750 \text{ liters /hour.}$$

Assuming the detention period as 18 hours

$\therefore$ Capacity of tank $= Q \times D_T$

$$C = 750 \times 18$$
$$C = 13500 \text{ liters.}$$

Assuming that the tank is to be cleaned every year, then the sludge storage capacity at the rate of 15 liter per person per year,

$$= 150 \times 15$$
$$= 2250 \text{ liters.}$$

$\therefore$ Total capacity of the tank

$$= 13500 + 2250 \text{ liter.}$$
$$= 15750 \text{ liter}$$

With the provision of future expansion, let the total capacity of tank to be 20,000 liter or $20m^3$.

Provide two units of septic tank each having a capacity of $10\ m^3$.

Assuming the depth of liquid as 1.6 m

$\therefore$ Plan area of the tank $= \dfrac{10}{1.6}$

$$= 6.25m^2$$

Assuming the ratio of length to width of a tank to be 3,

$\therefore$ $L \times B = 6.25\ m^2$

$$3B^2 = 6.25$$
$$B = 1.44m \cong 1.5m$$

Assuming the ratio of length to width of tank be 3.

Then,

$$L \times B = 25m^2$$
$$3B \times B = 25m^2$$
$$3B^2 = 25m^2$$
$$3 = 2.89 \approx 3m$$

Length of tank $=$ $3m \times 3m$

$$= 9m.$$

Assuming a free board of 400mm,

$\therefore$ Total depth $=$ $1.6 + 0.4$

$$= 2.0 \text{ m}$$

Hence, provide two septic tank of size $9m \times 3m \times 2m$

Size of soak well:

Let each unit will have its separate soak well. Assuming the percolating capacity of the filter media of a well as 1250 L/m^3/day.

Volume required for each soak well

$$= \frac{40 \times 1000}{1250}$$

$$= 32m^3$$

Assuming the depth of soak well as 4m,

$$\therefore \quad \text{Area of soak well} = \frac{32}{4}$$

$$= 8\ m^2$$

$$\text{Area} = \frac{\pi}{4} d^2$$

$$8 = \frac{\pi}{4} d^2$$

$$d = 3.91m.$$

$$d = 3.2m$$

Question 63

Design a septic tank for a small residential colony having a population of 500 persons. The rate of water supply is 150 liters per capita per day.

Ans. Assuming that the whole quality of water appears as sewage.

Then

$$Q = 500 \times 150$$

$$= 75000 \text{ liters / day}$$

$$= \frac{75000}{24} \text{ liters/ hour}$$

$$= 3125 \text{ liters / hour}$$

Assuming detention period of 18 hour,

$$\text{Capacity of tank} = Q \times D_T$$

$$= 3125 \times 18$$

$$= 56250 \text{ liters}$$

Assuming that the tank is to be cleaned every year, then the sludge storage capacity at the rate of 15 liters per person per year

$$= 500 \times 15$$

$$= 7500 \text{ liters}$$

$$\therefore \text{ Total tank capacity}$$

$$= [56250 + 7500]$$

$$= 63750 \text{liters}$$

With the provision of future expansion, let the total tank capacity be 80,000 liters or 80 m^3.

Provide two units of septic tank each having a capacity of 40m^3.

Assuming the depth of liquid as 1.6m

$$\text{Plan area of the tank} = \frac{40}{1.6} = 25m^2$$

$$L = 3B$$

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$$= 4.33$$

$$L \approx 4.5 \text{ m.}$$

Assuming a free board of 400mm

$$\therefore \quad \text{Total depth} = 1.6 + 0.4$$

$$= 2.0m$$

Hence provide two septic tank of size

$$4.5 \times 1.5 \times 2.0m$$

Size of soak well:

Let each unit will have its separate soak well. Assuming the percolating capacity of the filter media of a well as 1250 Lit /m^3/day.

Volume required for each soak well

$$= \frac{10 \times 1000}{1250}$$

$$= 8\ m^3.$$

Assuming the depth of soak well or 4m,

Area

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

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

$$d = 1.6m$$

Question 64

Write a short note on stabilization ponds.

Or

Question 65

Write a short note on aerobic ponds.

Or

Write a short note on facultative ponds.

Ans. A Stabilization pond is simply a shallow body of water contained in an earthen basin, open to sun and air. The ponds are classified, according to the nature of the biological activity which takes places within the pond, as

1. Aerobic Pond
2. Facultative Pond
3. Anaerobic Pond

In *aerobic stabilization pond*, the oxygen is supplied by natural surface aeration and by algal photosynthesis. Except for the algal population, the microbiological population present in the ponds is similar to that in activated sludge system. These aerobic population releases carbon dioxide which is taken up by the algae for their growth; algae in turn release oxygen which help in maintaining the aerobic condition of the pond. Very shallow depth of aerobic pond (of depth 0.15 m to 0.45 m,) is used for the treatment of irrigation return water or any other industrial waste, where the aim is the removal of nitrogen by algal growth. For the treatment of domestic waste water, pond

depth between 1 m and 1.2 m may be used. For better results, the contents of the aerobic pond must be mixed periodically. The hydraulic regime within the pond is assumed to be in between complete mix and plug flow.

Most of the stabilization ponds in India are *facultative* in nature. Three zones exist in this type of ponds. The top zone is an aerobic zone in which the algal photosynthesis and aerobic biodegradation takes place. In the bottom zone the organics of the municipal waste water settle and undergo anaerobic decomposition. In the intermediate zone which is partly aerobic and partly anaerobic, the decomposition of organic wastes are done by the facultative bacteria. The nuisance associated with the anaerobic reactions are eliminated due to the presence of top aerobic zone; the foul smelling end products of anaerobic decomposition are carried to the top zone by mixing currents and are oxidized or utilised by the aerobic population there. As such, the maintenance of an aerobic layer in the facultative pond is important; the depth of this layer is, however a function of solar radiation, waste characteristics, BOD loading, and temperature.

In anaerobic pond, the entire depth is in anaerobic condition except an extremely shallow top layer. Normally these tanks are used in series after facultative pond for complete treatment of a waste.

Question 66

Explain in brief principle of working of aerobic, anaerobic and facultative type of stabilization pond. *(CSVTU, April-May 2013)*

Ans. The principles of various ponds are:

1. **Oxidation Ponds**
   Oxidation ponds (usually designed from the same criteria as stabilization ponds) receive flows from stabilization ponds or primary settling tanks. These ponds provide biological treatment, additional settling, and some reduction of fecal coliform levels.
2. **Aerobic Ponds**
   In aerobic ponds, oxygen is present throughout the pond. All biological activity is aerobic decomposition. These ponds are not widely used.
3. **Anaerobic Ponds**
   In anaerobic ponds, no oxygen is present in the pond, and all biological activity is anaerobic decomposition. These ponds are normally used to treat high-strength industrial wastes.
4. **Facultative Ponds**
   Facultative ponds are the most common pond type by process. In the upper portions of the pond, the presence of oxygen means aerobic processes occur. In the lower levels of the pond, no oxygen is present and anoxic and anaerobic processes occur.
5. **Aerated Ponds**
   In aerated ponds, mechanical or diffused air systems provide oxygen throughout the pond. With aeration, pond depth and for the acceptable loading levels may increase. Mechanical or diffused aeration can supplement or replace natural oxygen production.

Question 67

Write short notes with neat sketches on Facultative Ponds & Mechanism of Purification.

(CSVTU, Nov- Dec 2011)

Ans. **Secondary Treatment of waste water: Facultative Ponds & Mechanism of Purification**

A facultative pond combines the features of the aerobic and anaerobic ponds constructed of intermediate depths (1 to 1.5 m). A facultative pond consist of three zones

1. Aerobic Zone at the top
2. Anaerobic zone at the bottom.
3. Facultative zone between the Aerobic and Anaerobic zone where the decomposition of inorganic waste and the products of anaerobic decomposition is done by facultative bacteria.

The pond depth inhibits mixing; hence organic solids which settle will remain on the bottom and will be subjected to anaerobic decomposition. The action in the aerobic zone is similar to the one found in the aerobic ponds giving rise to the bacterial –algal – symbiosis.

Mechanism of Purification: In facultative pond, the influent organic matter is stabilized by methane formation in the bottom layers and partly by the bacterial oxidation in the top layers. In the facultative zone facultative bacteria oxidize the incoming organics as well as the products of anaerobic decomposition of the bottom anaerobic zone. When the sewage enters the pond the suspended organic matter in the influent as well as bio flocculated

Colloidal organic matters settle to the bottom of the pond. In the absence of the dissolved oxygen at the pond bottom the settled sludge undergoes anaerobic fermentation with the liberation of methane which represents a BOD removal from the system. 0.25 gm of methane being liberated for every gram of the ultimate BOD utilized. In the liquid layers of the pond algae begins to grow under favorable conditions. The algae utilize the carbon dioxide in the sewage for photosynthesis during daylight hours liberating oxygen which maintains the aerobic condition in the upper layers of the pond. The aerobic conditions promote the oxidation of the oxidation of the organic waste matter by aerobic bacteria. Thus there is symbiotic association between the algae and bacteria.

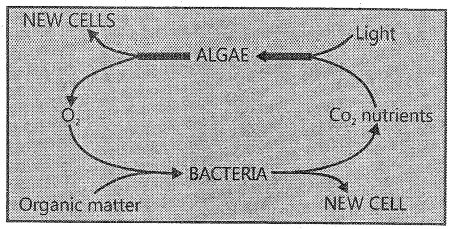


Fig. 2.10 Faculatative pond

Question 68

Explain the design aspects of the oxidation ditch.

Ans. **Design criteria for oxidation ditch**

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Oxidation ditches are aeration units in the shape of long channels 150-1000 m long, 1-5m wide and 1-1.5m deep.

- Detention period of 12-15 hrs is generally provided.
- BOD loading rate may be between 0.8 to 2.5 m^3/kg of BOD.
- Efficiency of treatment:

It removes more than 95% of suspended solids and more than 98% of BOD.

Question 70

Design an oxidation pond for treating sewage from a hot climate residential colony with 5000 persons, contributing sewage at 120 Liter /capacity /day. The 5 day BOD of sewage is 300 mg/L. *(CSVTU, April-May 2009)*

Ans. Quantity of sewage to be treated per day = 5000 × 120 = 60,0000Liter

$= 600m^3$

B. O. D content per day $= (0.60 \times 300)$

$= 180$ kg.

Assuming the organic loading in the pond as 300 kg / hectare per day,

$\therefore$ surface area required $= \frac{180}{30}$ hectare

$= (0.60 \times 10^4)m^2$

$= 6000m^2$.

Assuming the length of the tank as twice the width

$\therefore$ We have ,

$L \times B = 6000$

$2B^2 = 6000$

$\therefore \quad B = 54.77$ m

$B \approx 55$ m.

Now, $L = 2B$

$L = 110$m

Then, let the effective depth of the tank be 1.20m with total depth of 2.20m

The capacity = 110× 55×1.2

$= 7260\ m^3$

Now, capacity = sewage flow per day × D_T in days.

Detention time in days $= \frac{\text{capacity}}{Q}$

$= \frac{7260}{600}$

$= 12.10 \approx 12$ days

$\therefore$ Provide an oxidation pond of dimension 110× 55 ×1.20, having a detention period of 12 days.

Design of an inlet pipe

Assuming an average velocity of sewage as 900mm/sec and daily flow for 8 hrs,

$$Q = \left[\frac{600}{8 \times 60 \times 60}\right] = 0.021 m^3/sec$$

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Area of inlet pipe required $= \frac{\text{discharge}}{\text{Velocity}}$

$A = \frac{0.021}{0.90}$

$A = 0.023\ m^2$

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

$0.023 = \frac{\pi}{4} d^2$

$d = 0.17$m say 200mm.

The diameter of outlet pipe may be taken as 1.5 times that of inlet = 300mm.

Question 71

What is muffle furnace? *(CSVTU, Nov- Dec 2009)*

Ans. A muffle furnace is a front-loading box-type kiln for high-temperature applications such as fusing glass, creating enamel coatings furnace in which the subject material is isolated from the fuel and all of the products of combustion including gases and flying ash.

Question 72

Write a short note on Imhoff tank

Ans. **Imhoff Tank:** It is an improvement over the plain septic tank. In an imhoff tank both sedimentation and sludge digestion takes place in the same structure. Imhoff contains two compartments one for sedimentation and other for sludge digestion. Sometimes the Imhoff tanks are known as two storey digestion tank. The upper chamber is known as sedimentation chamber or flowing through chamber from which the sewage flows at very low velocity so that the sedimentation can take place. The lower chamber is known as digestion chamber in which the anaerobic or septic decomposition occurs.

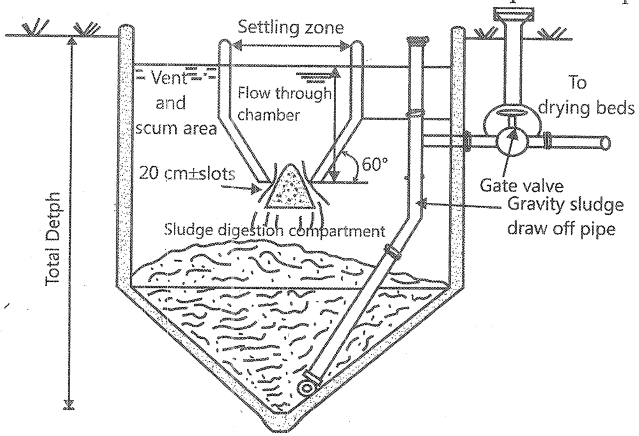


Fig. 2.12 IMHOFF tank configuration

The solids which are settling down at the bottom of settling chamber will slides down into digestion chamber through an entrance slot at lowest portion of sedimentation tank. The slot is trapped or overlapped in such a way that gases generated in the

digestion tank do not enter in the sedimentation chamber. The gas vent also called as scum area is provided with the digestion chamber. Gas vent or scum area should be 20 % of the total surface area.

Question 73

Explain the advantages and disadvantages of Imhoff Tank.

Ans. Following are the advantages and disadvantages Imhoff Tank.

Advantages:

1. They are quite economical in the operation.
2. They DO not require skilled attention during the operation.
3. There are no moving parts.
4. They require only preliminary treatment.
5. There is no difficulty in the sludge removal also the sludge volume and weight is less.
6. It removes 60-70 % of solids and 30-40% of the BOD.

Disadvantages:

1. Because of greater depth, cost of construction is high.
2. It is not suitable for the acidic influent.
3. Gives offensive odors when it is improperly operated.
4. They have tendency to foam or boil due o which sludge particles may enter the sedimentation zone affecting the quality of effluent.

Question 74

Write short notes with neat sketch of Oxidation Ditch. *(CSVTU, Nov- Dec 2011)*

Ans. **Oxidation Ditch:** This is a type of extended aeration activated sludge process. It consists of an endless ditch for the aeration tank and a rotor for the aeration mechanism and a long continuous channel usually oval in the plan. The influent from the screen is directly taken to the oxidation ditch where the sewage is aerated by a surface rotor placed across the channel. In addition to the aeration the rotor also imparts a velocity of 0.3 to 0.4 m.p.s to the mixed liquor preventing the settling of biological sludge. The rotor has the standard oxygen transfer capacity of 2.8 kg O_2 / m length per hour at 16 cm depth of immersion. The rotor imparts adequate circulation for 120-150 m^3 of ditch volume per meter length of rotor. The return sludge and raw sewage are discharged into the ditch upstream of rotors. The outlet of the ditch is located opposite to the inlet .Baffles are provided in the outlet weir so that the ditch water does not rise excessively and overload the rotors at peak flow period. The operation of the oxidation ditches may be intermittent or continuous type. In intermittent operation it works as settling tank. Intermittent operations are

1. Closing inlet and aerating sewage
2. Stopping the rotor and letting the contents settle
3. Letting in the fresh sewage which displaces an equal quantity of clarified effluent.

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The removal of the sludge is done from the mixed liquor at the bottom of the ditch. Generally the continuous operation is adopted in which the oxidation ditch is followed by a secondary settling tank.

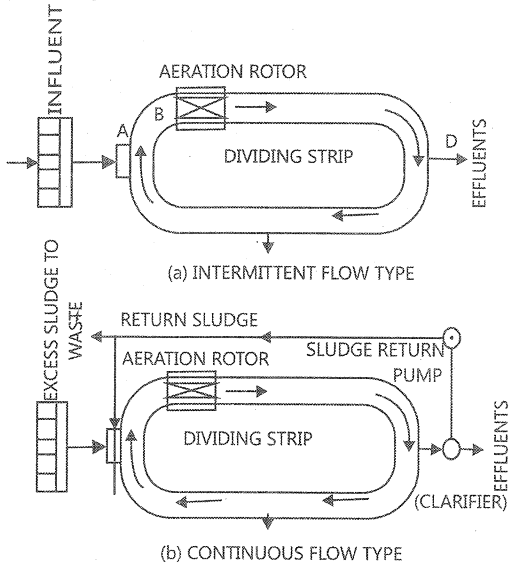


Fig. 2.11 Oxidation Ditches

Question 75

Derive Streeter – Phelps equation. *(CSVTU, April-May 2012)*

Ans. Streeter – Phelps equation is used for analysis of oxygen sag curve. It can be done by superimposing the rates of de-oxygenation and re-oxygenation. The Streeter – Phelps equation can be derived as follows:

$$\frac{dD_t}{dt} = f \text{ (deoxygenation and reoxygenation)}$$

$$\frac{dD_t}{dt} = k'L_t - R'D_t$$

Where, D_t = DO deficit at time t

L_t = Amount of first stage B.O.D. remaining in the water at time t.

k' = B.O.D reaction rate constant or deoxygenation constant base *e*

R' = Reoxygenation constant base *e*

t = Time in days

$$\frac{dD_t}{dt} = \text{Rate of change of DO deficit}$$

It is known that

$$L_t = L_0 e^{-k't}$$

Where, L_0 = B.O.D. remaining when t = 0

Where, $$\frac{dD_t}{dt} = k'L_0 e^{-k't} - R'D_t$$

$$\frac{dD_t}{dt} + R'D_t = k'L_0 e^{-k't}$$ (First order first degree differential equation)

The solution for the above differential equation is given by,

$$\therefore \quad D_t = \frac{k'L_0}{R' - K'}\left[e^{-k't} - e^{-R't}\right] + D_0 e^{-R't}$$

Changing it to the base 10, we get

$$\therefore \quad D_t = \frac{k'L_0}{R - K}\left[10^{-kt} - 10^{-Rt}\right] + D_0 10^{-Rt}$$

k = BOD reaction constant to the base 10

R = Reoxygenation constant to the base 10

D_0 = Initial oxygen deficit at the point of waste discharge at time t = 0

This equation is known as Streeter – Phelps equation.

CSVTU, APRIL-MAY 2013

Part – A

(a) *The wastewater sample contains BOD_3 as 75 mg/l and reaction rate to base e as 0.345 per day, the amount of BOD remaining after 10 days is* 2

(i) 3.12 mg/l

(ii) 3.45 mg/l

(iii) 3.69 mg/l

(iv) 3.92 mg/l

Ans. **Refer Question 25 Unit - 2**

Part – B

(b) *Explain the biochemical oxygen demand. Draw BOD curve for a domestic waste water sample and explain various segments on it. What is first stage BOD and second stage BOD?* 7

Ans. **Refer Question 6,7,8,9 Unit - 2**

(c) *Explain the purpose of the grit chamber. What is the logic that governs its design? Determine the dimensions (length × width × depth) and detention time for a grit chamber for a maximum waste water flow of 8000 m^3/day to remove particles having average settling velocity of 0.2 m/sec for a constant flow through velocity of 0.3 m/sec maintained by provision of proportional flow weir.* 7

Ans. **Refer Question 51 Unit - 2**

(d) *Explain the type-II setting adopted for the design of primary settling tank. Describe the settling column test to determine the relevant data for the design of the PST.* 7

Ans. **Refer Question 56, 58 Unit - 2**

CSVTU, NOV-DEC 2012

(a) *What is recirculation ratio?* 2

Ans. **Refer Question 10 Unit - 3**

(b) *The design flow of sewage is 3.8 million litres per day, and the BOD of raw sewage is 300mg/l. Design a single stage trickling filter to produce an effluent having a BOD of 45 mg/l.* 7

Ans. **Refer Question 20 Unit - 3**

(d) *Design a conventional sludge plant to treat settled domestic sewage with diffused air aeration system, for the following data:* 7

(i) *Population – 1,20,000*

(ii) *Per capita sewage contribution – 160 lpcd*

(iii) *Settled sewage BOD_5 – 200 mg/l*

(iv) *Effluent BOD_5 required – 15mg/l*

Ans. **Similar to Question 32 Unit - 3**

(d) *Explain in briefly principle of working of aerobic, anaerobic and facultative type of stabilization pond.* 7

Ans. **Refer Question 66 Unit - 2**

CSVTU, APRIL-MAY 2012

Part – A

(a) *Write the formula for determination of:* 2

(iii) *Total Solids*

(iv) *Total Volatile Solids*

Part – B

Ans. **Refer Question 4 Unit - 2**

(b) *Explain COD and its significance in waste water treatment.* 7

Ans. **Refer Question 13 Unit - 2**

(c) *What is meant by "Population Equivalent"? How is it determined?* 7

Ans. **Refer Question 15 Unit - 2**

(d) *Derive the Streeter Phelps Equation.* 7

Ans. **Refer Question 75 Unit - 2**

CSVTU, NOV-DEC 2011

(a) *(i) Standard $BOD_5$20°C when compared to ultimate BOD is about:*

(1) 58% *(2) 68%*

(3) 78% *(4) 90%*

(ii) Average BOD_5 of domestic sewage is

(2) 80 kg/d/p *(2) 8 kg/d/p*

(3) 0.08 kg/d/p *(4) 0.8 kg/d/p*

Ans. **Refer Question 10 Unit - 2**

(b) *The 4 days 15°C BOD of a sewage sample is 200 mg/l. Draw a graph (in answer sheet only. No graph paper required) of 5 day BOD as a function of temperature in the range of 10°C to 30°C in steps of 5°C.* 7

Ans. **Refer Question 33 Unit - 2**

(c) *Explain various types of settlings. Differentiate unit processes and operations with proper examples.* 7

Ans. **Refer Question 54 Unit - 2**

(d) *Write short notes with neat sketches:* 7

i. Facultative Ponds & Mechanism of Purification.

ii. Oxidation Ditch.

Ans. **Refer Question 67, 74 Unit – 2**

CSVTU, APRIL-MAY 2011

(a) *Define Relative Stability.* 2

Ans. **Refer Question 14 Unit - 2**

(b) *Define BOD, deduce expression for first stage BOD.* 7

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Ans. **Refer Question 6,7 Unit - 2**

(c) *Data from unseeded domestic wastewater BOD test are:5 ml of waste in 300 ml bottle, initial D.O. of 7.8 mg/l, and 5 days D.O. equal to 4.3 mg/l. Compute:* 7

(i) *The BOD; and*

(ii) *The ultimate BOD, assuming a k-rate of 0.10 per day.*

Ans. **Refer Question 29 Unit - 2**

(d) *Design of a rectangular grit-chamber from following data:* 7

Flow of sewage = 55 x 10^6 litres/day.

Specific gravity of the grit = 2.70.

Size of the grit particle to be removed = 0.21 mm.

Viscosity of water = 1.0 x 10^{-2} cm^2/sec.

Ans. **Refer Question 52 Unit - 2**

CSVTU, Nov-Dec 2010

(a) *What do you mean by overflow rate of a setting tank?* 2

Ans. **Refer Question 49 Unit - 2**

(b) *An analysis for solids is made on a wastewater sample. Two hundred milliliters of the sample is filtered through a fiber glass filter that has been pre-weighed at 0.138 g. The filter and residue is oven carried until a constant mass of 0.229 g is reached 100 mL of the filtrate is placed in an evaporation dish whose tare mass has been determined to be 327.485g. The contents of the dish are evaporated to dryness, and the total mass of the dish and solids is found to be 327.517g. Determine the total suspended solids and total dissolved solids.* 7

Ans. **Refer Question 34 Unit - 2**

(c) *What type of setting governs the design of primary setting tank in wastewater treatment? Describe the setting column analysis carried out on a sample of wastewater. How the setting column analysis data is analyzed for the design of wastewater primary setting tank?* 7

Ans. **Refer Question 58 Unit - 2**

(d) *A 2% solution of a sewage sample is incubated for 5 days at 20°C. The depletion of oxygen was found to be 4 mg/L. Determine the BOD of the sewage. What will be 3-day BOD of this sewage in summer when the temperature is 37°C? Take the BOD rate constant (base 10) as 0.1 per day at 20°C.* 7

Ans. **Refer Question 30 Unit - 2**

CSVTU, April-May 2010

(a) *What do you mean by Most Probable Number (MPN) in a waste water example?* 2

Ans. **Refer Question 18 Unit - 2**

(b) *Explain the procedure of determination of total solids, suspended solids and settleable solids for a waste water sample. How one can determine the organic and inorganic part of these solids?* 7

Ans. **Refer Question 4 Unit - 2**

(c) *Draw a waste water treatment flow diagram showing various treatment units. Clearly show the preliminary treatment, primary treatment and secondary treatment units on it. How and why the settling of solids in waste water treatment in primary settling tank is different than water treatment in plain sedimentation tank?* 7

Ans. **Refer Question 39, 57 Unit - 2**

(d) *The 5 day 20° C BOD of wastewater is 210 mg/L. What will be the ultimate BOD? What will be the 10-day BOD? Take the rate constant (natural log) as 0.23 per day.* 7

Ans. **Refer Question 23 Unit - 2**

CSVTU, Nov-Dec 2009

(a) *What is Muffle Furnace?* 2

Ans. **Refer Question 71 Unit - 2**

(b) *Explain the procedure of determination of total solids, suspended solids, and settleable solids for a waste water sample. How will you separate the organic and inorganic part of these solids?* 7

Ans. **Refer Question 4 Unit - 2**

(c) *Draw a waste water treatment flow diagram showing various treatment units. Clearly show the preliminary treatment, primary treatment and secondary treatment units on it. How and why the settling of solids in waste water treatment in primary settling tank is different than water treatment in plain sedimentation tank?* 7

Ans. **Refer Question 39, 57 Unit - 2**

(d) *A 2% solution of a sewage sample is incubated for 5 days at 20°C. The depletion of oxygen was found to be 4 mg/L. Determine the BOD of the sewage. What will be 3-day BOD if this sewage in summer when the temperature is 37°C? Take the BOD rate constant (base 10) as 0.1 per day at 20°C.* 7

Ans. **Refer Question 30 Unit - 2**

CSVTU, April-May 2009

(a) *What do you understand by "chemical oxygen demand"?* 2

Ans. **Refer Question 13 Unit - 2**

(b) *Discuss various physical properties of sewage.* 7

Ans. **Refer Question 1 Unit - 2**

(c) *What will be 5 day 20°C BOD if BOD of sewage in incubated for day at 30°C in 110 ppm. K_{20} = 0.1.* 7

Ans. **Refer Question 32 Unit - 2**

(d) *Design an oxidation pond for treating sewage from a hot climate residential colony with 5,000 persons, contributing sewage @ 120 liter/capita/day. The 5 day BOD of sewage is 300 mg/l.* 7

Ans. **Refer Question 70 Unit - 2**

CSVTU, Nov-Dec, 2008

(a) *Define Bio-chemical oxygen demand.* 2

Ans. **Refer Question 6 Unit - 2**

(b) *The 5-day 30°C BOD of sewage sample is 110 mg/l. Calculate its 5 day 20°C BOD. Assume the de-oxygenation constant at 20°C, K_{20} as 0.1.* 7

Ans. **Refer Question 32 Unit - 2**

(c) *Design the dimension of septic tank for small colony of 150 persons provided with an assured water supply from municipal head work at a rate of 120 litres/person/day. Assume any data.*

Ans. **Refer Question 62 Unit – 2**

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Wastewater Treatment Processes

	Process/Step	Purpose
1.	Primary Treatment	Removes 90-95% settleable solids, 40 to 60% total suspended solids, and 25 to 35% GOD_5
2.	Collection	Conveys wastewater from source to treatment plant
3.	Screening	Removes debris that could foul or damage plant equipment
4.	Shredding	Screening alternative that reduces solids to a size the plant equipment can handle
5.	Grit removal	Removes gravel, sand, silt, and other gritty materials
6.	Pre-aeration	Freshens septic wastes, reduces odors and corrosion, and improves solids separation and settling
7.	Chemical addition	Reduces odors, neutralizes acids or bases, reduces corrosion, reduces BOD_5, improves solids and grease removal, reduces loading on the plant, and aids subsequent processes
8.	Flow equalization	Reduces or removes the wide swings in flow rates for plant loadings
9.	Primary sedimentation	Concentrates and removes settleable organic and floatable solids from wastewater
10.	Secondary Treatment	Produces effluent with not more than 30 mg/L BOD_5 and 30 mg/L suspended solids
11.	Biological treatment	Provides BOD removal beyond that achievable by primary treatment, using biological processes to convert dissolved, suspended and colloidal organic wastes to more stable solids
12.	Secondary Treatment	Removes the accumulated biomass that remains after sedimentation
13.	Tertiary or Advanced Treatment	Removes pollutants, including nitrogen, phosphorus, soluble COD, and heavy metals to meet discharge or reuse criteria with respect to specific parameters
14.	Disinfection	Destroys any pathogens in the effluent that survived treatment
15.	Dechlorination	Protects aquatic life from high chlorine concentrations, needed to comply with various regulations
16.	Discharge	Releases treated effluent back to the environment through evaporation, direct discharge, or beneficial reuse.
17.	Solids treatment	Transforms sludge to biosolids for use as soil conditioners or amendments.

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Unit - 3 Secondary Treatment Systems

3.1 Introduction

Sewage is a dilute mixture of various wastes from residential, commercial, industrial and other public places.

In order to decide the line of treatment of sewage and disposal, the composition and characteristics of sewage has to be known. The characteristics of sewage depend upon the source of its discharge. Sewage consists of organic inorganic matter and living organisms.

3.2 Secondary Treatment Systems

The effluent coming from the primary clarifiers contains about 45-60 % of the unstable organic matter originally present in the sewage. The larger solids are removed by primary sedimentation tank and the organic matter present in the sewage in solution or in suspension or as colloidal matter is carried away by effluent from the settling tank.

The main function of the secondary treatment of sewage is to convert the remaining organic matter into stable form by oxidation. The secondary treatment of sewage is mainly accomplished by biological treatment.

3.3 Biological Treatment of Sewage

Question 1

What is the basic principle behind the working of the secondary treatment systems? What do you understand by attached growth process and suspended growth process? Explain giving two examples. *(CSVTU, Nov-Dec 2010)*

OR

What do you understand by suspended growth process and attached growth process? Explain the principle of treatment in treatment units belonging to these processes. *(CSVTU, Nov-Dec 2009) (CSVTU, April –May 2010)*

Ans.: The main function of the secondary treatment of sewage is to convert the remaining organic matter into stable form by oxidation. The secondary treatment of sewage is mainly accomplished by biological treatment.

The biological treatment of sewage is broadly classified in to two categories.

1. **Attached growth process**: This are the biological treatment process in which the microorganisms responsible for the conversion of organic matter or other constituents to gases and cell tissues are attached to some inert medium such as rock, slag or specially designed ceramic or plastic materials .

   It includes Intermittent sand filters, Trickling filters, Rotating biological contactors, packed bed reactors.

2. **Suspended growth process**: This are the biological treatment process in which the microorganisms responsible for the conversion of organic matter or other constituents

to gases and cell tissues are maintained in suspension within the liquid in the reactor by employing either natural or mechanical mixing. It includes activated sludge process, aerated lagoons, sludge digestion systems.

Principal of biological treatment process : when sewage is passed through the large porous surface containing large amount of air, the coarser particle of suspended matter are removed by the mechanical straining and the aerobic bacteria act on the sewage and stabilize it . Practically it has been observed that the major action takes place only at the surface, where a bacteria film of aerobic bacteria is formed. All the organic matter are first absorbed by the film, which is then acted upon by the bacteria. This bacteria film also contains algae, protozoa and other organism in addition to aerobic bacteria. When the sewage is passed through the beds, where aerobic action takes place following actions are done by the aerobic bacteria.

1. The colloidal & dissolved putrescible organic matters present in the sewage are absorbed within few minute in the trickling filter and within one hour in activated sludge treatment process.
2. The bacteria feed the organic matters so absorbed which are necessary for their life.
3. The bacteria convert the organic matter into stable inorganic forms by oxidizing them.
4. Finally Nitrates, CO_2 and sulphates etc remain in the sewage. The gases escape in the atmosphere.

3.3.1 Attached Growth Process

This is the biological treatment process in which the microorganisms responsible for the conversion of organic matter or other constituents to gases and cell tissues are attached to some inert medium such as rock, slag or specially designed ceramic or plastic materials.

Question 2

Explain the arrangement and working principle of a trickling filter. Draw the single stage and two stage recirculation systems. *(CSVTU, Nov-Dec 2009)*

Ans. **Trickling Filters**

1. A trickling filter is a fixed film attached growth aerobic process for treatment of organic matter from the wastewater.
2. The surface of the bed is covered with the biofilm and as with the aerobic bacteria and oxidation of organic matter occurs. In the past, rock was used as a bed material with size ranging from 25 mm to 100 mm. Now plastic media which offers higher surface area per unit volume is used.
3. The media is randomly packed in the reactor and the wastewater is applied on the top through rotary arm which trickles down over the filter media surface. Hence, this reactor is known as trickling filter.
4. Since, the wastewater is applied through the rotary arm from the top of the reactor the biofilm grown on the media surface receives wastewater intermittently.
5. As the wastewater trickles down leaving the wet biofilm, the biofilm is exposed to the air voids present in the media, and thus oxygen from the air, after solubalizing

in the water adhering on biofilm, is made available to aerobic bacteria grown in the biofilm by diffusion of oxygen through the biofilm.

6. The end product CO_2 diffuses out of the biofilm into the flowing liquid. Treated wastewater is collected from the bottom of the bed through an under drainage system and is settled in the final settling tank.
7. The biological film or slime forms on the surface of the filter media after application of wastewater. Organic matter is adsorbed on the slime layer and it is degraded by the aerobic microorganisms present in the slime.
8. As the thickness of the slime layer increases the condition near the surface of the media becomes anaerobic because of limitations of availability of oxygen.
9. At this stage the microbes lose their ability to cling to the surface of the media and the slime layer gets detached and washed out along with flowing liquid. This phenomenon is called as 'sloughing'.
10. Soon after the sloughing the new slime layer formation starts. Hence secondary sedimentation tank (SST) is provided to settle this washed out biomass. SST can be circular or rectangular tanks designed such that the overflow rate at peak flow should not exceed 50 m^3/m^2-d.
11. Based on hydraulic and organic loadings, the trickling filters may be classified as
    a. Low rate trickling filter and
    b. High rate trickling filter
12. Recirculation is employed in high rate filters to improve efficiency.
13. The recirculation helps in providing seeding to the filter bed and also dilutes the strong wastewater. Dilution is the major objective behind the recirculation.

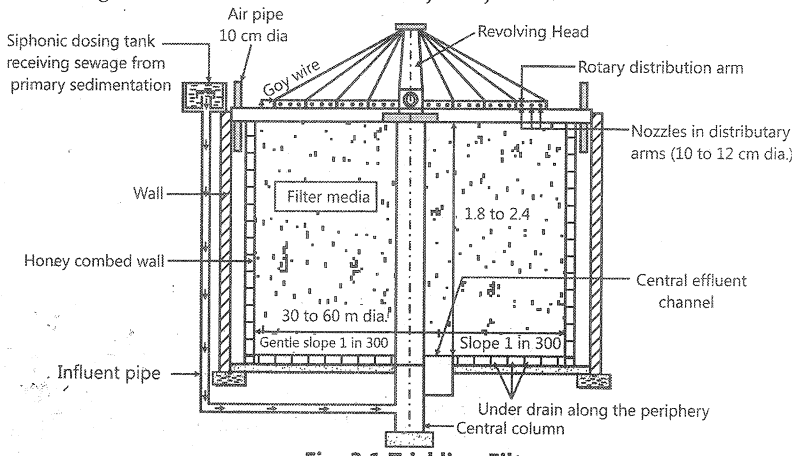


Fig. 3.1 Trickling Filter

Question 3

Explain the advantages and disadvantages of trickling filter.

Ans. Following are the **advantages** of the trickling filter.

1. The effluent obtained from the trickling filter is highly nitrified and stabilized. It therefore requires smaller volume of water for dilution.

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2. The mechanical wear and tear is small as it contains less mechanical equipment.
3. The moisture content of the sludge obtained from the trickling filters is as high as 99 % or so.
4. The operation of trickling filter requires less electrical power to run the mechanical equipment.
5. Trickling filters are flexible in operation and they can therefore withstand the application f variety of sewage having different concentration and composition.
6. The trickling filter may reduce the B.O.D and colloidal matter to the extent of about 75% and 80%.
7. The working principle of trickling filter is simple and does not require skilled supervision.

Following are the **disadvantages** of the trickling filter.

1. The cost of construction is very high.
2. The loss of head through the filter is very high and the installation of siphonic dosing tank is essential.
3. The process may develop fly nuisance and bad odor.
4. The process may require the primary treatment of sewage and hence the raw sewage cannot be purified by this process.

Question 4

Write the NRC formula for efficiency of trickling filter. *(CSVTU, April -May 2012)*

Ans. The efficiency of trickling filter can be expressed using NRC formula.

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

$$E(\%) = \frac{100}{1 + 0.44\sqrt{U}}$$

Where, E= Efficiency of the filter and its secondary clarifier, in terms of % of applied BOD removed.

$$E = \frac{C_i - C_e}{C} \times 100$$

Where, $C_{i\,b}$= Influent BOD concentration

$C_{e\,b}$= effluent BOD concentration

u = organic loading in kg / hectare-m /day, applied to the filter.

U = Unit hydraulic loading in kg/m³/day.

Question 5

Which of the following is NOT a unit physical unit operation?

(i) Equalization

(ii) Mixing

(iii) Adsorption

(iv) Screening *(CSVTU, Nov-Dec 2010)*

Ans. *Adsorption*

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Question 6

What are the operational problems of trickling filter?

Ans. Following are the operational problems of trickling filter.

1. **Odor Nuisance:** It is due to anaerobic decomposition, sludging and undesirable growth. The Odor Nuisance can be eliminated by preventing the conditions responsible for it.

Following are the remedies for the nuisance control.

i. The effluent obtained from the filter can be recirculated to continue aerobic condition and prevent anaerobic condition.
ii. The upper portion of the sewage can be kept fresh by its chlorination.
iii. The sewage can be kept in aerobic condition by chlorinating it before the PST.

2. **Ponding Nuisance:** When all the voids of the trickling filter are filled up due to choking by heavy fungus or other suspended matters the sewage cannot pass through the filters and accumulate at the surface in the shape of pond. Due to the ponding nuisance, the sewage cannot pass through the filter and the treatment work is stopped.

Following are the remedies for the ponding nuisance.

a. By drying the filter media for 15-48 hours by exposing in to the sun and loosening the aggregate by steel bars.
b. By washing and flushing the filter media with high velocity water jet and simultaneously loosening the aggregate by steel bars.
c. By flooding the filter top with water and allowing to stand for 24 hours. Within this period the impurities filled up in the voids of filter media shall be washed down.
d. By applying the heavy dose of chlorine or chlorinated lime up to a residual of 5 ppm in the filter influent for 2-6 hours after every 2-3 days. The chlorinated influent should be recirculated for opening the voids of the filter.

3. **Fly Nuisance:** This is the major trouble at the site of sewage treatment plants. The operation of trickling filter is done at slow rate the small moth like flies breed are developed at the site. This filter fly is known as 'psychoda' the filter fly also interferes with the working of the filters as it reaches in the filter media and chokes it.

Following are the main methods of preventing fly-Nuisance.

i. By chlorinating the sewage the chlorine will kill all the larva and the fly.
ii. By adding insecticide such as D.D.T in the sewage and sprinkling it from time to time on the ground and on the site of treatment plants.
iii. Flooding of the filter once a day within each breeding cycle of the fly.
iv. By sprinkling lime at the site and at all possible places, where its larva are breeding.

Question 6 (b)

(i) Average BOD removal efficiency in an Imhoff tank is: *(CSVTU, Nov-Dec 2011)*

(1) 70% *(2) 50%*

(3) 30% *(4) 60%*

Ans. 60%

Question 7

What do you mean by high rate tricking filters? *(CSVTU, Nov-Dec 2010)*

Ans. The high rate trickling filter is same as that of standard trickling filter, the difference is that the rate of loading is more than that of standard trickling filter.

Question 8

DP for a Grit chamber is: *(CSVTU, Nov-Dec 2011)*

(1) 1 min (2) 5 min

(3) 2-4 min (4) 1 hr

Ans. 2-4 min

Question 9

Define Recirculation. *(CSVTU, April-May 2011)*

Ans. **Recirculation:** It is the return of a portion of treated or partly treated sewage to the treatment process. Usually the return is from SST to the PST.

Question 10

What do you understand by term recirculation ratio? *(CSVTU, Nov-Dec 2009)*

Or

What is recirculation ratio? *(CSVTU, Nov-Dec 2012)(CSVTU, April-May 2011)*

Ans. The ratio of recirculated flow to the total flow of raw sewage is known as recirculation ratio. This ratio determines the required capacity of recirculating pumps and the hydraulic load placed upon the filters. Thus we have

Capacity of recirculating pump = R × (Influent sewage flow)

Hydraulic load of filter = (1 + R) × (Influent sewage flow)

Question 11

What do you understand by recirculation factor?

Ans. The number of effective passes through the fitter is known as recirculation factor (F)

Recirculation factor is given by the equation

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

F = Treatability factor

F = 0.9 for sewage

$$\text{Hydraulic recirculation factor} = \frac{\text{Inflow + Recirculation}}{\text{Inflow}} = (1+R)$$

Question 12

What is the importance of recirculation?

Ans. Recirculation is important as:

1. Recirculation keeps the self propelled distributors running at the time of reduced flow.
2. The thickness of biological film on contact media is reduced by forced film sloughing.
3. Recirculation loads deeper portions of the filter more effectively.
4. The applied sewage is seeded with active organisms and enzymes of effluent, due to which the efficiency of filter is increased.
5. The filter influent is freshened due to which foul odour is prevented.
6. Quality of filter effluent is improved.

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Question 13

Differentiate between the Standard rate trickling filter and High rate trickling filter. *(CSVTU, April-May 2012) (CSVTU, April-May 2009)*

Ans. SRTF is shown in fig. 3.2 whereas HRTF is shown in fig. 3.3.

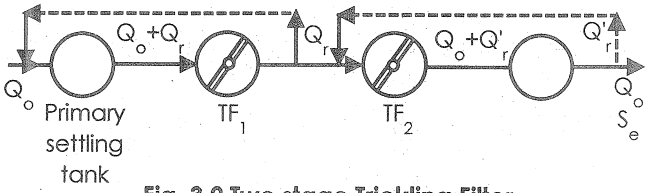


Fig. 3.2 Two stage Trickling Filter

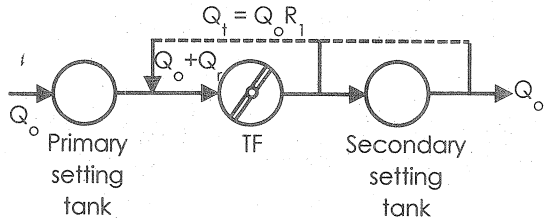


Fig. 3.3 Single Stage High Rate Trickling Filter.

S.NO	Standard Rate Trickling Filter	High Rate Trickling Filter
1.	The cost of construction is more.	The cost of construction is less.
2.	The depth is from 1.8 – 2.4 m.	The depth is from 900 mm – 1.8 m.
3.	The effluent obtained is highly nitrified and stabilized.	The effluent obtained is nitrified up to nitrite stage only and hence it is of inferior quality.
4.	It requires more area of land.	It requires less area of land
5.	The sludge obtained is black and highly oxidized with slight fine particles.	The sludge obtained is brown and not fully oxidized with fine particles.
6.	Recirculation is generally not included but it can be adopted, if the rate of loading is not exceeded.	Recirculation is always included however in some types it may be used during periods of low flow only.
7.	The size of filter media is between 30mm to 80 mm.	The size of filter media is between 30mm to 60 mm.
8.	The dosing of sewage generally varies from 3 min to 10 min. the sewage is usually not applied continuously but it is applied at intervals.	The dosing of sewage is not more than 15 sec. and the sewage is to be applied continuously.
9.	Kg of BOD per hectare –meter per day is 1000-2200.	Kg of BOD per hectare –meter per day is 8000-14000.

10.	Kg of BOD per day per 100 m^3 of filter media is from 15-30.	Kg of BOD per day per 100 m^3 of filter media is greater than 45.
11.	Hydraulic loading is between 25-40 million liters per hectare of surface area per day.	Hydraulic loading is between 100-300 million litres per hectare of surface area per day.

3.4 Design Criteria for Trickling Filter

Question 14

Explain design criteria for trickling filters.

Ans. The design criteria for the design of trickling filter is as given in the following table

Design Criteria	*Standard Rate Low Rate TF*	*High Rate TF*
Hydraulic loading (MLD/ha/day)	22-44	110 – 300 usually 220 b
Organic loading (BOD_5/ha-m/day)	900-2200	6000-18000
Depth of filter (m)	1.5-3.0	1.0-2.0
Recirculation Ratio (R)	0	1-4
BOD_5 Removal Efficiency	80-90%	65-80%

Question 15

A single stage filter is designed for on organic loading of 10, 000 Kg of BOD in raw sewage per hectare m/day with a recirculation ratio of 1.2. This filter treats a flow of 4 MLD of raw sewage with a BOD of 220 mg/L. Use NRC formula. Determine the strength effluent. *(CSVTU, April-May 2013) (CSVTU, Nov-Dec 2011)*

Sol: Total BOD of raw sewage $= (4 \times 10^6) \times 220 \times 10^{-6}$

$= 880$ kg/day

$\therefore$ Required filter volume $= \dfrac{\text{Total BOD of raw sewage}}{\text{Permissible BOD loading}}$

$V = \dfrac{880}{10{,}000} \times 10^4$

$V = 880\ m^3$

Let us assume that primary clarifier removes 35% BOD.

$\therefore$BOD of influent applied to the filter

$= 0.65 \times 880$

$= 572$ kg

The efficiency to filter is given,

$$E = \frac{100}{1 + 0.44\sqrt{W/VF}}$$

Here, $W = 572$ kg/day

$V = 880\ m^3$

$F =$ Recirculation factor

$= \dfrac{1+R}{(1+0.1\,R)^2}$

$= \dfrac{1+1.2}{(1+0.1\times 1.2)^2}$

$= 1.754$

Now, $E = \dfrac{100}{1 + 0.44\sqrt{572/880 \times 1.754}}$

$E = 78.87\%$

$\therefore$ Total BOD of effluent $= (100 - 78.87) \times \dfrac{572}{100}$

$= 120.84$ kg

BOD concentration of effluent $= \dfrac{120.84 \times 10^6}{4 \times 10^6}$

$= 30.21$ mg/L

3.5 Design of Trickling Filter

Question 16

A single stage filter is designed for on organic loading of 12000 kg of BOD in a raw sewage per hectare per meter per day with a recirculation of 1.5. This filter treats a flow of 5 MLD of raw sewage with a BOD of 200 mg/L. Using NRC formula; determine the strength of the effluent. *(CSVTU, Nov-Dec 2009) (CSVTU, Nov-Dec 2010)*

Sol: Given,

Organic loading $= 12000$ Kg of BOD/ ha – m/ day

Recirculation Ratio $= 1.5$

$Q = 5$ MLD

BOD of raw sewage $= 200$ mg/L

Total BOD of raw sewage $= (5 \times 10^6) \times (200 \times 10^{-6})$

Total BOD or raw sewage $= 100$ kg/day

Required filter volume $= \dfrac{\text{Total BOD of raw sewage}}{\text{Permissible BOD loading}}$

$= \dfrac{1000}{12000} \times 10^4$

Required filter volume $= 833.33\ m^3$

Let us assume that primary clarifier removes 35% of BOD.

$\therefore$ BOD of influent applied to filter $= 0.65 \times 833.33$

$= 541.66$kg

Now, the efficiency of the filter is given by

$$E = \frac{100}{1 + 0.44\sqrt{W/VF}} \text{ or } \frac{100}{1 + 0.44\sqrt{U}}$$

$\dfrac{W}{VF} = U$

Here, $W = 541.66$ kg/day.

$V =$ volume of filter $= 833.33\ m^3$

$F =$ Recirculation factor

$F = \dfrac{1+R}{(1+0.1R)^2}$

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$$F = \frac{1 + 1.5}{(1 + 0.1 \times 1.5)^2}$$

$$F = 1.89$$

$$\therefore \quad E = \frac{100}{1 + 0.44\sqrt{W/VF}}$$

Therefore, the value of E becomes,

$$E = \frac{100}{1 + 0.44\sqrt{\frac{541.66}{833.33 \times 1.89}}}$$

$$E = 79.84\%$$

$$\therefore \quad \text{Total BOD effluent} = (100 - 79.84) \times \frac{541.66}{100}$$

$$= 111.09 \text{ kg}$$

$$\text{BOD concentration of effluent} = \frac{\text{Total BOD}}{\text{Sewage volume}}$$

$$= \frac{111.09 \times 10^6}{5 \times 10^6}$$

$$= 22.21 \text{ mg/L}$$

Question 17

It is proposed to install a two stage trickling filter for treatment of 4.0 MLD of raw waste water having the influent BOD of 180 mg/L. Assuming the primary treatment removes 30% of BOD, the filter loading rate is 1000 gm/m³ of BOD. The recirculation ratio is 1.2 for each filter & if two filters equally share the load. Determine the BOD of the effluent. *(CSVTU, Nov-Dec 2010)*

Sol: Given,

$$Q = 4 \text{ MLD}$$

$$\text{BOD of influent} = 180 \text{ mg/L}$$

$$\text{Removal of BOD in PST} = 30\%$$

$$\text{Organic loading} = 1000 \text{ gm/m}^2 \text{ of BOD}$$

$$R = 1.2$$

$$Q = 4 \text{ MLD}$$

∴ Total BOD present in raw sewage

$$= 4 \times 10^6 \times 180 \times 10^{-6}$$

$$= 720 \text{ kg}$$

The BOD on the influent $720 - 0.3 \times 720 = 504$ kg

Now,

$$\text{The Volume of filter} = \frac{\text{Total BOD in raw sewage}}{\text{Organic Loading}}$$

$$V = \frac{720 \times 10^3}{1000}$$

$$V = 720 \text{m}^3$$

Now, 30% of the BOD is removed in primary classifier.

∴ Amount of BOD applied to the filter $= 0.7 \times 720 = 540$kg

For the first stage filter, the efficiency is given by

$$\eta = \frac{1000}{1 + 0.044\sqrt{\frac{W}{VF}}}$$

Where, W = Total BOD applied to the filter.

V = volume of filter

$$= \frac{720}{2} = 360 \text{m}^3$$

$$\eta = \frac{100}{1 + 0.0044\sqrt{\frac{468}{360 \times F}}}$$

Now,

$$F = \frac{1 + R}{(1 + 0.1R)^2}$$

$$= \frac{1 + 1.2}{(1 + 0.1 \times 1.2)^2}$$

$$= 1.75$$

$$\therefore \quad \eta = \frac{100}{1 + 0.0044\sqrt{\frac{468}{360 \times 1.75}}}$$

Question 18

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

Flow = *4.5 MLD*

Recirculation ratio = *1.4*

BOD of raw sewage = *250 mg/L* *(CSVTU, April-May 2011)*

Sol: Assuming that the BOD removal in the primary tank is about 30% and final desired BOD of effluent = 30mg/L.

Now, $Q = 4.5$ MLD

And BOD concentration = 250 mg/L

∴ Total BOD present in raw sewage

$$= 4.5 \times 10^6 \times 250 \times 10^{-6} = 1125 \text{ kg}$$

Since 30% of BOD is removed in primary settling tank.

∴ Total BOD entering the filter unit

$$= 0.7 \times 1125 = 787.5 \text{ kg}$$

BOD concentration desired in effluent

$$= 30 \text{ mg/L}$$

∴ Total BOD left in effluent per day

$$= 4.5 \times 30 = 135 \text{ kg}$$

∴ BOD removed by the filter

$$= 787.5 - 135 = 652.5 \text{ kg}$$

Now, the efficiency of the filter

$$E = \frac{\text{BOD removed}}{\text{BOD applied}} \times 100$$

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$$= \frac{652.5}{787.5} \times 100$$
$$= 82.85\%$$

Now, the efficiency of high rate trickling filter is given by

$$\eta = \frac{100}{1 + 0.0044\sqrt{\frac{W}{VF}}}$$
$$= \frac{100}{1 + 0.0044\sqrt{\frac{787.5}{V \times F}}}$$

Where,

$$F = \frac{1 + R}{(1 + 0.1R)^2}$$
$$= \frac{1 + 1.4}{(1 + 0.1 \times 1.4)^2}$$
$$F = 1.846$$

Now,

$$82.85 = \frac{100}{1 + 0.0044\sqrt{\frac{787.5}{V \times 1.846}}}$$

$$1 + 0.0044\sqrt{\frac{787.5}{V \times 1.846}} = \frac{100}{82.85}$$

$$= 1 + 0.0044\sqrt{\frac{426.59}{V}} = 1.207$$

$$\sqrt{\frac{426.59}{V}} = 47.04$$

$$V = 0.1927 \text{ ha} - \text{m} = 1927 \text{ m}^3$$

Assuming the depth of filter as 1.5 m.

∴ Surface area required

$$= \frac{1927}{1.5} \text{m}^2$$
$$= 1284.66 \text{ m}^2$$

Diameter of circular fitter

$$A = \frac{\pi}{4}D^2$$
$$1284.66 = \frac{\pi}{4}D^2$$
$$D^2 = 520.655$$
$$\mathbf{D = 22.81m.}$$

Hence use a trickling fitter with 22.81m diameter, 1.5m deep with recirculation ratio 1.4

Question 19

Determine the size of high rate trickling filter for following data

(i) Sewage flow	=	*5 MLD*	
(ii) Recirculation Ratio	=	*1.5*	
(iii) BOD of raw sewage	=	*230 mg/L*	
(iv) BOD removal in primary	=	*30% clarifier*	
(v) Final effluent BOD desired	=	*25 mg/L*	*(CSVTU, April-May 2008)*

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Sol: Q = 5MLD

BOD concentration of raw sewage = 230 mg/L

∴ Total BOD of raw sewage = $(5 \times 10^6) \times (230 \times 10^{-6})$
= 1150 kg/day

∴ BOD removal in primary setting tank = 30%

∴ BOD left in sewage entering the filter

$$W = 1150 \times 0.7 = 805 \text{ kg/day}$$

Desired BOD concentration in effluent = 25 mg/L

Total BOD left in effluent = $25 \times 5 = 125$ kg/day

Hence BOD removed by the filter = $805 - 125 = 680$ kg/day

∴ $$\text{Efficiency of filter} = \frac{\text{BOD removal}}{\text{Total BOD present}} \times 100$$
$$= \frac{680}{805} \times 100 = 84.47\%$$

But the efficiency, given by NRC equation is

$$E = \frac{100}{1 + 0.44\sqrt{W/VF}}$$

Where,

W = total BOD applied to the filter = 805 kg/day

V = Volume of filter (m^3)

F = Recirculation factor

$$F = \frac{1 + R}{(1 + 0.1R)^2}$$
$$= \frac{1 + 1.5}{(1 + 0.1 \times 1.5)^2}$$
$$F = 1.89$$

Now,

$$E = \frac{100}{1 + 0.44\sqrt{W/VF}}$$
$$84.47 = \frac{100}{1 + 0.44\sqrt{805/(V \times 1.05)}}$$

Solving the above equation, we get

$$V = 2439.5 \text{m}^3$$

Let us assume the depth of filter as 1.8m.

∴ $$\text{Surface area of the filter} = \frac{2439.5}{1.8}$$
$$= 1355.28 \text{ m}^2$$
$$A = \frac{\pi}{4}d^2$$
$$1355.28 = \frac{\pi}{4}d^2$$

∴ $$d = 41.5\text{m}$$

Therefore, provide a single stage high rate filter of 41.5m diameter and 1.8m deep filter media with a recirculation ratio of 1.5.

Question 20

The design flow of sewage is 3.8 million liters per day and the BOD of raw sewage is 300 mg/L Design a single stage trickling filter to produce an effluent having a BOD 45 mg/L. *(CSVTU, Nov-Dec 2012)*

Ans.

$$Q = 3.8 \text{ MLD}$$

$$= \frac{3.8 \times 10^6}{10^3 \times 24 \times 3600}$$

$$= 0.044 \text{ m}^3/\text{sec.}$$

Total BOD present in raw sewage

$$= 3.8 \times 300$$

$$= 1140 \text{ kg/day.}$$

Assuming that 35% of this BOD is removed in primary settling tank.

∴ Total BOD applied to the filter

$$= 0.65 \times 1140$$

$$= 741 \text{ kg}$$

Now, Total BOD removed by the filter

$$= 3.8 \times 10^6 \times 45 \times 10^{-6}$$

$$= 171 \text{ kg/day.}$$

∴ BOD removed by the filter

$$= 741 - 171$$

$$= 570 \text{ kg.}$$

∴ Efficiency

$$= \frac{570}{741} \times 100$$

$$= 76.92 \%$$

Assuming the organic loading between 9000-14000 kg/ha-m/day.

∴ Adopting 10,000 kg/ha-m/day.

Volume of the filter read

$$= \frac{\text{Total daily BOD removed}}{\text{Organic loading}}$$

$$= \frac{570}{10{,}000} = 0.057 \text{ na} - \text{m}$$

$$V = 570 \text{ m}^3$$

Now,

$$\eta = \frac{100}{1 + 0.0044\sqrt{\frac{W}{V.F}}}$$

$$76.92 = \frac{100}{1 + 0.0044\sqrt{\frac{500}{0.057 \times F}}}$$

$$76.92 = \frac{100}{1 + 0.44\frac{1}{\sqrt{F}}}$$

$$1 + 0.44\frac{1}{\sqrt{F}} = \frac{100}{76.92} = 1.3$$

$$\frac{0.44}{\sqrt{F}} = 0.3$$

$$F = \left(\frac{0.44}{0.3}\right)^2 = 2.15$$

But

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

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

$$2.15 = \frac{1 + \frac{R}{I}}{\left(1 + 0.1\frac{R}{I}\right)^2}$$

∴ $R = 1.47$

Hence Recirculation Ratio of 1.47 is to be adopted.

3.6 Suspended Growth Process

Question 22

Describe with sketches the treatment of sewage by activated sludge process. Mention the advantage and disadvantages of this system. *(CSVTU, April-May 2013)(CSVTU, Nov-Dec 2010) (CSVTU, April-May 2011)*

Ans. **Activated Sludge Process:** The ASP was developed in England in 1914. The activated sludge process consists of an aeration tank, where organic matter is stabilized by the action of bacteria under aeration and a secondary sedimentation tank (SST) is used, where the biological cell mass is separated from the effluent and the settle sludge is recycled partly to the aeration tank. Recycling is necessary for activated sludge process. The aeration conditions are achieved by the use of diffused or mechanical aeration. The activated sludge is the sludge which is obtained by settling the sewage in the presence of abundant oxygen so as to be supercharged with favorable aerobic microorganism. The activated sludge process of sewage treatment is based on providing intimate contact between the sewage and biological active sludge. Such sludge is developed initially by prolonged aeration under conditions which favor the growth of organism with special ability to oxidize the organic matter.

The effluent from PST is mixed with the dose of activated sludge and is aerated in the aeration tank for a period of some hours. During the aeration, the micro-organism in the sewage multiplies by assimilating part of the influent organic matter. In this process, part of organic matter is synthesized into new cells and part is oxidized

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to derive energy. The synthesis reaction followed by the subsequent separation of the resulting biological mass and the oxidation reaction are the main mechanism of BOD removal in the activated sludge process. The mixture of recycled sludge and sewage in the aeration tank is known as mixed liquor. The recycle sludge helps in initial build up of high concentration of active micro-organisms in the mixed liquor which accelerates the BOD removal.

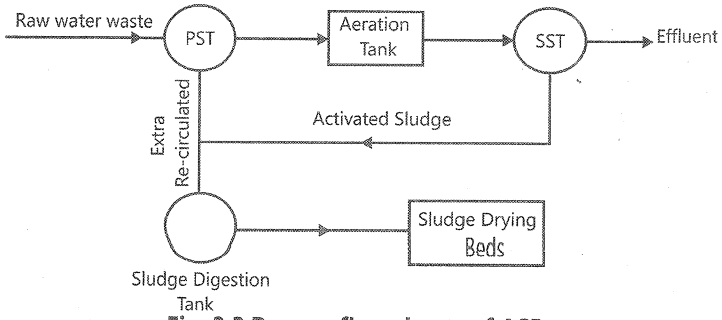


Fig. 3.3 Process flow sheets of ASP

The figure shows the flow diagram of activated sludge process.

Following are the three basic operations involved in the ASP.

1. **Mixing of Activated Sludge:** The activated sludge is mixed properly with raw or settled sewage. The activated sludge is added to the effluent of primary clarifier.
2. **Aeration:** The mixed liquor containing the activated sludge and effluent is agitated in the aeration tank. This is the chief operation of activated sludge process.
3. **Settling in the secondary clarifier:** The mixed liquor after agitation is taken to the secondary clarifier. The sludge is allowed to settle in this tank. The settled sludge is the activated sludge and portion of it is sent for recirculation. The extra activated sludge is taken to the sludge digestion tank and then to the sludge drying beds for further treatment.

Question 23

Explain the advantages and disadvantages of activated sludge treatment process. *(CSVTU, April-may 2011)*

Ans. Following are the advantages of activated sludge treatment process.

1. The cost of installation is low.
2. The effluent of good quality is obtained.
3. It requires small area of land.
4. Operating head is less as there is no need of pumping.
5. Effluent is free from offensive odors.
6. Degree of purity can be varied as per our desire.
7. Highly efficient the removal of SS, bacteria and BOD is around 90% each.

Following are the disadvantages of activated sludge treatment process.

1. If there is sudden increase in the volume or character of sewage, there are adverse effects on working of process and consequently the effluent of bad quality is obtained.

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2. The disposal of large amount of wet sludge produced at the end of the process is difficult.
3. The process is sensitive to certain types of industrial waste.
4. The process requires skilled supervision for its efficient working. It becomes necessary to ascertain that the sludge actually remains active during the process.

Question 24

Define "Sludge Age". *(CSVTU, April-May 2009)*

Ans. **Sludge Age:** The solid retention period in an activated sludge is known as sludge age.

Sludge age = V × MLSS / (Q× SS)

SS = Suspended solids in influent sewage mg/L.

Question 25

Explain the different aeration units employed for activated sludge treatment process.

Ans. Aeration units employed in ASP can be classified as follows.

1) Diffuser Air Units
2) Mechanical Aeration Units
3) Combined Mechanical and Diffused Air Units.

1. **Diffused Aeration:** In diffused air aeration, compressed air is blown through diffusers. The tanks of these units are generally in the form of narrow rectangular channels. The air diffusers are provided at the bottom of tank. The air before passing through diffusers must be passed through air filter to remove dirt. The required pressure is maintained by means of air compressors.

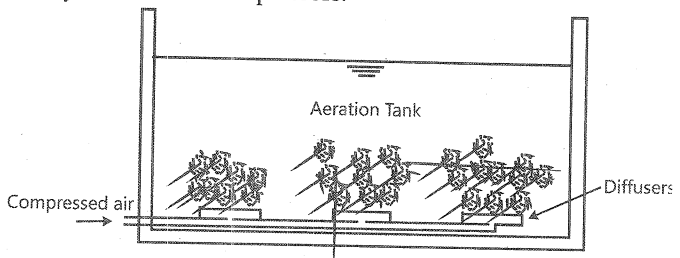


Fig. 3.4 Air Diffuser Arrangement

Types of air diffusers

a) **Jet diffusers:** These diffusers give direct stream of air in the form of jet downward and strike against a small bowl kept just below the nozzle of the jet. The air flashes over the surface of the bowl and escapes in the form of fine bubbles.

b) **Porous diffusers:** Manufactured in the form of tubes and plates from grains of crushed quartz, aluminum oxide or carbon fused to form a porous structure. These are tile shaped or tubular shape. 10 to 20 % area of the tank is covered with porous tiles. The supply of air is done through pipeline laid in the floor of the tank and is controlled by the valves.

Depending upon the size of the air bubbles these can be classified as fine or medium bubble diffused-air aeration device.

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Mechanical Aeration Unit

The main objective of mechanical aeration is to bring every time new surface of wastewater in contact with air. In diffuse aeration, only 5 to 12% of the total quantity of the air compressed is utilized for oxidation and rest of the air is provided for mixing. Hence, mechanical aeration was developed. For this, surface aerators either fixed or floating type can be used .The rectangular aeration tanks are divided into square tank and each square section is provided with one mixer. The impeller are so adjusted that when electric motors starts, they suck the sewage from the centre, with or without tube support, and throw it in the form of a thin spray over the surface of the wastewater. When the wastewater is sprayed in the air more surface area is brought in contact with the air and hence aeration will occur at accelerated rate. Detention period of the aeration tank treating sewage is usually 5 to 8 hours. The volume of aeration tank should be worked out considering the return sludge volume.

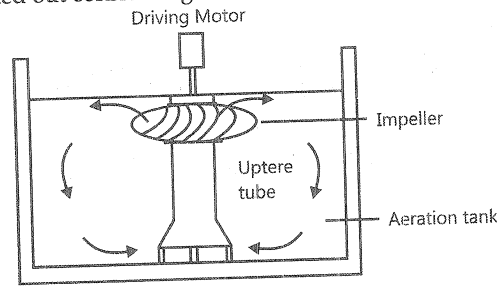


Fig. 3.5 Mechanical Aeration unit

Question 26

Explain the following terms.

1. *Loading Rate*
2. *Solid Retention Time (SRT) or Mean Cell Residence Time (MCRT)*
3. *Sludge Volume Index*
4. *Quantity of Return Sludge*
5. *MLSS*

(CSVTU, April-May 2013) (CSVTU, Nov-Dec 2011) (CSVTU, April-May 2012)

Ans.

1. **Loading Rate (F/M RATIO):** The organic matter loading rate applied to the reactor is quantified as kg of BOD applied per unit volume of the reactor per day, called as volumetric loading rate, or kg of BOD applied per day per unit mass of microorganisms present in the reactor (i.e. in the aeration tank), called as organic loading rate or F/M. This can be calculated as stated below:

Volumetric loading = $Q \times L \times 10^{-3} / Vol$

Where, L = Influent BOD_5 to aeration tank, mg/L

Q = Flow rate, m^3/day

Vol. = Volume of aeration Tank, m3

Organic Loading Rate(F/M) = $Q \times L / (V \times x_t)$

Where, x_t = MLVSS concentration in the aeration tank, mg/L

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The F/M ratio is the main factor controlling BOD removal. Lower F/M values will give higher BOD removal. The F/M can be varied by varying MLVSS concentration in the aeration tank.

2. **Solid Retention Time (SRT) or Mean Cell Residence Time (MCRT):** The performance of the ASP in terms of organic matter removal depends on the duration for which the microbial mass is retained in the system. The retention of the sludge depends on the settling rate of the sludge in the SST. If sludge settles well in the SST, proper recirculation of the sludge in aeration tank is possible, this will help in maintaining desired SRT in the system. Otherwise, if the sludge has poor settling properties, it will not settle in the SST and recirculation of the sludge will be difficult and this may reduce the SRT in the system. The SRT can be estimated as stated below:

SRT = (kg of MLVSS in aeration Tank) / (kg of VSS wasted per day + kg of VSS lost in effluent per day)

Generally, the VSS lost in the effluent are neglected, as this is very small amount as compared to artificial wasting of sludge carried out from the sludge recycle line or from aeration tank.

3. **Sludge Volume Index:** The quantity of the return sludge is determined on volumetric basis. The sludge volume index (SVI) is the volume of the sludge in mL for one gram of dry weight of suspended solids (SS), measured after 30 minutes of settling. The SVI varies from 50 to 150mL/ g of SS. Lower SVI indicates better settling of sludge.

SVI = $(V_S \times 1000) / MLSS$

4. **Quantity of Return Sludge:** Usually, solid concentration of about 1500 to 3000 mg/L (MLVSS 80% of MLSS) is maintained for conventional ASP and 3000 to 6000 mg/L for completely mixed ASP. Accordingly, the quantity of return sludge is determined to maintain this concentration. The sludge return ratio is usually 20 to 50%. The F/M ratio is kept as 0.2 to 0.4 for conventional ASP and 0.2 to 0.6 for completely mixed ASP.
5. **MLSS:** The sludge solids contained in the mixed liquor is known as MLSS. The MLSS in an aeration tank is an index of the activity of microorganism as these metabolize biologically.
6. **MLVSS:** It denotes mixed liquor volatile suspended solids. It is the concentration of volatile suspended solids in the aeration tank.

Question 27

What are the operational problems of activated sludge process?

OR

Explain in brief, various operation problems commonly encountered in activated sludge plants. *(CSVTU, Nov-Dec 2008)*

Ans. Following are the operational problems of activated sludge process.

1. **Sludge Bulking:** An excellent activated sludge when overloaded becomes sick and it results in the swelling of sewage in volume. This process is known as *bulking of sludge*. The sludge which does not settle well in sedimentation tank is called as bulking sludge. Bulking of sludge may be due to either

a) The growth of filamentous microorganisms which do not allow desirable compaction;
b) The production of non-filamentous highly hydrated biomass.
c) Aeration below the required degree
d) Presence of harmful industrial waste
e) Sudden change in the character of sewage
f) Unusual detention of the sludge in the clarifiers.

There are many reasons for sludge bulking. The presence of toxic substances in influent, lowering of temperature, insufficient aeration, and shock loading can also cause sludge bulking.

Remedial Measures of bulking of sludge:

1. Chlorination of sewage.
2. Prolonged Aeration
3. Raising of pH value of sewage to about 8 by adding lime.
4. Reaeration of returned activated sludge.
5. Reduction in suspended solids in the sewage.
6. Reduction in sewage flow to aeration tank for a short period.

2. **Rising of sludge:** Rising of sludge may be due to denitrification in the settling tank releasing nitrogen bubbles which buoys up the sludge. This problem is associated with
   a. High sludge age and
   b. Long solid retention time in the clarifier.

   When the sludge age exceeds 10 days and DO content is in excess of 2 mg /L a degree of conversion of ammonia to nitrate will occur. Because of longer retention time the endogenous metabolism of sludge exhausts the available oxygen and the bacteria reduce any nitrate present to the nitrogen gas. The resulting gas bubbles then buoys the sludge to the surface. Rising of sludge can be differentiated from bulking of sludge by noting the presence of small gas bubbles attached to the floating solids.

Remedial Measures of bulking of sludge:

1. By increasing the returned sludge age.
2. By increasing the speed of the sludge scrapper mechanism.
3. Decreasing the mean cell residence time by increasing sludge washing rate.
4. Decreasing the rate of flow of aeration liquor into the offending tank if sludge depth cannot be reduced by increasing return activated sludge withdrawal rate.

Question 28

Write short notes on modification of ASP. *(CSVTU, April-May 2012)*

Ans. **Extended Aeration Process**

It is the modification over the activated sludge process and it uses long aeration periods of 24-48 hrs. The process operates in the endogenous respiration zone which requires a relatively low organic loading and long aeration time. The process produces less sludge volume and digested sludge is relatively inoffensive in nature. The sludge produced is thus capable of being taken directly to the sludge drying beds.

The operation of the process is also simple due to the elimination of primary settling tank and separate sludge digestion. The operating cost of the process is however higher because of the long aeration time.

The process is extensively used for prefabricated package plants for small communities, institutions, schools etc. having low sewage flow.

Question 29

Design criteria for Activated Sludge Treatment process.

Ans. The major criteria that are usually assumed for the design of activated sludge plant are as follows:

(1) The number of aeration tanks
N = minimum 2 (for small plant)
= usually 4 (for large plants)

(2) Depth of wastewater in the tank.
= 4.5-7.5 m (for diffused aeration)
= 1.0-6.0 m (for surface aeration)
= 3-4.5 m (usually)

(3) Free board
= 0.3-0.6 m (for diffused aeration)
= 1.0-1.5 m (for surface and mechanical aeration)

(4) For Rectangular Aeration tank
L:B = 5:1 (for each channel for large plants)
B:D = 3:1 to 4:1 (depends on aeration system)

(5) Air Requirement
(i) 20-55m^3 of air/kg of BOD removed for diffused aeration when F/m $\geq$ 0.3
(ii) 70-115 m^3 of air/kg of BOD removed when F/m $\leq$0.3

(6) Power required for complete mixing
= 10-14 kW/1000m^3 of tank volume for surface aeration system.

3.7 Stabilization Ponds (Oxidation Ponds)

It is a shallow body of water contained in an earthen basin, open to sun and air. Longer time of retention from few days to weeks is provided in the pond. The purification of wastewater occurs due to symbiotic relationship of bacteria and algae. The ponds are classified according to the nature of the biological activity which takes place within the pond as aerobic, facultative and anaerobic. These are cheaper to construct and operate in warm climate as compared to conventional treatment system and hence they are considered as low cost wastewater treatment systems. However, they require higher land area as compared to conventional treatment system

Question 30

An average operating data for conventional activated sludge treatment plant is as follows: *(CSVTU, April-May 2008)*

(i) Waste water flow = 50,000 m^3/day
(ii) Volume of aeration tank = 15,000 m^3

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(iii) *Influent BOD* = 200mg/L
(iv) *Effluent BOD* = 25 mg/L
(v) *Mixed liquor suspended solids (MLSS) = 3000 mg/L.*
(vi) *Effluent suspended solids* = 40 mg/L
(vii) *Quantity of waste sludge* = 250 mg/L.

Based on information above determine.

i) Aeration period (hours)
ii) Food to Micro-organism Ratio (F/M Ratio) (kg BOD/day / kg MLSS)
iii) Percentage efficiency of BOD removal
iv) Sludge Age (days)

Sol:

(a) Aeration period: The Aeration period on Hydraulic Retention Time is given by the formula,

$$T = \frac{V}{Q} \times 24$$

Where, Q is in m^3/day

$$T = \frac{15500}{50{,}000} \times 24$$

$$T = 7.44 \text{ hrs.}$$

(b) F/M Ratio: F/M Ratio is expressed as,

$$\frac{F}{M} = \frac{Q \times Y_0}{V \times x_t}$$

Where,

$Q = 50{,}000\ m^3/day$
Y_0 = Influent BOD = 200 mg/L
V = Volume of Aeration tank
$V = 15500\ m^3$
$x_t = 3000$ mg/L

$$\therefore \quad \frac{F}{M} = \frac{50{,}000 \times 200 \times 10^{-3}}{15500 \times 3000 \times 10^{-3}}$$

$$= \frac{10{,}000}{46500} = 0.215 \text{ kg /BOD/ day/ kg of MLSS}$$

(c) Percentage efficiency of BOD removal:

$$\eta = \frac{BOD_i - BOD_{eff}}{BOD_i} \times 100$$

$$= \frac{200 - 25}{200} \times 100$$

$$= 87.5\%$$

(d) Sludge Age is calculated by using following formula:

$$\text{Sludge Age} = \frac{V \times x_t}{Q_w \times x_r + (Q - Q_w) \times x_e}$$

$$\text{Sludge Age} = \frac{15500 \times 3000}{(250 \times 12000) + (50000 - 250)40}$$

$$\text{Sludge Age} = 9.32 \text{ days}$$

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Question 31

Design an activated sludge unit treatment pitch following data for a population of 65000. *(CSVTU, April-May 2009)*

(i) Average sewage flow = 210 liters/capital day.
(ii) BOD of raw sewage = 210 mg/L.
(iii) Suspended solids in raw sewage = 300 mg/L.
(iv) BOD removal in primary treatment = 40%
(v) Overall BOD removal designed = 90%

Sol:

Daily Sewage flow $Q = 210 \times 65000$

$Q = 13650000$ L/day

$Q = 13650\ m^3$/day

Since 40% of BOD is removed in primary treatment

∴ BOD applied to the Aeration unit

$Y_0 = 60\% \times 210$ mg/L

$Y_0 = 126$ mg/L

Now as the overall BOD removal designed is 90%, therefore BOD left in effluent,

$= 10\% \times 210$ mg/L

$= 21$ mg/L

∴ BOD removed in activated sludge treatment process,

$= 126 - 21 = 105$ mg/L

∴ Efficiency required in Activated Plant,

$$= \frac{105}{126} = 83.33\%$$

Now for the efficiency 80 – 92% F/M ratio between 0.3 to 0.4 can be assumed and MLSS between 1500 – 3000 for conventional activated sludge treatment plant.

Assuming F/M = 0.35 and MLSS (x_t) = 2000 mg/L

i)
$$\frac{F}{M} = \frac{Q \cdot L_a}{V \cdot x_t}$$

$$0.35 = \frac{13650 \times 126}{V \times 2000}$$

V = Volume of Aeration tank

$\therefore \quad V = 2457\ m^3$

ii) Check for Aeration period or H.R.T

$$t = \frac{V}{Q} \times 24$$

$$= \frac{2457}{13650} \times 24$$

$$t = 4.32 \text{ hrs}$$

Since t is within the limits 4 – 6 hrs, hence O.K.

Check for S.R.T (θ_c)

$$V \cdot x_t = \frac{a_y \cdot Q(Y_0 - Y_E)\theta_c}{1 + k_e \cdot \theta_c}$$

Where, $V = 2457\ m^3$

x_t = 2000 mg/L

a_y = Yield coefficient = 1.0

Q = 13650 m^3/day

k_e = Endogenous Respiration rate constant

= 0.06d^{-1}

Y_0 = BOD of influent in Aeration tank

= 126 mg/L

Y_E = BOD of effluent = 21mg/L

$$\therefore \quad 2457 \times 2000 = \frac{1.0 \times 13650(126 - 21) \times \theta_c}{1 + 0.06 \times \theta_c}$$

$$1 + 0.06 \times \theta_c = \frac{1.0 \times 13650(105) \times \theta_c}{2457 \times 2000}$$

$$= \frac{1433250 \times \theta_c}{4914000}$$

$$1 + 0.06\,\theta_c = 0.291\,\theta_c$$

$$1 = 0.291\theta_c - 0.06\theta_c$$

$$1 = 0.231\,\theta_c$$

$$\theta_c = 4.32$$ O.K.

iii) Check for volumetric loading.

$$\text{Volumetric loading} = \frac{Q \cdot Y_0}{V} \text{ gm of BOD /m}^3 \text{ of tank volume}$$

$$= \frac{13650 \times 126}{2457}$$

$$= 700 \text{ gm/m}^3 = 0.7 \text{ kg/m}^3$$

Permissible within the range of 0.3 – 0.7 kg/m^3 ∴ O.K.

iv) Check for returned sludge ratio,

$$\frac{Q_R}{Q} = \frac{x_t}{\left[\frac{10^6}{SVI} - x_t\right]}$$

Where, SVI = 100 ml/gm assumed since this values should be within range of 50 – 150

x_t = 2000 mg/L

$$\therefore \quad \frac{Q_R}{Q} = \frac{2000}{\left[\frac{10^6}{100} - 2000\right]}$$

$$= 0.25 = 25\%$$

Within the prescribed range of 25 – 50% ∴ O.K.

But for the conservation purpose we will assume 33% returned sludge.

$$\therefore \quad 0.33 = \frac{200}{\left[\frac{10^6}{SVI} - 2000\right]}$$

$$\frac{10^6}{SVI} - 2000 = 6060.60$$

$$\frac{10^6}{SVI} = 8060.60$$

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∴ SVI = 124.060. Which is O.K

The sludge pumps for brining re-circulated sludge from secondary sedimentation tank will thus have a capacity,

= 33% × Q

= 33% × 13650

= 4504 m^3/day

Tank Dimensions: Adopting Aeration tank of depth 3 m and width 4.5 m. The total length of Aeration channel required.

$$L = \frac{\text{Total volume required}}{B \times D}$$

$$L = \frac{2457}{3 \times 4.5}$$

L = 182 m.

∴ Provide a continuous channel with 5 aeration chambers having length 36.4 m.

∴ The total width of the unit, including 2 baffles each of 0.25 m thickness

= 3 × 4.5 + 2 × 0.25

= 14 m.

Assuming a free board of 0.6 m

∴ Total Depth of the tank = 3 + 0.6 = 3.6 m.

Therefore,

Overall dimension of tank = 36.4 × 14 × 3.6 m

Rate of Air Supply Required

Assuming the air requirement of the aeration tank as 100 m^3 of air per kg of BOD removed.

$$\therefore \quad \text{Air required} = 100 \times \frac{105 \times 13650}{1000}$$

$$= 143325 \text{ m}^3\text{/day}$$

$$= \frac{143325}{24 \times 60}$$

$$= 99.53 \text{ m}^3\text{/minute}$$

Design of Secondary Sedimentation Tank

Assume a surface loading rate of 20 m^3/day /m^2 at average flow of

Q = 13650 m^3/day

We have,

Surface area required,

$$= \frac{13650}{20} = 682.5 \text{ m}^2$$

Adopting a solids loading of 125 kg/day /m^2 for MLSS of 2000 mg/L, we have, surface area required,

$$= \frac{13650 \times 2000}{1000} \times \frac{1}{125}$$

$$= 218.4 \text{ m}^2$$

The higher surface area of 315 m^2 is adopted.

Adopting a circular tank,

$$\therefore \quad \text{Diameter of tank} = \sqrt{\frac{315 \times 4}{\pi}} = 20.02 \text{ m}$$

Question 32

Design a conventional activated sludge plant to treat domestic sewage given the following data:
Population = 35,000
Average sewage flow = 180 lpcd
BOD removed in primary treatment = 30%
Overall BOD reduction desired = 85% *(CSVTU, April-May 2009)*

Sol. Daily sewage flow

$$= Q = 180 \times 35000 \ l/\text{day} = 6300 \text{m}^3/\text{day}$$

BOD of sewage coming to aeration

$$Y_0 = 70\% \times 220 \frac{\text{mg}}{l} = 154 \text{mg}/l$$

(∵ 30% BOD is removal in primary settling)

BOD left in effluent

$$Y_E = 15\% \times 220 \text{mg}/l = 33 \text{mg}/l$$

(∵ Overall 85% BOD removal is desired)

∴ BOD removed in activated plant

$$= 154 - 33 = 121 \text{mg}/l$$

∴ Efficiency required in activated plant

$$= \frac{121}{154} = 0.79$$

For efficiency of 85%-92%, we use F/M ratio as 0.4 to 0.3, and MLSS between 1500 to 3000.

So let us adopt F/M = 0.35

Similarly adopt MLSS(x_t) = 2000mg/l

Using equation

$$\frac{F}{M} = \frac{Q.Y_0}{V.x_t}$$

Where $\frac{F}{M} = 0.35$ (assumed)

$Q = 6300 \text{m}^3/\text{day}$

$Y_0 = 154 \text{mg}/l = 154 \text{gm}/\text{m}^3$

$x_t = 2000 \frac{\text{mg}}{l}$ (assumed)

$$\therefore \quad 0.35 = \frac{6300 \times 154}{V \times 2000}$$

V = volume of aeration tank

$$= \frac{6300 \times 154}{2000 \times 0.35} = 1386 \text{m}^3$$

(i) Check for aeration period or H.R.T.(t)

We have

$$t = \frac{V}{Q} \times 24\text{h} = \frac{1386}{6300} \times 24\text{th}$$

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= 5.28 (within the limit of 4 to 6 h) OK

(ii) Check for S. R. T. (θ_c)

We have

$$V.x_t = \frac{a_y.Q(Y_0 - Y_E)\theta_c}{1 + k_e\theta_c}$$

Where V = 1386 m^3

x_t = 2000mg/l(assumed)

a_y = yield coefficient = 1.0w. r. t MLSS

Q = 6300 m^3/d

k_e = Endogeneous respiration constant = 0.06d^{-1}

Y_0 = BOD of influent in aeration tank = 154mg/l

Y_E = BOD of effluent = 13mg/l

Substituting the values, we get

$$1386 \times 200 = \frac{0.5 \times 6300(154 - 33)\theta_c}{1 + 0.06 \times \theta_c}$$

$$\text{Or } 1 + 0.06\theta_c = \left(\frac{1.0 \times 6300 \times 121}{1386 \times 2000}\right)\theta_c = 0.275\theta_c$$

$$\text{Or } 1 + 0.06\theta_c = 0.275\theta_c$$

$$1 = (0.275 - 0.06)\theta_c$$

$$\text{Or } 1 = 0.215\theta_c$$

$$\theta_c = \frac{1}{0.215} = 4.65\text{days} = 5\text{day; OK}$$

(iii) Check for volumetric loading

We have

$$\text{Volumetric loading} = \frac{Q.Y_0}{V} \text{gm of BOD}/\text{m}^3\text{of tank vol.}$$

$$= \frac{6300 \times 154}{1386} \text{g m}/\text{m}^3 = 700\text{g m}/\text{m}^3 = 0.7\text{g m}/\text{m}^3\text{); OK}$$

(Within the permissible range of 0.3-07 gm/m^3); OK

(iv) Check for return sludge ratio (for SVI ranging between 50-150 ml gm; say 100 ml/gm).

We have

$$= \frac{Q_r}{Q} = \frac{x_t(\text{i. e. MLSS})}{\frac{10^6}{SVI} - x_t}$$

Where SVI = 100 ml/gm

$x_t = 2000 \text{m g}/l$

$$= \frac{2000}{\left[\frac{10^6}{100} - 2000\right]}$$

$= 0.25$

(i.e. within the permissible range of 25-50); OK

We will, for conservation purposes, however provide 33% return sludge giving SVI = 125, OK.

The sludge pumps for bringing recalculated sludge from the secondary sedimentation tank thus have a capacity = 33% × 6300 m^3/d = 2100 m^3/d

Tank dimensions. Adopt aeration tank of depth 3m and width 4.5 m. The total length of the aeration channel required

$$= \frac{\text{Total volume required}}{B \times D} = \frac{1386}{4.5 \times 3} m$$

Provide a continuous channel, channel, width 3 aeration chambers, each of 35 m length.

Total width of the unit, including 2baffles each of 0.25 m thickness = 3 × 4.5m + 2 × 0.25 = 14m.

Total depth provided including free board of 0.6 m will be 3+06 = 3.6m.

Overall dimensions of the aeration tank will be 35m × 14m × 3.6.

Question 33

Explain in brief principle of working of aerobic, anaerobic and facultative type of stabilization pond. *(CSVTU, Nov-Dec 2010) (CSVTU, April-May 2009)*

Ans.

1. **Aerobic Ponds:** In aerobic pond, the microbial population similar to ASP exists along with algae.

   The aerobic population release CO_2, which is taken up by the algae for their growth. Algae in turn release O_2, which helps in maintaining the aerobic condition in the pond. Very shallow depth of aerobic pond (0.15 to 0.45 m) is used for the treatment of wastewater for removal of nitrogen by algae growth. For general wastewater treatment depth of 0.5 to 1.2 m may be used.

   The solar radiation should penetrate to the entire depth of the pond to support photosynthesis to keep entire pond content aerobic. When shallow ponds (0.5 m deep) are used for tertiary treatment of wastewater, they are very lightly loaded and such ponds are called as *maturation pond*. These maturation ponds may release oxygen in atmosphere during day time.

2. **Facultative stabilization Ponds (Fig. 3.6):**

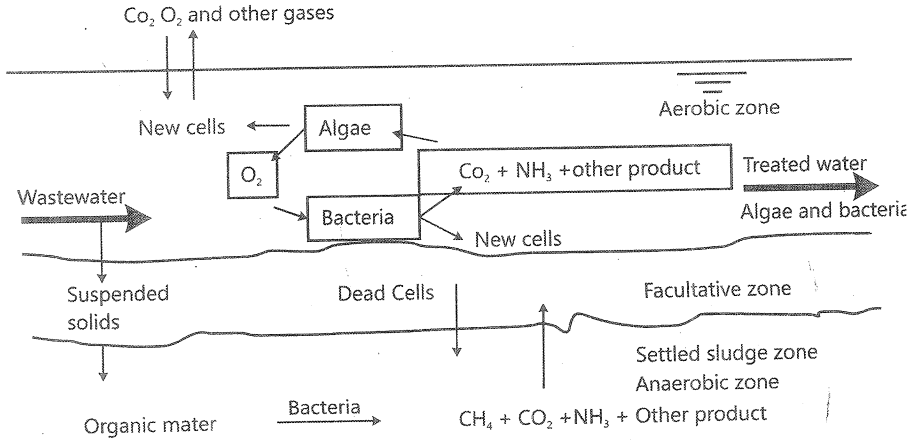


Fig. 3.6

Most of the ponds exist in facultative nature. Three zones exist in this type of ponds. The top zone is an aerobic zone in which the algal photosynthesis and aerobic

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biodegradation takes place. In the bottom zone, the organic matter present in wastewater and cells generated in aerobic zone settle down and undergo anaerobic decomposition. The intermediate zone is partly aerobic and partly anaerobic. The decomposition of organic waste in this zone is carried out by facultative bacteria. The nuisance associate with the anaerobic reaction is eliminated due to the presence of top aerobic zone. Maintenance of an aerobic condition at top layer is important for proper functioning of facultative stabilization pond, and it depends on solar radiation, wastewater characteristics, BOD loading and temperature. Performance of these ponds is comparable with conventional wastewater treatment.

3. **Anaerobic pond:** In anaerobic pond, the entire depth is under anaerobic condition except an extremely shallow top layer. Normally these ponds are used in series followed by facultative or aerobic pond for complete treatment. The depth of these ponds is in the range of 2.5 to 6 m. They are generally used for the treatment of high strength industrial wastewaters and sometimes for municipal wastewater and sludges. Depending upon the strength of the wastewater, longer retention time up to 50 days is maintained in the anaerobic ponds. Anaerobic lagoons are covered these days by polyethylene sheet for biogas recovery and eliminating smell problem and green house gas emission in atmosphere.

Question 34

What are the advantages and disadvantages of oxidation pond?

Ans. Following are the advantages of oxidation pond.

1. Lower initial cost than required for mechanical plant.
2. Lower operating costs.
3. Treatment system is not significantly influenced by a leaky sewage system bringing storm water along with sewage.
4. Regulation of effluent discharge possible thus providing control of pollution during critical times of the year.

Following are the disadvantages of oxidation pond.

1. It requires extensive land area.
2. Assimilative capacity of certain industrial waste is poor.
3. There are potential odor problem.
4. If used in urban areas expansions of towns and new developments may encroach on the lagoon site.
5. Effluent quality standards of 30 mg/L for suspended solids are not meet.

3.8 Oxidation Ditch

Question 35

Write short notes on oxidation ditch. *(CSVTU, April-May 2012)*
(CSVTU Nov-Dec 2010) (CSVTU, Nov-Dec 2011)(CSVTU, April-May 2010)

Ans. **Oxidation Ditch:** This is a type of extended aeration activated sludge process. It consists of an endless ditch for the aeration tank and a rotor for the aeration mechanism and a long continuous channel usually oval in the plan. The influent from the screen is directly taken to the oxidation ditch where the sewage is aerated by a surface rotor

placed across the channel. In addition to the aeration the rotor also imparts a velocity of 0.3 to 0.4 m.p.s to the mixed liquor, preventing the settling of biological sludge. The rotor has the standard oxygen transfer capacity of 2.8 kg O_2/m length per hour at 16 cm depth of immersion. The rotors impart adequate circulation for 120-150 m^3 of ditch volume per meter length of rotor. The return sludge and raw sewage are discharged into the ditch upstream of rotors. The outlet of the ditch is located opposite to the inlet. Baffles are provided in the outlet weir so that the ditch water does not rise excessively and overload the rotors at peak flow period. The operation of the oxidation ditches may be intermittent or continuous type. In intermittent operation it works as settling tank. Intermittent operations are

1. Closing inlet and aerating sewage
2. Stopping the rotor and letting the contents settle
3. Letting in the fresh sewage which displaces an equal quantity of clarified effluent.

The removal of the sludge is done from the mixed liquor at the bottom of the ditch. Generally, the continuous operation is adopted in which the oxidation ditch is followed by a secondary settling tank.

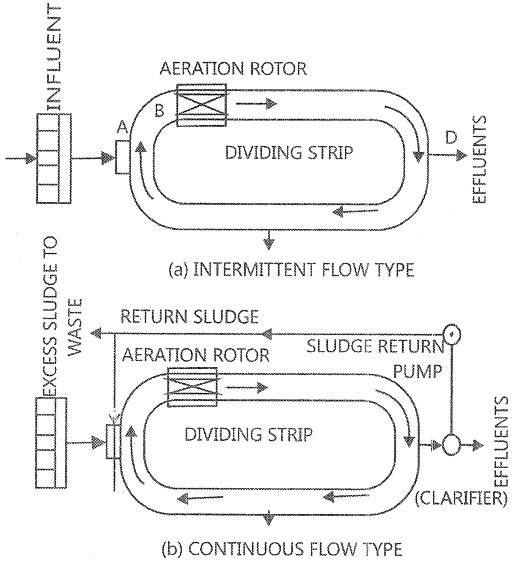


Fig. 2.11 Oxidation Ditches

Question 36

Explain the merits and demerits of oxidation Ditch.

Ans. Following are the merits and demerits of oxidation ditch.

1. **Merits of oxidation ditch.**

Following are the advantages of oxidation ditch.

1) It can be easily maintained.
2) It is hard to be effected by load fluctuations and forms only a little sludge.
3) Oxidation ditch can be easily controlled by changing the rotation of the rotor and the dipping depth.

4) It requires relatively little energy as the rotor is operated efficiency.
5) It can perform nitrification and denitrification easily.

Following are the demerits of the oxidation ditch.

1) As the tank is large and the depth is small, it requires a large area. It can be said the Oxidation Ditch method is particularly suitable for small scale equipment.

3.9 Contact Bed

Question 37

What do you understand by contact bed? What are the operations of contact bed? Draw a neat sketch of contact bed. *(CSVTU, April-May 2011)*

Ans. **Contact Bed:** These are also known as contact filters and sewage effluent is kept in contact with the filtering media for some period. As sewage effluent passes through the filtering media an organic film is produced around the particles of filtering media. A large number of aerobic bacteria present in this film carry out the oxidation of organic matter. In second contact period, i.e. when bed is standing empty, the filters obtain oxygen from the atmosphere and the organic matter caught in the voids of the filtering media gets oxidized.

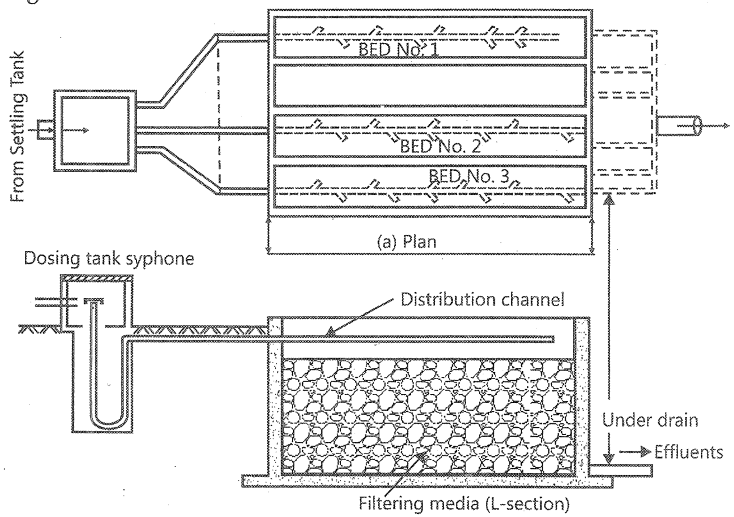


Fig. 3.7 Contact BED

Operation of contact bed is usually carried out in the four stages.

1. The tank is filled with the sewage effluent which may take about two hours.
2. The sewage effluent is allowed to stand on the filtering media for a period of two hours.
3. The tank is then emptied and the sewage effluent is allowed to flow through the effluent pipe without disturbing the organic film of the bed. This may require about two hours.
4. The contact bed is then allowed to stand empty for a period of six hours.

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Question 38

Explain the advantages and disadvantages of Contact bed.

Ans Following are the advantages of contact bed.

1. It is possible to operate contact bed without exposing the sewage effluent to view.
2. The contact bed consumes relatively small head.
3. There is no nuisance of filter flies.
4. The undesirable odor is also less as compared to that in case of trickling filter.

Following are the disadvantages of contact bed.

1. The cost of contact bed is more as compared to that of trickling filter.
2. The operation of contact bed requires skilled supervision.
3. It requires long rest period.
4. The treatment of sewage is very low.
5. For efficient working of contact beds, the primary treatment of sewage effluent is essential otherwise the bed would be easily clogged.

Question 39

Explain the following terms:

(i) Autotrophs

(ii) Heterotrophs

(iii) Phototrophs

(iv) Facultative hetrerotrophs *(CSVTU, Nov-Dec 2010)*

Ans.

(i) **Autotrophs:** These organisms can independently of external source of organic matter and they are capable of synthesizing their organic requirements from inorganic sources. They derive their carbon from carbon dioxide.

(ii) **Heterotrophs:** These organisms require an external source of organic matter for their growth and thus they obtain their energy from the breakdown of complex organic substances. They derive their cell carbon from organic carbon.

(iii) **Phototrophs:** A Phototroph is an organism that is capable of oxidizing its organic matter by using light energy.

(iv) **Chemotrophs:** A Chemotroph is an organism that is capable of oxidizing its organic matter by using chemical energy.

(v) **Facultative Hetrotrophs:** These are the organisms derive their energy in from the breakdown of organic matter both in presence of oxygen and absence of oxygen.

3.10 Tertiary Treatment of Water

Question 40

Write a detailed short note on tertiary treatment of water. *(CSVTU, April-May 2012)*

Ans. Tertiary treatment involves the removal of non-biodegradable organic pollutant and a significant percentage of nutrients like nitrogen and phosphorus. Tertiary effluent can be described as no foul odor and coliform bacterial count is less than 2.2 per millimeter and can be used safely for most purposes.

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Sometimes primary and secondary waste water treatment are not found to be adequate for the waste water from the industry containing specific pollutant which can be achieved by tertiary treatment of waste water.

Tertiary treatment is generally provided when it is found that,

1. The quality of conventionally treated waste water (Secondary Effluent) is unsuitable for final disposal requirement in to the body of water or on the land.
2. The concentration of residual organic materials or suspended solid require further reduction or complete removal for specific reuse or recycling of waste water after secondary treatment.
3. The concentration of residual nutrient phosphorus and nitrogen is high for final disposal or reuse and recycling of waste water.

The different techniques available for the tertiary treatment are given in table.

S.No	*Techniques*	*For complete removal or further reduction of*
1	Granular media filtration , Ultra filtration	Residual suspended solids
2	Biological Nitrification denitrification, Ion exchange and Air stripping	Removal of Nitrogen, Chlorine and Dissolved Gases.
3	Biological and Chemical Process	Residual nitrogen and Phosphorus
5	Ion Exchange, Reverse Osmosis, Electro dialysis, Chemical Precipitation, Adsorption	Residual dissolved inorganic solids, toxic and complex organic compounds.

Question 41

Write a short note on tertiary waste water treatment. *(CSVTU, April-May 2012)*

Ans. Tertiary treatment is the next wastewater treatment process after secondary treatment. This step removes stubborn contaminants that secondary treatment was not able to clean up. Nutrients such as phosphorus, nitrogen and most BOD and suspended solids are removed using this process. Wastewater effluent becomes even cleaner in this treatment process through the use of stronger and more advanced treatment systems like

1. Rapid Gravity Filters
2. Deep Bed Filters

Alternatively, the treatment process consists of flocculation basins, clarifiers, filters. Lagoons and chorine basins or ozone or ultraviolet treatment processes.

CSVTU, APRIL-MAY 2013

Part – A

(a) Which of the following STPs has inherent problem of fly nuisance, odor and ponding? 2

(i) UASB

(ii) ASP

(iii) Trickling Filters
(iv) Oxidation Ditch

Ans. Trickling Filters

Part – B

(b) Explain the conventional activated sludge process. 7

Ans. **Refer Question 22 Unit - 3**

(c) A single stage filter is designed for an organic loading of 10000 kg of BOD in raw sewage per hectare meter per day with a recirculation ratio of 1.2. This filter treats a flow of 4 MLD of raw sewage with a BOD of 220 mg/L. Using NRC formula determine the strength of the effluent. 7

Ans. **Refer Question 15 Unit - 3**

(d) Define with respect to biological waste water treatment:- 7

(i) MLSS
(ii) MLVSS
(iii) F/M Ratio
(iv) SVI

Ans. **Refer Question 26 Unit - 3**

CSVTU, Nov-Dec 2012

(a) Define SVI. 2

Ans. **Refer Question 26 Unit - 3**

(b) Why there is need to adopt effluent standards for waste water disposal in surface water bodies? Why these standards differ for disposal into a public sewage? What are stream standard? 7

Ans. **Refer Question 24 Unit - 4**

(c) Explain the type – II setting adopted for the design of primary setting tank. Describe the setting column test to determine the relevant data for the design of the PSP. 7

Ans. **Refer Question 56 & 58 Unit - 2**

(d) Discuss various standards applicable to wastewater treatment in brief. What are the general logic behind these standards? 7

Ans. **Refer Question 24 Unit - 4**

CSVTU, April-May 2012

Part – A

(a) Which of the following is NOT a unit physical unit operation: 2

(v) Equalization
(vi) Mixing
(vii) Adsorption
(viii) Screening

Ans. Refer Question 5 Unit - 3

Part – B

(b) Draw the flow diagram of an STP for a developed city. Explain the components. 7

Ans. **Refer Question 39 Unit - 2**

(c) Write a detailed note on tertiary waste water treatment. 7

Ans. **Refer Question 41 Unit - 3**

(d) Write short notes on: 7

(i) Disposal of Screenings.
(ii) Comminutors (Sketch essential)

Ans. **Refer Question 44 & 47 Unit - 2**

CSVTU, Nov-Dec 2011

(a) A single stage filter is designed for an organic loading of 10, 000 kg of BOD in raw sewage per hectare meter/day with a recirculation ratio of 1:2. This filter treats a flow of 4 mld of raw sewage with a BOD of 220 mg/l. Use NRC formula, determine the strength effluent. 7

Ans. **Refer Question 15 Unit - 3**

(b) Define: 7

i. SVI
ii. F/M ratio
iii. MLSS
iv. ML VSS

Ans. **Refer Question 23 Unit - 3**

(c) Explain briefly the flow chart of sludge treatment & disposal. 7

Ans. **Refer Question 1 Unit - 4**

CSVTU, April-May 2011

(a) What do you understand by term recirculation? 2

Ans. **Refer Question 8 Unit - 3**

(b) What do you understand by contact bed? What are the operations of contact bed? Draw a neat sketch of contact bed. 7

Ans. **Refer Question 37 Unit - 3**

(c) Describe with sketches the treatment of sewage by activated sludge process. Mention the advantage and disadvantages of this system. 7

Ans. **Refer Question 22 Unit - 3**

(d) Determine the size of high rate trickling filter for following data: 7

Flow = 4.5 MLD
Recirculation ratio = 1.4
BOD of raw sewage = 250 mg/l.

Ans. **Refer Question 18 Unit - 3**

CSVTU, Nov-Dec 2010

(a) What do you mean by high rate tricking filters? 2

Ans. **Refer Question 7 Unit - 3**

(b) What is the basic principle behind the working of the secondary treatment systems? What do you understand by attached growth process and suspended growth process? Explain giving two examples. 7

Ans. **Refer Question 1Unit - 3**

(c) Example the following terms: 7

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(v) Autotrophs
(vi) Heterotrophs
(vii) Phototrophs
(viii) Facultative heterotrophs
(ix) Ans. **Refer Question 39 Unit - 3**

(d) *It is proposed to install a two stage trickling filter for treatment of 4.0 mld of raw wastewater having the influent BOD of 180 mg/l Assuming that the primary treatment removes 30% of the BOD, the filter loading rate is 1000 gm/m³ of BOD, the recirculation ratio is 1.2 for each filter, and if two filters are provided to equally share the load, determine the BOD of the effluent.*

Ans. **Refer Question 17 Unit - 3**

CSVTU, APRIL-MAY 2010

(a) *What do you understand by suspended growth process and attached growth process? Explain the principle of treatment in treatment units belonging to these processes.* 7

Ans. **Refer Question 1 Unit - 3**

(b) *A single stage filter is designed for an organic loading of 12000 kg of BOD in raw sewage per hectare meter per day with a recirculation ratio of 1.5. This filter treats a flow of 5 MLD of raw sewage with a BOD of 200 mg/L. Using NRC formula, determine the strength of the effluent.* 7

Ans. **Refer Question 16 Unit - 3**

(c) *Write notes on the following:* 7

(i) Activated Sludge Process — **Refer Question 22 Unit - 3**
(ii) Oxidation ditch — **Refer Question 35 Unit - 3**
(iii) Facultative Lagoon — **Refer Question 33 Unit - 3**

CSVTU, NOV-DEC 2009

(a) *What is re-circulation ratio?* 2

Ans. **Refer Question 10 Unit - 3**

(b) *What do you understand by suspended growth process and attached growth process? Explain the principle of treatment in treatment units belonging to these processes.* 7

Ans. **Refer Question 1 Unit - 3**

(c) *A single stage filter is designed for an organic loading of 12000 kg of BOD in raw sewage per hectare meter per day with a recirculation ratio of 1.5. This filter treats a flow of 5 MLD of raw sewage with a BOD of 200 mg/L. Using NRC model, determine the strength of the effluent.* 7

Ans. **Refer Question 16 Unit - 3**

(d) *Explain the arrangement and working principle of a trickling filter. Draw the single stage and two stage recirculation systems.* 7

Ans. **Refer Question 2 Unit - 3**

CSVTU, APRIL-MAY 2009

(a) *Define "Sludge Age".* 2

Ans. **Refer Question 24 Unit - 3**

(b) *Distinguish between standard rate and high rate trickling filter.* 7

Ans. **Refer Question 13 Unit - 3**

(c) *Explain in brief principle of working of aerobic, anaerobic and facultative type of stabilization pond.* 7

Ans. **Refer Question 33 Unit - 3**

(d) *Design the activated sludge unit treatment with following data for a town of population of 65,000.* 7

(i) Average sewage flow = 210 litres/capita/day
(ii) BOD of raw sewage = 210 mg/l
(iii) Suspended solid in raw sewage = 300 mg/l
(iv) BOD removal in primary treatment = 40%
(v) Over all BOD removed desired = 90%

Ans. **Refer Question 33, 31 Unit - 3**

CSVTU, NOV-DEC 2008

(a) *Define activated sludge process.* 2

Ans. **Refer Question 22 Unit - 3**

(b) *Explain in brief, various operation problem commonly encountered in activated sludge plants.* 7

Ans. **Refer Question 27 Unit - 3**

(c) *An average operating data for conventional activated sludge treatment plant is as follow:* 7

(i) Waste water flow = 50,000 m³/day
(ii) Volume of aeration tank = 15,000 m³
(iii) Influent BOD = 200 mg/l
(iv) Effluent BOD = 25 mg/l
(v) Mixed liquor suspended solid (MLSS) = 3,000 mg/l
(vi) Effluent suspended solid = 40 mg/l
(vii) Quantity of waste sludge = 250 mg/l

Based on information above determine:

(A) Aeration period (hours)
(B) Food to microorganism ratio (F/M) (kg BOD per day/kg MLSS)
(C) Percentage efficiency of BOD removal
(D) Sludge Age (days)

Ans. **Refer Question 30 Unit - 3**

(d) *Determine the size of high rate tricking filter for following data:* 7

(i) Sewage flow = 5 MLD
(ii) Recirculation ratio = 1.5
(iii) BOD of raw sewage = 230 mg/l
(iv) BOD removal in primary clarifier = 30%
(v) Final effluent BOD desired = 25 mg/l

Ans. **Refer Question 19 Unit - 3**

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Unit - 4

Sewage Sludge Treatment
Sewage Disposal

4.1 Introduction

There are two end products obtained from various waste water treatment plants.

1. Effluent and
2. Sludge

The treated effluent is directly discharged either in receiving waters or in land. However, the sludge is to be processed first before their final disposal. Objectives of processing sludge are to extract water from the solids and dispose the dewatered residue through a combination of physical chemical and biological operations.

Question 1

What is sewage sludge? *(CSVTU, April-May 2011) (CSVTU, April-May 2010)*

Ans. The suspended solids which are accumulated at the bottom of the clarifier or settling tank from the flowing waste water is known as sewage sludge.

4.2 Sludge Treatment

Question 2

Explain the process of sludge treatment in brief.

Ans. Sludge treatment may include all or a combination of the following unit operations and processes:

1. **Thickening:** The purpose of thickening is to reduce moisture of the sludge, and consequently to increase the solids concentration. This practice is adopted for the separation of greater amount of water from the sludge solids than can be attained in tanks. Three types of thickening commonly practiced are (i) Gravity thickening (ii) air floatation (iii) centrifugation.
2. **Digestion:** The principal objective of sludge digestion is to subject the organic matter present in the settled sludge to anaerobic or aerobic decomposition so as to make it innocuous and amenable to dewatering on sand beds or mechanical filters before final disposal.
3. **Conditioning:** Conditioning improves the drainability of digested sludge. Prior conditioning of sludge before application of dewatering methods renders it more amenable to dewatering. Conditioning can be achieved by various methods such as elutriation, chemical conditioning, heat treatment, freezing etc.
4. **Dewatering:** The purpose of dewatering is to further reduce the volume of sludge and thereby increase the solids concentration. Most of the digested primary or mixed sludge can be compacted to a water content of about 90% in the digestor itself by gravity. However, further dewatering is accomplished either by air drying on sand drying beds, or by mechanical means such as vacuum filtration, centrifugation, pressure filtration etc.

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5. **Heat Drying:** The purpose of heat drying is to reduce further the moisture content and volume of dewatering sludge, so that it can be used after drying without causing offensive odors or risk to public health. Several methods such as sludge drying under controlled heat, flash drying, rotary kiln, multiple-hearth furnace etc have been used in combination with incineration devices. Drying is brought about by directing a stream of heated air or other gases at about 350°C. The hot gases, dust and ash released during combustion are to be removed by suitable control mechanisms to minimize air pollution. The dried sludge removed from the kilns is granular and clinker-like which may be pulverized before use as soil conditioner.
6. **Incineration:** Incineration involves the combustion of the sludge in a reactor under high temperature, along with auxiliary fuels, if needed. The purpose of incineration is to destroy the organic material, the residual ash being generally useful as land fill. During the process, all the gases released from the sludge are burnt off and all the organisms are destroyed. Dewatered or digested sludge is subjected to temperature between 65°C to 75°C. Cyclone or multiple hearth and flash type furnaces are used with proper hearth and flash type furnaces are used with proper heating arrangements with temperature control and drying mechanisms.
7. **Sludge disposal:** The ultimate disposal of dewatered sludge or the ash (after incineration) may be on to the land or into the sea.

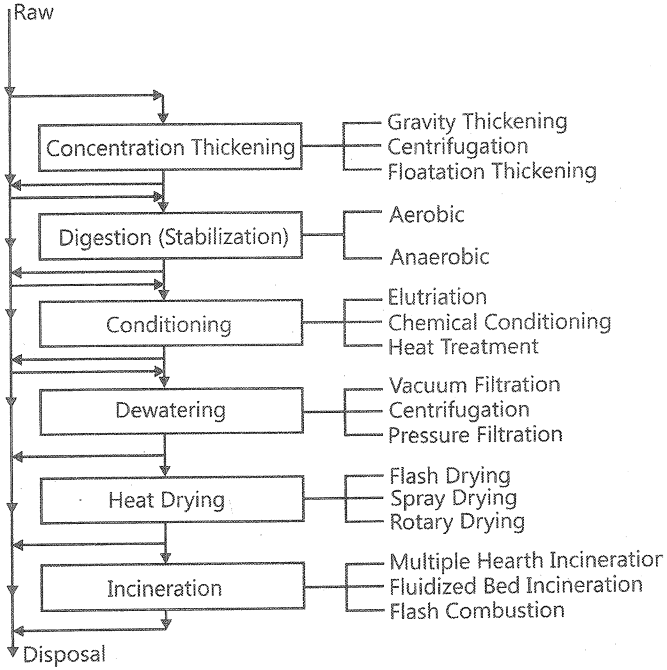


Fig. 4.1 Flow Chart for Sludge Treatment & Disposal

4.3 Amount and Characteristics of Sludge

Question 3

Write a short note on characteristics of sludge.

Ans. Sewage sludge consists of organic and inorganic solids present in the raw sewage and removed in the primary clarifier plus organic solids generated in secondary treatment and removed in secondary clarifier. The quantity and nature of sludge generated relates to character of the raw wastewater and processing units employed. The inorganic fraction of sludge has specific gravity of about 2.5 while organic matter has a specific gravity of 1.01 to 1.06 depending upon its source.

The characteristics of sludge are determined by various tests for the determination of specific gravity, moisture content, volatile and fixed solids, color, odor etc. The moisture content of sludge is usually determined indirectly by evaporating a given weight of sludge on the water bath and drying the residue to constant weight in an oven at a temperature of about 110°C. The weight of residue gives the percentage of dry solids by weight and the difference in weights is the measure of moisture content. When the dry sludge obtained above, is ignited, an ash-like residue is obtained which is also *fixed residue*, while the loss of weight on ignition represents the organic content (or volatile matter) of the dry solids.

The amount and characteristics of sludge produced in various treatment processes are briefly as follows.

1. **Sludge from primary settling tanks:** Primary sludge is grey-colored, greasy, odorous slurry of settleable solids accounting for about 50-60% of the SS applied, and tank skimmings. It contains fecal matter, vegetable parings and fine silt. The sludge is sticky and does not drain easily. Primary precipitates can be dewatered readily after chemical conditioning because of fibrous and coarse nature. Typical solids concentrations in raw primary sludge are 6-8% and the portion of volatile solids varies from 60 to 80%.
2. **Chemical precipitation (primary treatment):** It resembles in its general properties with the above except that the odor is less pronounced. It includes precipitated chemicals and entangled solids in more or less stoichiometric amount. It takes its colour from the coagulating chemicals used in the process and is slightly heavier also.
3. **Trickling filter humus:** This is dark brown in colour, flocculent and relatively less offensive when fresh. However, during unloading period of filters that are operated at low rates, humus will contain many dead worms and its odour becomes quite offensive. The suspended particles are fragments of biological growth washed from the filter media. Although they exhibit good settleability, the precipitate does not compact to a high density. For this reason, and the fact that sloughing is irregular, underflow from the final clarifier containing filter humus is returned to the wet well for mixing with the inflowing raw wastewater. Thus humus is settled with raw organics in the primary clarifier. The combined sludge has a solids content of 4-6% which is slightly thinner than residue with raw organics only.
4. **Activated sludge:** It is golden-brown, flocculent suspension of activate microbial masses, inoffensive when fresh, but turns septic because of its biological activity. It

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contains the largest percentage of moisture (about 98-99%) and is the most voluminous amongst the sludge. Waste activated sludge can be thickened effectively by floatation or centrifugation, though chemical addition may be needed to ensure high solids capture in the concentrating process. Thickness of return activated sludge is 0.5-2% suspended solids with a volatile fraction of 0.7-0.8.

4.4 Sludge Digestion

Question 4

What do you understand by digestion of sludge?

(CSVTU, Nov –Dec 2008) (CSVTU, April-May 2009)

Ans. This is the process of decomposing the organic matter of sewage sludge anaerobically under the condition of adequate operational control.

Sludge digestion is a biological process in which organic solids are decomposed into stable substances. Digestion reduces the total mass of solids, destroys pathogens, and makes it easier to dewater or dry the sludge. Digested sludge is inoffensive, having the appearance and characteristics of a rich potting soil.

Question 5

State the objects of sludge digestion.

Ans. Following are the various reasons or purposes for which the sludge is to be digested.

i) The digested sludge is of better quality and can therefore be conveniently handled and treated easily.

ii) The digestion destroys the pathogenic bacteria.

iii) The digestion gives fertilizer and other valuable by products which without digestion would have gone to waste.

iv) The digestion results in the recovery of combustible gases which may be used as fuel or power.

v) The volume of sludge is reduced and hence it becomes easier to dispose it off.

Question 6

Explain the procedure for the Sludge Digestion.

Ans. This is the process of decomposing the organic matter of sewage sludge anaerobically under the condition of adequate operational control. The sludge is broken up into the three different forms.

1. *Digested sludge* which is stable humus like solid matter with reduced moisture content.
2. *Supernatant liquor* which includes liquefied and finely divided solid matter.
3. *Gases of decomposition*-Methane, CO_2 and Nitrogen etc.

Digested sludge is dewatered, dried up and used as manure while gases produced are used as fuel or for driving gas engines. The supernatant liquor is retreated at the treatment plant along with the raw sewage.

The tank in which sludge digestion is carried out are called *sludge digestion tanks.*

Three stages are known to occur in the biological action involved in the process of sludge digestion as:

1. Acidification or period of intensive acid production.
2. Liquification or a period of Acid digestion
3. Gasification or a period of intensive digestion and stabilization.

Question 7

Explain the important factors which affect the process of sludge digestion.

(CSVTU, Nov-Dec 2011) (CSVTU, April-May 2009)

Or

Discuss the effect of pH and temperature on sludge digestion. (CSVTU, April-May 2011)

Ans. In order to have an adequate control over the process of sludge digestion, it is important to maintain a few optimum conditions in operation of these tanks.

These are

(a) Maintenance of temperature most favorable for developing and digesting organisms of sludge.

(b) Maintenance of the alkaline range of pH of the sludge.

(c) Seeding of the digested sludge with the raw sludge through proper mixing, dosing and withdrawal of sludge.

(d) Mixing

Following are the factors affecting sludge digestion.

1. **Effect of temperature on the sludge digestion.**

The anaerobic decomposition of organic solids in the sewage is greatly influenced by temperature at which it takes place.

There are two distinct temperature zones in the sludge digestion.

(a) Zone of thermophilic digestion: In the zone of thermophilic digestion, the heat loving or thermophilic organisms are more active and it ranges from 35°C to 60°C. The optimum temperature in this zone is about 54°C and at this temperature the digestion period can be brought down about 7 -10 days only.

(b) Zone of mesophilic digestion: In the zone of mesophilic digestion, the common or mesophilic organisms are more active and its range is 26°C to 35°C. . The optimum temperature in this zone is about 29°C and at this temperature the digestion period can be brought down about 30 days only.

2. **Effect of pH value on sludge digestion**: The desired pH range for the efficient digestion of sludge is 6.8 to 7.2 and to maintain the pH value within this range following remedies are applied:
   1. Addition of lime.
   2. Introducing the required quantity of raw sludge
   3. Controlling the removal of digested sludge.
3. **Sludge seeding:** The process of adding fresh sludge into previously digested sludge is known as sludge seeding and it should be done in such a way that alkaline condition may prevail in the tank. For this purpose, the raw sludge is added to the partly digested and some fully digested sludge. Raw sludge is usually added about 2.5 to 3.5 % by weight of fresh dry solids. The proper seeding of the sludge develops favorable

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conditions for micro organisms and the digestion of the sludge takes place in a short period.

4. **Mixing:** The incoming fresh raw sludge should be thoroughly mixed with digested sludge by some effective method of mechanical agitation. The proper mixing results in the even distribution of the incoming sludge, maintenance of uniform temperature in the tank reduction of scum and increase in production of gas.

Question 8

State and explain the various stages in sludge digestion process. *(CSVTU, April-May 2010)*

Ans. The following three stages are known to occur in the biological action involved in the process of sludge digestion:

1. Acidification or a period of intensive acid production.
2. Liquification or period of acid digestion.
3. Gasification or the period of intensive digestion and stabilization.

(1) **Acidification –** As the fresh sewage-sludge begins to decompose, an aerobic bacteria attacks easily on the available food substances as carbohydrates and soluble nitrogenous compounds.

Intensive acids are produced which lowers pH value to less than 6. Highly putrefactive odors evolved.

(2) **Liquification -** In this stage, organic acid and nitrogenous compounds of the first stage are liquefied i.e. transformed from large solid particles to either a soluble or finely dissolved form.

The pH value rises a little high to about 6.8, odor is extremely offensive and decomposing sludge entraps gases of decomposition, becomes forming and rises to the surface to from scum. This stage is known to last much longer than the proceeding stage of acidification. Hence it is also termed as acid regression.

(3) **Gasification -** In this stage, due to breaking of more resistance materials like proteins and organic acids, large volume of methane gas of high calorific value, along with comparatively smaller volume of CO are evolved. The H value goes to alkaline range above 7 and tarry odor appears.

Finally, gasification becomes very slow; sludge becomes well adjusted and is stable enough for disposal. This stage is also termed as *alkaline termination*.

Question 9

Explain the aerobic digestion of sludge.

Ans. **Aerobic digestion**

Aerobic digestion stabilizes waste sludge by long term aeration, thereby reducing BOD and destroying volatile solids. Aerobic digestion is generally defined as the process in which micro-organisms obtain energy by endogenous or auto-oxidation of their cellular protoplasm. The biologically degradable constituents of the cellular material are slowly oxidized to carbon dioxide, water and ammonia. Aerobic digestion produces volatile solids reduction, comparable to those in anaerobic digestion. It has low BOD in the supernants, fewer operational problems and lower initial cost. Aerobic digestion is accomplished in one or more tank mixed by diffused aeration.

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Advantages of aerobic digestion:

1. Lower BOD concentration in digestion supernatant.
2. Production of basic fertilizers value in the digested sludge.
3. Low capital cost.
4. Fewer operational problems.
5. Odorless and easily de-waterable, biologically stable digested sludge.

Disadvantages of aerobic digestion:

1. Higher power costs generate higher operating costs comparable with anaerobic digestion.
2. Gravity thickening processes following aerobic digestion tend to generate high solid concentration in the supernatants.
3. Some aerobically digested sludge's do not dewater easily in vacuum filtration.
4. No methane gas is produced for recovery as a by -product.
5. The aerobic digestion process appears to be particularly well suited for industrial sludge treatment and for small municipal activated sludge plants.

Question 10

Discuss the anaerobic digestion of the sludge. *(CSVTU, Nov-Dec 2010)*

Ans. **Anaerobic digestion**

Sludge digestion involves the treatment of highly concentrated organic wastes in the absence of oxygen by anaerobic bacteria. The anaerobic treatment of organic wastes resulting in the production of carbon dioxide and methane, involves two distinct stages.

In the first stage, referred to as "*acid fermentation*", complex waste components, including fats, proteins, and polysaccharides are first hydrolyzed by a heterogeneous group of facultative and anaerobic bacteria. These bacteria then subject the products of hydrolysis to fermentation, oxidation, and other metabolic processes leading to the formation of simple organic compounds, mainly short-chain (volatile) acids and alcohols.

However, in the second stage, referred to as "*methane fermentation*", the end products of the first stage are converted to gases (mainly methane and carbon dioxide) by several different species of strictly anaerobic bacteria.

The bacteria responsible for acid fermentation are relatively tolerant to changes in pH and temperature and have a much higher rate of growth than the bacteria responsible for methane fermentation. If the pH drops below 6.0, methane formation essentially ceases, and more acid accumulates, thus bringing the digestion process to a standstill. As a result, methane fermentation is generally assumed to be the rate limiting step in anaerobic wastewater treatment. The methane bacteria are highly active in mesophilic (27-43°C) with digestion period of four weeks and thermophilic range (35-40°C) with digestion period of 15-18 days. But thermophilic range is not practiced because of odor and operational difficulties.

Question 11

Differentiate between aerobic and anaerobic digestion. *(CSVTU, April-May 2010)*

Ans.

No.	Aerobic Digestion	Anaerobic Digestion
1.	Higher power costs generate higher operating costs comparable with anaerobic digestion.	Less operating costs comparable with aerobic digestion.
2.	There is no by product recovery from this process.	There is by product recovery from this process. Methane gas is produced for recovery as a by -product.
3.	Low capital cost.	Cost is higher as compared to Aerobic digestion.
4.	End products of the digestion are ammonia CO_2 and water.	End products of the digestion are methane CO_2 and other gases.
5.	This is suitable for small activated sludge.	This process is suitable for highly concentrated organic waste.

4.5 Sludge Digestion Tank

A sludge digestion tank is a RCC or steel tank of cylindrical shape with hopper bottom and is covered with fixed or floating type of roofs.

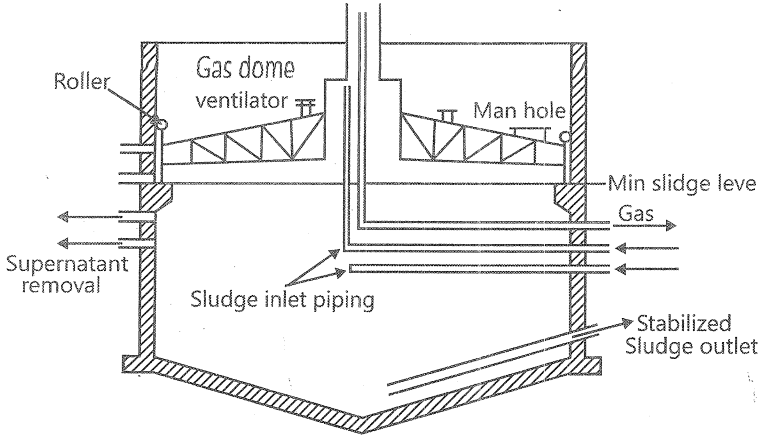


Fig. 4.2 Sludge diagram tank

4.6 Types of anaerobic digesters

The anaerobic digesters are of two types: *standard rate* or *conventional digester* and *high rate digester*. In the standard rate digestion process, the digester contents are usually unheated and unmixed. The digestion period may vary from 30 to 60 d. In a high rate digestion process, the digester contents are heated and completely mixed. The required detention period is 10 to 20 d.

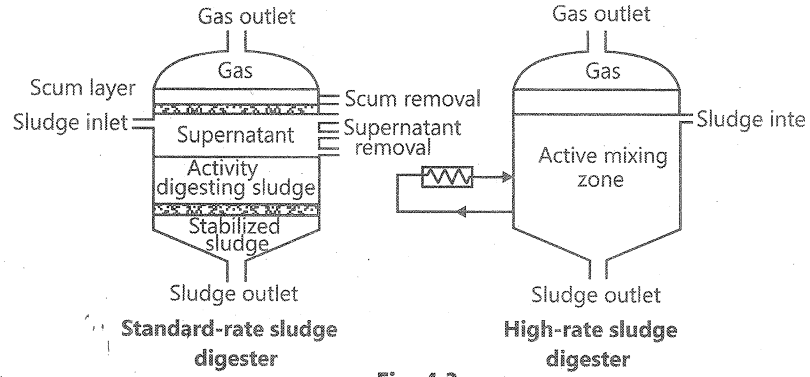


Fig. 4.3

4.7 Anaerobic Digestions

Question 12

(i) Main gases generated during anaerobic digestion of sewage sludge.

(1) CO_2 & CH_4 *(2)* CH_4, H_2S

(3) CO_2 & H_2S *(4) None* *(CSVTU, April-May 2012)*

Ans. (1) CO_2 & CH_4

(ii) Correct relationship given in as:

(1) TOD>BOD>COD

(2) TOD>COD>BOD

(3) COD>BOD>TOD

(4) BOD>COD>TOD

Ans. COD>BOD>TOD

Question 13

Explain the process of drying in drying beds and mention the uses of dried sludge.

Ans. In this method of sludge disposal, the sludge is dried by spreading over the land. Air drying of sewage can be done in open air of under glass covered roof. The open drying beds are generally 30-40 cm deep and are filled with gravel or stone ballast over which 10-15 cm thick layer of sand is spread. In some cases, cinder coke, breeze and blast furnace slag are also used for the above purpose. The sewage sludge is applied on these beds in about one week or so, the surface of sludge cracks and at this stage, the sludge is ready for removal. The sludge at this stage contains about 70% moisture. The sludge cakes are then removed by spades and they are dumped into a pit for further drying or they may even be kept on the drying beds for a period of about 3 to 4 weeks. The liquid that has percolated through the drying bed is collected and conveyed by underdrains to the sumps. The different sumps are suitably connected with each other and the

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percolated liquid is thus either conveyed to the influent of the treatment plant or to the natural stream or river. The conveyance of liquid may be achieved either by gravity or by pumping.

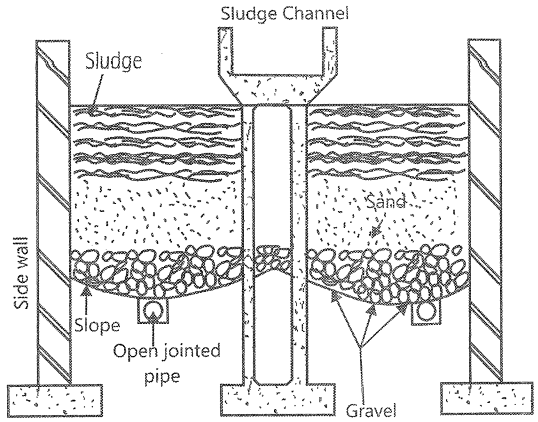


Fig. 4.4 Sludge Drying BED

Uses of dried sludge: The sludge cakes formed on the surface of drying beds should be carefully removed. It should be observed that the sand is not being taken out along with the sludge cakes. This sludge has got the fertilizing value as it contains nitrogen, phosphoric acid and potash. It can therefore be utilized as fertilizer it can also be dumped into low lying areas or buried or incinerated.

The area required for drying beds will depend on the quantity of sludge, quality of sludge and weather conditions prevailing at the site of drying beds. In general the area of drying bed is determined on per capita basis. For sewage treatment plant of capacity of about 10 MLD or more, the usual provision made for drying beds is about $0.05m^2$ per capita.

Question 14

Write a short note on TOC and ThOD. *(CSVTU, Nov-Dec 2011)*

Ans. **TOC:** In order to evaluate the amount of organic matter present in the waste water. TOC is especially applicable to small concentration of organic matter. The TOC test consists of acidification of the waste water sample to convert the inorganic carbon in to CO_2 which is then striped. The sample is then injected to high temperature furnace where it is oxidized in the presence of catalyst. The CO_2 produced is then measured by means of an infrared analyzer and converted instrumentally to the original organic carbon content. This test is rapid accurate and correlate well with the BOD. TOC will be slightly less than the actual amount present in the sample.

ThOD: Theoretical oxygen demand is process of computing the oxygen demand of various constituents of organic matter present in waste water. The organic matter present in the waste water consists of principal group such as carbohydrate, protein, fats and products of their decomposition. These are the combination of carbon, hydrogen oxygen and nitrogen based on its chemical formula. Hence, if the chemical formula of the constituent is known then the ThOD can be easily computed. For example, the glycerine having a chemical formula $CH_2(NH_2)COOH$. The ThOD can be computed by adding the oxygen required in the all the steps of the following reaction.

1. The carbon is converted to CO_2 and nitrogen is converted to ammonia.
2. Now Ammonia is oxidized to nitrite.
3. Nitrite is oxidized to nitrate.

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4.8 Self Purification of Natural Streams

Question 15

What is self purification of a river? *(CSVTU, Nov-Dec 2009)*

Ans. The self purification of natural water systems is a complex process that often involves physical, chemical, and biological processes working simultaneously. The amount of dissolved Oxygen (DO) in water is one of the most commonly used indicators of a river health. As DO drops below 4 or 5 mg/L the forms of life that can survive begin to be reduced. A minimum of about 2.0 mg/L of dissolved oxygen is required to maintain higher life forms. A number of factors affect the amount of DO available in a river. Oxygen demanding wastes remove DO; plants add DO during day but remove it at night; respiration of organisms removes oxygen. In summer, rising temperature reduces solubility of oxygen, while lower flows reduce the rate at which oxygen enters the water from atmosphere.

The process of purification of stream water due to natural forces of purification is known as self purification.

Question 16

Enlist the factors affecting self purification of stream.

Ans. Following are the factors affecting self purification of stream.

1. **Dilution:** When sufficient dilution water is available in the receiving water body, when the wastewater is discharged, the DO level in the receiving stream may not reach to zero or critical DO due to availability of sufficient DO initially in the river water before receiving discharge of wastewater.
2. **Current:** When strong water current is available, the discharged wastewater will be thoroughly mixed with stream water preventing deposition of solids. In small current, the solid matter from the wastewater will get deposited at the bed following decomposition and reduction in DO.
3. **Temperature:** The quantity of DO available in stream water is more in cold temperature than in hot temperature. Also, as the activity of microorganisms is more at the higher temperature, hence, the self-purification will take less time at hot temperature than in winter.
4. **Sunlight:** Algae produces oxygen in presence of sunlight due to photosynthesis. Therefore, sunlight helps in purification of stream by adding oxygen through photosynthesis.

5. **Rate of Oxidation:** Due to oxidation of organic matter discharged in the river DO depletion occurs. This rate is faster at higher temperature and low at lower temperature. The rate of oxidation of organic matter depends on the chemical composition of organic matter.

Question 17

Write a short note on
1. Oxygen sag curve.
2. Deoxygenation and Reoxygenation Curves *(CSVTU, Nov-Dec 2011)*

Or

What do you understand by DO sag curve? *(CSVTU, Nov-Dec 2012)*

Ans.

1. **Oxygen sag curve or DO Sag Curve:**

The oxygen sag or oxygen deficit in the stream at any point of time during self purification process is the difference between the saturation DO content and actual DO content at that time.

Oxygen deficit, D = Saturation DO – Actual DO

The saturation DO value for fresh water depends upon the temperature and total dissolved salts present in it; and its value varies from 14.62 mg/L at 0°C to 7.63 mg/L at 30°C.

At the point of discharge of waste water in to the stream, it is not necessary that the DO content of the stream will be equal to the saturation DO; and there may be initial oxygen deficit 'D_0'. At this stage, when the effluent with initial BOD load L_0, is discharged in to stream, the DO content of the stream starts depleting and the oxygen deficit (D) increases. The variation of oxygen deficit (D) with the distance along the stream, and hence with the time of flow from the point of pollution is depicted by the 'Oxygen Sag Curve' as shown in fig. 4.5. The major point in sag analysis is point of minimum DO, i.e., maximum deficit. The maximum or critical deficit (D_C) occurs at the inflexion points of the oxygen sag curve.

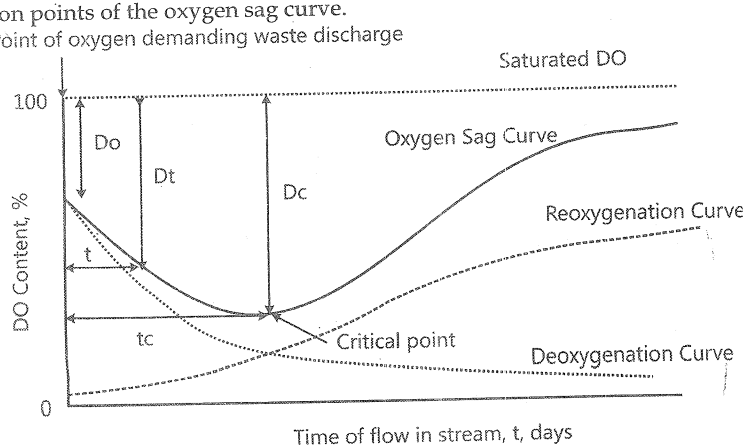


Fig. 4.5 Deoxygenation, Reoxygenation and Sag curve

2. **Deoxygenation and Reoxygenation Curves**

When wastewater is discharged in to the stream, the DO level in the stream goes on depleting. This depletion of DO content is known as deoxygenation. The rate of deoxygenation depends upon the amount of organic matter remaining (L_t), to be oxidized at any time t, as well as temperature (T) at which reaction occurs. The variation of depletion of DO content of the stream with time is depicted by the deoxygenation curve in the absence of aeration. The ordinates below the deoxygenation curve indicate the oxygen remaining in the natural stream after satisfying the bio-chemical demand of oxygen.

When the DO content of the stream is gradually consumed due to BOD load, atmosphere supplies oxygen continuously to the water, through the process of re-aeration or reoxygenation, i.e., along with deoxygenation, re-aeration is continuous process.

The rate of reoxygenation depends upon:

i) Depth of water in the stream: more for shallow depth.
ii) Velocity of flow in the stream: less for stagnant water.
iii) Oxygen deficit below saturation DO: since solubility rate depends on difference between saturation concentration and existing concentration of DO.
iv) Temperature of water: solubility is lower at higher temperature and also saturation concentration is less at higher temperature.

Question 18

Write a short note on zones of pollution in stream. *(CSVTU, Nov-Dec 2010)*

Ans. **Zones of Pollution in a Stream:** A polluted stream undergoing self purification can be divided in to following four zones.

1. Zone of degradation
2. Zone of active decomposition
3. Zone of recovery
4. Zone of cleaner water

1) **Zone of degradation or zone of pollution:** This zone is found for a certain length just below the point where the sewage is discharged in to the river.

This zone is characterized by water becoming dark and turbid with the formation of sludge deposit at the bottom. D. O is reduced to about 40% of saturation value. There is increase in carbon dioxide content the reoxygenation occurs but is slower than the de-oxygenation. This condition is unfavorable for the aquatic life.

2) **Zone of active decomposition:** This zone is marked by the heavy pollution. This zone is characterized by water becoming greyish and darker than in zone of pollution. D.O. concentration falls down to zero and anaerobic conditions may set in with the evolution of gases like methane, carbon dioxide, hydrogen sulphide etc. forming a scum layer at the surface. As the organic decomposition slackens due to stabilization of organic matter, the re-aeration sets in and the D.O rises to original level.

In this zone, bacteria flora will flourish. At the upper end, anaerobic bacteria will replace aerobic bacteria while at its lower end the position will be reversed.

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3) **Zone of recovery:** In this zone the river tries to recover from its degraded condition to its former appearance. The water becomes clearer and so the algae reappear while fungi decrease. B.O.D falls down and D.O. content rises above 40 %of the saturation value. The organic material will be mineralized to form nitrates, sulphates, phosphates and carbonates etc.

4) **Zone of cleaner water:** In this zone the river attains the original condition with D.O. rising up to saturation value. Water becomes clearer and attractive in appearance. Some pathogenic organisms may still, however survive in this zone.

4.9 Sewage Disposal

Question 19

Explain disposal by dilution in brief.

(CSVTU, April-May 2011) (CSVTU, April-May 2010)

Or

Explain in brief various methods of final disposal of sludge.

Ans. **Sewage Disposal by Dilution**

The disposal of sewage is carried out by discharging in to water course such as streams, rivers or large body of water such as lake, sea, is called dilution. This method of disposal is only possible when the natural water required in the desirable quantity is available near town.

While discharging the sewage in this way, care should be taken that the sewage may not pollute the natural water and render it unfit for any other purposes such as bathing and drinking, fish culture, industrial use or irrigation.

The method of sewage disposal by dilution is the most suited under the following circumstances:

1. When the city is situated near the sea, river or lake.
2. When the sewage reaching the point of the disposal is fresh or non-septic.
3. When at the point of the disposal depth of the water is sufficient and the current can prevent the deposition near the outfall.
4. When the volume of receiving water is large enough to take the load of the sewage safety without causing its pollution.
5. When during flood receiving water will not cause backward flow in the sewer.

Sewage Disposal by Land Treatment:

When the sewage is evenly spread on the surface of the land, the method is called land treatment. The water of the sewage percolates in the ground and the organic suspended solids remain at the surface of the ground. The organic suspended solids are partly acted upon by the bacteria and are partly oxidized by exposure to atmospheric actions of heat, light and the air. The sewage adds to the fertilizing value of the land.

Land treatment can be further classified as:

(i) Filtration

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(ii) Sewage farming and Broad irrigation

The natural process method of the sewage purification in both treatments is same, viz., filter ratio of sewage by straining action of ground, soil, oxidation and biochemical action of organic matters. The complex compounds of the sewage are converted into harmless mineral salts which serve as valuable fertilizers. In filtration, more depth of the soil below ground in the level takes part in the sewage treatment than the broad irrigation which is only upper 5.8cm. Depth does this work. Overall it will be observed that the sewage takes very long time for the actual development of fertilizers which can be used up by the crops.

Question 20

Explain the advantages and disadvantages of land treatment of sewage.

Ans. Following are the advantages and disadvantages of the land treatment.

Advantages:

1. The disposal of sewage is done by natural treatment.
2. The natural water course is prevented from pollution.
3. The method is cheap and does not require the sewage treatment plants requiring high initial and maintenance cost.
4. The land is irrigated and receives high value of fertilizing substances without extra cost.
5. The disposal of sewage is done without natural courses.

Disadvantages:

1. Large area of the land is required for this type of disposal.
2. During rainy season and the winter wet climate, this method is not very effective and suitable.
3. If the land is used for growing crops, special attention against the spread of disease shall have to be taken.
4. During application of the sewage to the land it is to be properly supervised, otherwise the land may become sick.
5. The disposal of sewage cannot be done by this method, if the land consists of clayey soil.

Question 21

Explain the factors to be considered for the land disposal of sewage.

Ans. Following factors to be considered for the land disposal of sewage:

1. When the overall rainfall is very low, the land can be irrigated by sewage.
2. When there is no river, or natural water courses in which sewage can be discharged.
3. When the quantity of sewage is more which will pollute the river water.
4. When rivers generally run dry or have very small flow during summer.
5. When water table is much deep even during monsoon and there are no chances of its pollution by land treatment of sewage.

6. When vegetables have good market, the land treatment will have good income in return also.
7. When Large area of land is sandy, loamy and alluvial soil over soft murum,land treatment is most suited, because porous soil will allow good aeration.

4.10 Industrial Waste Water

Characteristics of the industrial wastewater usually vary from industry to industry and also vary from the process to process even for the same industry, yet industrial effluent as a group differs widely from normal domestic sewage obtained from the residences and commercial establishments. They have either too high a proportion of the suspended solids dissolved organic and inorganic solids, BOD, alkalinity acidity and their different constituents will not be in the same proportions as they exists a normal domestic sewage.

Question 22

Enlist the pollutants present in Industrial waste water and also explain their effects on the treatment units.

Ans. **Pollutant in industrial wastewater and their effects:**

Following are various types of pollutants that may be present in the industrial wastewaters.

1. **Organic substances:** This depletes DO of the streams and impose great load on the secondary treatment unit.
2. **Inorganic substances:** This includes carbonates, chlorides, nitrogen phosphorous etc. They are undesirable for the micro-plant of the receiving water body. This renders the water body unfit for the further use.
3. **Acids and alkalies:** These greatly affect the aquatic life of receiving water body. They also cause serious problems in the operation of the treatment units.
4. **Toxic substances:** These include cyanides, sulphides, acetylene, alcohol etc, due to which flora and fauna of receiving water is generally affected. They cause problem in the treatment apart from endangering the life of workmen.
5. **Color producing substances:** They impart objectionable color in the receiving water body.
6. **Oil etc:** These hinder self purification process of stream and also cause operational problems in the treatment plants.

4.11 Treatment of Industrial waste water

Industrial wastewater have either too high a proportion of suspended solids, dissolved organic and inorganic solids, BOD, alkalinity or acidity, and their different constituents will not be in the same proportion throughout, as they exist in domestic wastewater. The important factors which affect the planning for an industrial wastewater treatment plant are (i) discontinuous flow and sometimes seasonally discharged wastewater, (ii) high concentration of pollutants, and (iii) non-biodegradability and toxicity of some

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pollution parameters. Treatment of industrial wastewater generally consists of one or more of the following processes:

(i) Equalization, (ii) Neutralization, (iii) Physical treatment (iv) Chemical treatment, and (v) Biological treatment.

Question 23

Write short notes on:

1. *Equalization & Proportioning*
2. *Neutralization*
3. *Proportioning* *(CSVTU, Nov-Dec 2011)*

Or

Explain various processes used in treatment of industrial waste water.

Ans. The various processes used in treatment of industrial waste water are as follows:

1. **Equalization:** When the characteristic of the wastewater varies during the day and also when the discharge is either not uniform or else is discontinuous, equalization is necessary. The process of equalization consists of holding the wastewater for predetermined time, in continuously mixed holding tanks/basins so as to get wastewater of uniform character and at uniform rate. Thus, equalization needs adequate storage.
2. **Neutralization:** The process of bringing alkaline and acidic waste to neutral by adding suitable amount of acid or alkali is known as Neutralization. This is necessary when the wastewater maintains either excess alkali or excess acid, and is achieved by the addition of either acid or alkali respectively. This may be done either in the equalization tank, if the conditions so permit or else in a separate neutralization tank.
3. **Proportioning**: The process of discharging the industrial waste in proportion to the flow of the sewage is known as proportioning.

   The various objectives of proportioning are as follows:
   1. To protect the sewage treatment plant during the deficit hours.
   2. To minimize the fluctuation in the flow.
   3. The characteristics of the industrial waste water should be equal to the characteristics of waste water.

   Proportioning is either done with the help of a proportioning tank or valve which may be automatic or manual.
4. **Physical treatment:** Physical treatment is similar to primary treatment of domestic wastewater. Various processes that fall under this head are: (i) Screening (ii) Sedimentation, (iii) Floatation and (iv) Filtration.

   Primary sedimentation becomes essential when the wastewater contains high percentage of settleable solids. Floatation is provided to remove the finer particles. In floatation, the rising air bubbles lift the finer particles to the surface from where these are removed by skimming.
5. **Chemical treatment:** Chemical treatment is one of the essential parts in the treatment of industrial wastewater, especially for those which are amenable to biological treatment. Sometimes, physico-chemical treatment is applied to the industrial wastewaters, either

in absence of biological treatment or in conjunction with biological treatment. Various chemical and physico-chemical processes that are used for industrial wastewater treatment are: (i) Coagulation, (ii) Chemical precipitation, (iii) Hyper-filtration or reverse-osmosis, (iv) Chemical oxidation (v)Adsorption (vi) Ion exchange

6. **Biological treatment:** This process is employed to only when the industrial wastewater contains large quantities of biodegradable substances.
   - If the BOD/COD ratio of the industrial wastewater is more than 0.6, it is biologically treatable.
   - If the ratio is less than 0.6 but is up to 0.3, acclimatization is necessary before biological treatment.
   - If, however, the ratio is less than 0.3 biological treatments is not necessary.

Acclimatization is a process of seeding or raising initial microbial population under a controlled condition, by gradual exposure of the wastewater in increasing concentration. Various biological treatment methods that can be used are (i) activated sludge process, (ii) trickling filter (iii) oxidation pond (iv) aerated lagoon (v) oxidation ditch, and (vi) oxidation lagoon followed by aerated lagoon. Amongst these, trickling filters prove better than activated sludge process, since filters can handle a number of toxic wastes quite satisfactorily. When BOD of wastewater approaches 1000 mg/*l* recirculation of effluent will prove more useful.

Question 24

Why there is need to adopt effluent standards for waste water disposal in surface water bodies? Why these standards differ for disposal into a public sewer? What are stream standards? *(CSVTU, Nov-Dec 2010) (CSVTU, Nov-Dec 2011) (CSVTU, Nov-Dec 2012)(CSVTU, April-May 2010)*

Or

Discuss various standards applicable to waste water treatment in brief. What is the general logic behind these standards? *(CSVTU, Nov-Dec 2009)*

Ans. The Water Pollution Act 1972 mandated the environmental protection agency to establish standards for waste water discharge. Secondary treatment of municipal waste water is generally assumed to include settling, biological treatment and disinfection along with sludge treatment and disposal.

- *Effluent standards* are the specification of the physical, chemical and biological quality of effluent to be produced by the treatment. It includes allowable concentration of BOD, COD, suspended solids, nitrogen, phosphorus etc.
- *Stream standards* are those which are designed to prevent deterioration of the existing water quality, set limits and amount of specific pollutant allowed in stream, river or lake.

These standards are necessarily to adopt while disposing the waste water either in the public sewer or in the stream because the sewage contains high amount of the organic matter which might result in problems such as high BOD. If the sewage is directly disposed off in the stream or sewer it will cause threat to the environment and

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receiving bodies. So to keep a control over these, the effluent standards are imposed by the pollution control board.

The effluent standards to be followed for the various pollutants are as given in the table.

S.NO	*Name of pollutant in effluent*	*Standards for the disposal in inland surface water*	*Standards for the disposal in public sewer*
1.	Color and odor	Effort should be made to remove color and unpleasant odor as far as possible	Effort should be made to remove color and unpleasant odor as far as possible
2.	Total suspended solids	300mg/L	600mg/L
3.	BOD_5 at 20°C	30 mg/L	350 mg/L
4.	COD	250 mg/L	-
5.	pH	5.5-9.0	5.5-9.0
6.	Temperature	Should not exceed above 5 °C of receiving body.	-
7.	Oil and grease	10 mg/L	20 mg/L
8.	Total residual chlorine	1.o mg/L	-
9.	Total Kjeldahl Nitrogen	100mg/L	-

Question 25

Write a short note on industrial effluent standards for disposal on land.

Ans. The use of industrial effluent for irrigation purpose has been quite popular, particularly from food processing industries, pharmaceutical industry, pulp and paper industries. While using the effluent standards, care should be taken that it should percolate into the field and do not create the problem of fly breeding. The industrial waste can be treated in oxidation ponds or lagoons and disposed off.

Question 26

What are the tolerance limits for industrial effluents discharged into sewers?

Ans. According to IS: 3306-1965, the tolerance limits for industrial effluents discharged into public sewer are as follows:

i) Its pH value should be between 5.5 to 9.0.
ii) Lead, copper and zinc should not exceed 1.3 to 1.5 mg/*l*.
iii) Effluent temperature should not exceed 45°C.
iv) Quantity of suspended solids should not exceed 600 mg/*l*.
v) Chromium, nickel and cyanide should not exceed 2% each.
vi) Effluent containing solids such as straw, plastic, wood, paint, residue, gross solid from cannery/wastes cinder, ash, sand, rag hair metal shavings, garbage, broken glass etc. should not be discharged into public sewers.

vii) Suspended solids should not exceed 600 mg/*l*.

viii) Chloride and boron should not exceed 600 and 2 mg/*l* respectively.

4.12 Treatment of effluent of various Industries

Question 27

Describe the characteristics of waste generated from dairy industry and also mention the treatment methodologies adopted for such a waste.

Ans. Large quantities of wastewater originate due to different operations of dairy industry. Various operations in a dairy industry may include pasteurization, bottling filling in cans, and preparation of butter, cream, cheese, milk powder etc. Wastewater from dairy industry consists primarily of dilutions of milk and its products which impart a very high BOD sometimes up to about 1000 mg/*l*. The wastewater may also contain detergents, germicides and other chemicals.

Typical characterization of the dairy waste water is as follows.

S. No.	Characteristics	Value
1	pH	7 – 7.5
2	Suspended solids	720 mg/L
3	Total dissolved solids	1020 mg/L
4	BOD	1190 mg/L
5	COD	90 mg/L
6	Oil and Grease	320 mg/L
7	Total Nitrogen	90 mg/L
8	Phosphorus	12 mg/L

Suggested Treatment Method

Physical treatment followed by aerobic biological treatment in the form of high rate trickling filters or activated sludge process. Equalization tank is commonly provided. Sludge can be dried on sludge drying beds. Oxidation ponds and oxidation ditches can also be provided. The treatment employed for the treatment of the dairy waste water is as shown in the flow diagram.

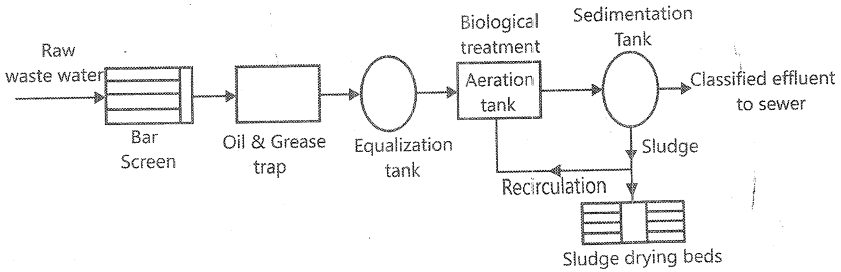


Fig. 4.6 Flow sheet for dairy waste water

Question 28

Describe the characteristics of waste generated from a sugar factory and also mention the treatment methodology to be adopted for such waste.

(CSVTU, April-May 2010)

Ans. The average quantity of liquid waste produced from a cane sugar industry wastewater is of the order of about 3000 litres/tonnes of 500 mg/*l* and BOD of 500 to 600 mg/*l*. Because of low pH (5-7), disposal becomes a difficult problem.

Suggested Treatment Method

Pollution Characteristics	Suggested Treatment Method
1. High BOD 2. High volatile solids 3. Low pH	Using digestion in stages with detention periods of one and six days for the primary and secondary digester followed by oxidation pond.

Alternative treatment method employed for the treatment of the sugar waste water is as shown in the flow diagram.

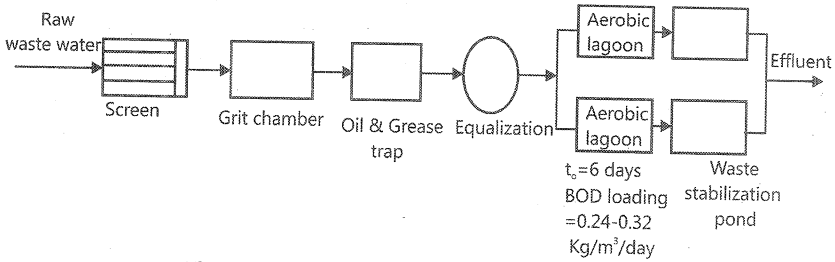


Fig. 4.7 Flow sheet for sugar Industry waste

Question 29

Describe the characteristics of waste generated from a distillery and also mention the treatment methodology to be adopted for such waste. *(CSVTU, Nov-Dec 2010)*

Ans. Various products that are manufactured in distilleries include industrial alcohols, rectified spirit, silent spirit, absolute alcohol, beverage alcohol etc. The products are obtained through the high as raw material. Also these products contain ethyl alcohol in different proportions. The unwanted residue obtained at the time of preparation of the medium, contain very high BOD which makes it non amenable to aerobic biological treatment. Following are the pollution characteristics of combined brewery wastes. Figure gives the flow diagram for treatment of wastewater obtained from breweries.

S. No.	Parameter	Values
1.	pH	4.0 – 7.0
2.	BOD	250 – 3000 mg/L
3.	COD	300 – 3500 mg/L
4.	Total solids	272 – 2724 mg/L
5.	Suspended solids	16 – 516 mg/L

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Pollution Characteristics	Suggested Treatment Method
1. Very High BOD 2. High COD 3. High chlorides and sulphates 4. Highly coloured – brownish yellow	1. Two stage aerobic treatment using trickling filters. 2. Use of anaerobic lagoons and aerated lagoon, followed by polishing ponds.

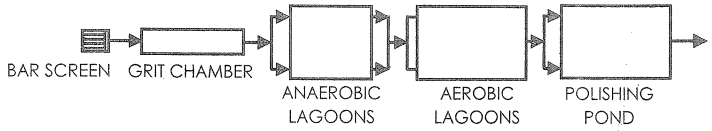


Figure 4.8 (FLOW CHART FOR TREATING DISTILERY WASTES)

4.13 Textile Industries Waste

Question 30

Describe the characteristics of waste generated from a textile industry and also mention the treatment methodology to be adopted for such waste.

Ans. The characteristics of waste from a textile industry depend up to the type of fiber used. These fibers may be classified into four groups:

1. Cotton
2. Wool
3. Regenerated and
4. Synthetics

The pollutants in the textile industry waste include natural impurities in the fiber used, as well as the processing chemicals. Following table shows the pollution characteristics of the cotton textile.

S. No.	Parameter	Values
1.	pH	9.8 – 11.8
2.	BOD	760 mg/L
3.	COD	1418 mg/L
4.	Total solids	6170 mg/L
5.	Total chromium	12.5 mg/L

Figure 4.9 gives the flow diagram for treatment of wastewater obtained from cotton textile industry.

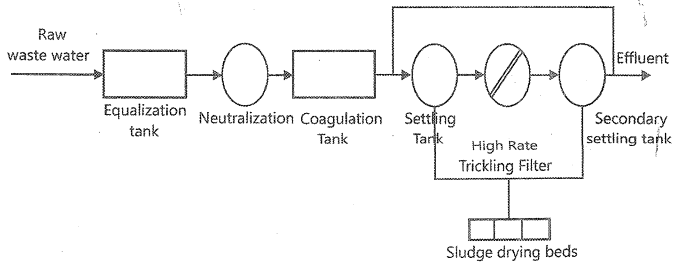


Fig. 4.9 Flow sheet for treatment of cotton textile Industry

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Question 31

Sewage has a suspended solid content of 250 mg/L. The sedimentation tank removes 55% of suspended solids and water content of the sludge is 95%. Determine the quantity of the sludge produced after treating 6.5×10^6 liter of sewage.

Ans. The sedimentation tank removes 55% of the suspended solids,

$$\therefore \quad \text{Removal of solids} = \frac{55}{100} \times 250 = 137.5 \text{ mg/L}$$

$$\text{Total solids removed} = \frac{137.5}{1000} \times 6.5 \times 10^6 = 137.5 \times 10^3 \text{gm.}$$

With the solid content of 5%, the volume of sludge

$$= 893.75 \times \frac{100}{5} \times 10^3$$

Assuming specific gravity of sludge as unit,

$$= \frac{893.75 \times 100}{5 \times 1000} \times 10^3$$

$$= 17875 \text{ liter}$$

$$= 17.875 \text{ m}^3$$

Question 32

The domestic sewage of town is to be discharged into a stream after treatment. Determine the maximum permissible effluent BOD and the percentage purification required in the treatment plant from following data.

(i) Population of town : 50, 000
(ii) D.W.F. of sewage : 150 litres/capita/day
(iii) BOD contribution per capita : 0.075 kg/day
(iv) Minimum flow of stream : 0.20 m³/s
(v) BOD of stream: 3 mg/l.
(vi) Max. BOD of stream on downstream: 5 mg/l.

(CSVTU, April-May 2011)

Ans.

Population = 5000
D. W. F of sewage = 150 liter/capita/day
B. O. D contributed per day = 0.075 kg/day
Minimum flow of stream = 0.20 m^3/sec
Maximum BOD of stream on = 5mg/L
DOwnside BOD of stream = 3mg/L
D.W.F of sewage = 5000×150
$= 750 \times 10^3$ liter/day
$= 0.0868$ m^3/sec
Stream discharge = 0.20 m^3/sec

The BOD (y_m) of mixture at downstream

$$Y_{mix} = \frac{y_1 \times Q_1 + y \times Q_2}{Q_1 + Q_1}$$

y_{mix} = 5 mg/L (given)
y_1 =BOD of effluent
Q = Discharge of effluent

y_2 = BOD of stream

Q_2 = Discharge of stream

$$y_{mix} = \frac{(y_1 \times 0.0868) + (3 \times 0.2)}{0.0868 + 0.2}$$

$$5 = \frac{(y_1 \times 0.0868) + (3 \times 0.2)}{0.0868 + 0.2}$$

$\therefore$ $y_1 = 9.608$ mg/L

Now, BOD per capita per day

$= 0.075 \times 1000 \times 1000$

$= 75000$ mg/day

Sewage DWF = 150 lit/day

$$\text{Actual BOD of effluent} = \frac{75000}{150} = 500 \text{ mg/L}$$

$$\therefore \%\text{ Pacification required} = \frac{500 - 9.608}{500} \times 100$$

$= 98.1\%$

Question 33

The sewage discharge of a town is 1.72 m^2/sec. If the sewage is discharged into a river, whose minimum discharge is 7240 lps. If the minimum DO to be maintained in the river is 4.4 mg/L. Determine the degree of sewage treatment to be DOne. Temperature of sewage and river = 20°.

$k_1 = 0.1$ $k_2 = 0.5$

BOD_5 (S) = 225 mg/L BOD_5 (R) = 1.2 mg/L

At T = 20°C

$DO_{(R)}$ =80%

$DO_{sat}(20°C) = 9.17$ mg/L (CSVTU, April-May 2009)(CSVTU, Nov-Dec 2011)

Ans. DO of river = 80% of saturation DO

$= 0.8 \times 9.17$

$= 7.336$ mg/L

DO of the mix

$$= \frac{DO_{(R)} \times Q_{River} + DO_{(S)} \times Q_{Sewage}}{Q_{River} + Q_{sewage}}$$

$$DO\ mix = \frac{7.336 \times 7.240 + 0 \times 1.72}{7.240 + 1.72}$$

$= 5.92$ mg/L

$\therefore$ Initial DO deficit = DO $= 9.17 - 5.92$

$= 3.25$mg/L

Minimum DO to be maintained in the river = 4.4mg/L

$\therefore$ Maximum permissible saturation deficit (D_c)

$D_c = 9.17 - 4.4$

$= 4.77$mg/L

Now, the first stage BOD of mixture of sewage and stream is

$$\left[\frac{L_0}{f_s \times D_c}\right]^{f_s - 1} = f_s\left\{1 - \{f_s - 1\}\frac{DO}{L_o}\right\}$$

Where,

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$$f_s = R/k = \frac{0.5}{0.1} = 5$$

DO = 3.25mg/L and

D_c = 4.77mg/L

$$\therefore \left[\frac{L_0}{5 \times 4.77}\right]^{5-1} = 5\left[1 - (5-1)\frac{3.25}{L_0}\right]$$

$$\left[\frac{L_0}{23.85}\right]^4 = 5\left[1 - \frac{13}{L_0}\right]$$

$$\frac{{L_0}^4}{323.55 \times 10^3} = 5\left[1 - \frac{13}{L_0}\right]$$

$$\frac{{L_o}^4}{323.55 \times 10^3} = 5\left[1 - \frac{13}{L_o}\right]$$

Solving above equation by trial and error method, we get

$L_o = 34.95$ mg/L.

5 Day BOD at 20° c may be assumed as 75% of L_o

5 Day BOD= 0.75×34.95

$= 26.21$ mg/L

BOD of mix is

$$26.21 = \frac{7.240 \times 1.2 + 1.72 \times y}{7.24 + 1.72}$$

$$26.21 = \frac{8688 + 1.72y}{8.96}$$

$y = 131.5$ mg/L

y = Permissible BOD of sewage

$\therefore$ Degree of treatment required to the sewage

$$= \frac{225 - 131.5}{225} \times 100$$

$= 41.5\%$

Degree of treatment required to the sewage is 41.5 %.

Question 34

The rate of flow in the river is 30m^3/sec and has a BOD_5 of 2 mg/L. The river is saturated with DO of 9.2 mg/L 20°C. Waste water having BOD_5 of 120 mg/L and DO content zero with a flow rate of 3 m^3/sec is discharged into river. Assuming temperature of 20° C throughout, deoxygenation coefficient 0.1 per day and reoxygenation coefficient 0.3 per day. Find out the degree of treatment required of the minimum DO to be maintained in river is 4 mg/L. (CSVTU, Nov-Dec 2009)

Ans. $Q_{River} = 30 m^3$/sec

BOD_5 (R) = 2mg/L

DO sat (20°c) = 9.2mg/L

BOD_5 of (Sewage) = 120 mg/L

DO of (Sewage) = 0

$Q_{Sewage} = 3 m^3$/sec

R = 0.3

k = 0.1

DO to be maintained in river = 4mg/L.

Assuming DO of river is 80% of the saturation DO

$$\therefore \quad DO\ (R) = 0.8 \times 9.2$$
$$= 7.36 mg/L$$
$$DO\ of\ mix = \frac{7.36 \times 30 + 0 \times 3}{(3 + 30)}$$
$$= 6.69 mg/L$$
$$Initial\ DO\ deficit = 9.2 - 6.69$$
$$DO = 2.51\ mg/L$$

Minimum DO to be maintained in the stream = 4mg/L

Minimum permissible saturation deficit is

$$D_c = 9.2 - 4$$
$$= 5.2 mg/L$$

Now the first stage BOD of mix of sewage and stream is

$$\left[\frac{L_o}{f_s D_c}\right]^{fs-1} = f_s \left[1 - \{f_s - 1\}\frac{DO}{L_o}\right]$$
$$f_s = \frac{R}{k} = 3$$
$$\Rightarrow \quad \left[\frac{L_o}{3 \times 5.2}\right]^2 = 3\left[1 - (3-1) \times \frac{2.51}{L_o}\right]$$
$$\left[\frac{L_o}{3 \times 5.2}\right]^2 = 3\left[1 - (3-1) \times \frac{2.51}{L_o}\right]$$
$$\frac{L_o^2}{15.6^2} = 3\left[1 - \frac{5.02}{L_o}\right]$$
$$\frac{L_o^2}{730.08} = \frac{L_o - 5.02}{L_o}$$
$$L_o^3 = 730.08\, L_o - 3665.0016$$
$$L_o^3 + 0L_o^2 - 730.08\, L_o + 3665.0016 = 0$$

Solving above equation we get,

$$L_o = 24.03\ mg/L$$

Hence
$$y_5 = L_o\,(1 - (10)^{-0.1 \times 5})$$
$$= 24.03\,(1 - (10)^{-0.5})$$
$$= 16.43\ mg/L$$

Hence 5- day BOD of mixture = 16.43 mg/L

$$16.43 = \frac{(2 \times 30) + y_e \times 3}{30 + 3}$$
$$542.19 = 60 + 3y_e$$

From above equation,

$$y_e = 160.73\ mg/L$$

Question 35

A town discharges 80 m^3/sec of sewage into stream having a rate of flow of 1200 cumecs during lean days at a 5 day BOD of sewage at given temperature is 250 mg/L. Find the amount of critical deficit and its location in downstream portion of stream assuming deoxygenation coefficient k as 0.1 and coefficient of self purification (f_s) as 3.5. Assume saturation DO at given temperature as 9.2 mg/l. (CSVTU, Nov-Dec 2008)

Ans.

DO (stream) = 9.2mg/L

DO(efficient) = 0 mg/L

$$DO\ mix = \frac{(9.2 \times 1200) + (0 \times 80)}{1200 + 80}$$
$$DO\ mix = 8.625\ mg/L.$$
$$Initial\ DO\ deficit\ DO = 9.2 - 8.625$$
$$= 0.575 mg/L$$

Also 5 day BOD of mix is given by

$$y_5 = \frac{(0 \times 1200) + (250 \times 80)}{1200 + 80}$$
$$= 15.625\ mg/L$$

But
$$y_5 = L_o\left[1 - 10^{-k \times 5}\right]$$
$$15.625 = L_o\left[1 - 10^{-0.1 \times 5}\right]$$

Form above equation

$$L_o = 22.85\ mg/L.$$

$$\therefore \quad t_c = \frac{1}{k(f_s - 1)} \log_{10}\left\{f_s\left((1 - (f_s - 1)\frac{DO}{L_o}\right)\right\}$$
$$= \frac{1}{0.1 \times (3.5 - 1)} \log_{10}\left[3.5\{1 - (3.5 - 1)\} \times \frac{0.575}{22.85}\right]$$
$$t_c = 2.063\ day$$

Also

$$D_c = \frac{L_o}{f_s}(10)^{-k.t_c}$$
$$= \frac{22.85}{3.5}(10)^{-0.1 \times 2.063}$$
$$= 4.06\ mg/L$$

Hence

$$x_c = v \times t_c$$
$$= 0.12\,(2.063 \times 24 \times 60 \times 60) \times 10^{-3}$$
$$x_c = 21.39\ km$$

Question 36

City discharges sewage at the rate of 1200 liters per second in a stream whose minimum flow is 5000 liter/second. The temperature of both being 20°C. The 5 day BOD 20°C for sewage is 160 mg/l and that of river water is 2 mg/l. The DO content of sewage is zero while that of stream is 90% of saturation Do find out the degree of the treatment required if minimum Do to be maintained in the stream is 4 mg/l. Assume De-oxygenation coefficient as 0.3. The saturation Do at 20°C is 9.17 mg/l.

Ans.

D_o of stream = 90% of saturation Do

$= 0.9 \times 9.17$

$= 8.259\ mg/L$

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D_o of maximum flow $= \dfrac{8.253 \times 5000 + 0 \times 1200}{5000 + 1200}$

$= 6.656$ mg/l

Initial D_o deficit $= 9.17 - 6.656$

$= 2.541$ mg/L

Minimum D_o to be maintained in the stream

$= 4$ mg/L

∴ Maximum permissible saturation deficit is

$D_c = 9.17 - 4 = 5.17$ mg/L

Now, the first stage BOD of mixture of sewage and stream is

$$\left[\frac{L_o}{F_s D_c}\right]^{F_s-1} = F_s\left[1 - (F_s - 1)\frac{D_o}{FL_o}\right]$$

Now, $F_s = \dfrac{R}{k} = \dfrac{0.3}{0.1} = 3$

$D_o = 2.514$ mg/L

$D_c = 5.17$ mg/L

$$\left[\frac{L_o}{3 \times 5.17}\right]^{3-1} = 3\left[1 - (3-1)\frac{2.514}{L_o}\right]$$

$$\frac{L_o^2}{240.56} = 3\left[1 - (3-1)\frac{2.514}{L_o}\right]$$

Solving this by trial and error we get

$L_o = 23.86$ mg/L

Now, $y = L_o[1 - 10^{-k \times t}]$

$y_5 = 23.86[1 - 10^{0.1 \times 5}]$

$y_5 = 16.31$ mg/L

This is permissible BOD of the mix.

∴ $$16.31 = \frac{(2 \times 5000)\, y_e \times 1200}{5000 + 1200}$$

$y_e = 75.95$ mg/L

Therefore permissible BOD of the effluent

$= 75.95$ mg/L

But actual BOD of effluent = 1600 mg/L

∴ Degree of treatment required

$$= \frac{160 - 75.94}{160} \times 100$$

$= 52.5\ \%$

Question 37

The population of the town is 60,000 and the domestic sewage is 160 lit/capita/day having per capita BOD 70 g/day. The dairy waste of the town is 2.5 × 10⁶ lit/day with a BOD of 1600 mg/l and waste from other inducting is 1.7 x 10⁶ lit/day with BOD 2000 mg/L. An overall expression factor of 15% is to be provided. The waste water is discharged in the natural stream having a minimum discharge of 7500 lit/sec and a saturation dissolved oxygen content of 9.0 mg/L. It is necessary to maintain a do content of 4 mg/L in the stream. Determine the degree of the treatment required to the waste water prior to its discharge into the stream. Assume suitable values of deoxygenation and reoxygenation constant.

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Sol. $Q = 60000 \times 160$

$= 9.6 \times 10^6$ lit/day

Per capita BOD of domestic sewage

$= 70 \times 1000$ mg/day

per capita sewage = 160 lit/day

BOD of domestic sewage

∴ $= \dfrac{70 \times 1000}{160} = 437.5$ mg/L

Average BOD of effluent

$$= \frac{437.5 \times 9.6 + 1600 \times 2.5 + 2000 \times 1.7}{9.6 + 2.5 + 1.7}$$

$= 840.6$ mg/L

Total effluent = $(9.6+2.5+1.7) \times 10^6$

$= 13.8 \times 10^6$ lit/day

$= 159.7$ lit/day

using expansion factor of 15%.

Design effluent $= 1.15 \times 159.7$

$= 184$ lit/day

Initial Do of stream = 9.0 mg/L

∴ (Do) min $= \dfrac{9.0 \times 7500 + 0 \times 184}{7500 + 184} = 8.78$ mg/L

Initial Do Deficit = $D_o = 9 - 8.78$

$= 0.22$ mg/L

Critical D_o deficit = $D_C = 9 - 4$

$= 5$ mg/L

Now,

$$\left[\frac{L_o}{fsd_c}\right]^{fs-1} = fs\left[1 - (fs-1)\frac{D_o}{L_o}\right]$$

∴ $$\left[\frac{L_o}{3 \times 5}\right]^{3-1} = 3\left[1 - (3-1) \times \frac{0.22}{L_o}\right]$$

Solving by Trial and Error we get

$L_O = 25.76$ mg/L

∴ $y_5 = L_o[1 - (10)^{-0.1 \times 5}]$

$= 25.76[1 - (10)^{-0.5}]$

$y_5 = 17.61$ mg/L

BOD of effluent

$$17.61 = \frac{y_5 \times 184 + 0 \times 7500}{184 + 7500}$$

$y_5 = 736.4$ mg/L

∴ Degree of Treatment

$$= \frac{840.6 - 736.4}{840.6} \times 100 = 12.5\ \%$$

Question 38

A sedimentation tank treats 6 MLD containing 250 mg/L of suspended solids .The tank removes 60% of the suspended solids. Compute the weight and volume of sludge produced daily, if the moisture content of sludge is 1) 97.52) 95%.

(CSVTU, Nov-Dec 2008)

Ans. Weight of solids in sewage

$$= \frac{(6 \times 10^6) \times 250}{10^6}$$

$$= 1500 \text{ kg/day}$$

Since only 60% of the influent solids are removed.

∴ Weight of solids removed in sedimentation tank = 0.6×1500

$$= 900 \text{kg/day}$$

Hence $w_s = 900 \text{kg/day}$

Now, volume of sludge,

$$V_{sludge} = \frac{w_s}{\rho_w \times S_s L \times \rho_s}$$

$\rho_w = 1000 \text{kg/m}^3$

$S_s L = 1.02$

a) At moisture content (m) = 97.5

$$\rho_s = 1 - 0.975$$

$$= 0.025$$

$$V_s L = \frac{900}{1000 \times 1.02 \times 0.025}$$

$$= 35.3 \text{m}^3$$

Weight of sludge

$$w_s L = \text{volume} \times \text{unit weight of sludge}$$

$$= 35.3 \times (1.02 \times 1000)$$

$$= 36000 \text{kg}$$

b) At a moisture content of 95%

$$\rho_s = 1 - 0.95 = 0.05$$

$$V_s L = \frac{900}{1000 \times 1.02 \times 0.05}$$

$$= 17.65 \text{m}^3$$

$$w_s L = 17.65 (1.02 \times 1000) = 18000 \text{kg}$$

Question 39

Design a sludge digestion tank with following data.
Average flow of sewage = 60×10^6 lit/day.
Total suspended solids = 350mg/L.
Volatile suspended solids =250 mg/L.
Moisture content of digested =87% sludge
Assume suitable data necessary.

Ans. Assuming 65 % removal in PST and the fresh sludge has water content of 95 %.

Volume of sludge collected in PST,

$$V = \frac{65}{100} \times \frac{350}{1000} \times \frac{60 \times 10^6}{1} \times \frac{100}{5} \times \frac{1}{10^3}$$

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$$= 273000 \text{ liter}$$

$$= 273 \text{ m}^3/\text{day}$$

Volume of digested sludge at 87% moisture content

$$273 = \frac{V_1(100 - 87)}{(100 - 95)}$$

$$273 \times 5 = 13V_1$$

$$V_1 = 105 \text{ m}^3/\text{day}$$

Assuming digestion period = 30 days

$$\text{Capacity} = t\left[V - \frac{2}{3}[V - V_1]\right]$$

$$= 30\left[273 - \frac{2}{3}(273 - 105)\right]$$

$$= 4813.2 \text{ m}^3$$

Providing 6m depth

∴ $$\text{Area of tank} = \frac{4813.2}{6}$$

$$= 802.2 \text{ m}^2$$

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

$$802.2 = \frac{\pi}{4} d^2$$

$$d = 31.3 \text{m}$$

Provide 6m deep and 31.3 m diameter sludge digestion tank.

Question 40

Town with a population of 30.000 has to design a sewages treatment plant to handle industrial as well as domestic wastewaters of the town. A sanitary survey revealed the following. Dairy wastes of 3 million liters per day with BOD of 1100 mg/l. And sugar mill waste of 2.4 million liters per day with BOD of 1500 mg/l are produced. In addition, domestic sewage is produced at the rate of 240 liters per capita per day. The per capita BOD of domestic sewage being 72 gm/day. An overall expansion factor of 10 percent is to be provided. The sewage effluents are to be discharged to a river stream with a minimum dry weather flow of 4500 litre per second and a saturation dissolved oxygen content of 9 mg/l. It is necessary to maintain dissolved oxygen content of 4 mg/l in the stream. Determine the degree of treatment required to be given to the sewage. Assume suitable values of coefficients of de oxygenation and re oxygenation.

Ans. Per capita B.O.D of the domestic sewage,

$$= 72 \text{ gm/day}$$

$$= 72 \times 1000 \text{ mg/day}$$

The per capita sewage produced,

$$= 240 \text{ litre/day}$$

∴ B.O.D per litre of the domestic sewage,

$$= \frac{72 \times 1000}{240} \text{mg/l}$$

$$= 300 \text{ mg/l}.$$

Amount of domestic wastewater produced per day,

$= 30.000 \times 240$ litres

$= 7.2$ million litres

Net B.O.D of all wastewaters (i.e., domestic + industrial)

$$= \left[\frac{7.2 \times 300 + 3 \times 1100 + 2.4 \times 1500}{7.2 + 3 + 2.4}\right]$$

$= 179\ mg/l.$

Total wastewater discharge

$$= \frac{\text{Vol. of wastewaters entering per day}}{\text{No. of secs in 1 day}}$$

$$= \frac{3ML + 2.4ML + 7.2ML}{1 \times 24 \times 60 \times 60sec} \frac{12.6 \times 10^6}{24 \times 3600} l/s$$

Total wastewater discharge with 10% expansion factor

$= 1.1 \times 145.8\ l/s$

$= 160\ l/s$

Initial D.O of saturated stream water,

$= 9\ mg/l$ (i. e saturation D. O as given)

∴ D.O of mixture at t = 0 i.e., at start point

$$= \frac{\text{D. O of river} \times Q_R. \text{ of sewage} \times Q_S}{Q_R + Q_S}$$

$$= \frac{9 \times 4500 + 0 \times 160}{4500 + 160}$$

(Assuming that the D.O of wastewater is Nil)

$= 8.69\ mg/l$

Initial D.O deficit

$= D_o = 9 - 8.69$

(Assuming instantaneous mixing)

$= 0.31$ mg/l

We have

$$\left[\frac{L}{D_c.f}\right]^{f-1} = f\left[1 - (f-1)\frac{D_o}{L}\right]$$

Where $D_c = 5$ mg/l,

$D_c = 0.31$ mg/l,

$k_D = 0.1 : k_R = 0.3 : f = 3$

(Assumed values at mix. temp)

∴ $$\left[\frac{L}{5 \times 3}\right]^2 = 3\left[1 - \frac{2 \times 0.31}{L}\right]$$

Solving by hit and trial,

$L = 25.65\ mg/l$

Max. Permissible 5 day B.O.D of mix at mix temp,

$= y_5 = L[1 - (10)^{-1.0 \times 5}]$ (K_D at mix temp.is assumed −0.1)

$= 0.684L$

$= 0.684 \times 25.65$

$= 17.54\ mg/l$

We have

$$C = \frac{C_S Q_S + C_S Q_R}{Q_S + Q_R}$$

We get $17.54 = \frac{C_s \times 160 + 0 \times 4500}{160 + 4500}$

Where C_S = max. permissible B. O. D_5 of wastewaters

or $C_S = 510.99\ mg/l.$

∴ Permissible B.O.D of wastewaters

$= 510.99\ mg/l$

Initial B.O.D of city wastewater

$= 719\ mg/l$

∴ Degree of treatment required

$$= \frac{719 - 510.99}{719}$$

$= 28.93\%$ **Ans.**

Question 41

A waste water effluent of 560 l/s with a BOD = 50mg/l, Do = 3.0mg/l and temperature of 23°C enters a river where the flow $28m^3/sec$, and BOD= 4.0 mg/l, DO = 8.2 mg/l, and temperature of 17°C. k_1 of the water is 0.10 per day at 20°C. The velocity of water in the river downstream is 0.18m/g and depth of 1.2m. Determine the following after mixing of waste water with the river water,

(i) Combined discharge,

(ii) BOD,

(iii) DO, and

(iv) Temperature.

Ans.

Particulars of Sewage thrown	Particulars of River
$Q_s = 560\ l/s$	$Q_R = 28\ m^3/sec$
$= 0.56\ m^3/sec$	Concentrations (C_R)
Concentrations (C_s)	BOD = 4.0 mg/ l
BOD = 50 mg/ l	Do = 8.2 mg/l
Do = 3.0 mg/ l	Tempt. = 17°
Temp.= 23°C	

(i) Combined discharge

$Q_S + Q_R$

$= 0.56 + 28$

$= 28.56\ m^3/sec.$

Now, using equation for cone of mix as

$$C = \frac{C_S.Q_S + C_R.Q_R}{0.56 + Q_R}, \text{ we have}$$

(ii) BOD of mix,

$$\frac{50 \times 0.56 + 4.0 \times 28}{0.56 + 28} = \frac{140}{28.56} = 4.9\ mg/l$$ Ans

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(iii) Do of mix

$$= \frac{3.0 \times 0.56 + 8.2 \times 28}{0.56 + 28} = 8.098 \text{ mg/}l. \text{ Ans.}$$

(iv) Temperature of mix

$$= \frac{23 \times 0.56 + 17 \times 28}{0.56 + 28} = 17.12°C.$$

Question 42

125 cumecs of sewage of a city is discharged in Perennial River which is fully saturated with oxygen and flows and minimum rate of 1600 cumecs with a minimum velocity of 0.1m/sec, if the 5 day BOD of the sewage is 300 mg/l, find out where the critical DO will occur in the river. Assume.

(i) The coefficient of purification of the river as 4.0,

(ii) The coefficient of DO as 0.11, and

(iii) The ultimate BOD as 125% of the 5 day BOD of the mixture sewage and river water.

Ans. Assume saturation D.O. Concentration of the given river = 9.2.

The D.O of the river at the mixing point after disposal of sewage (D),

$$= \frac{125 \times 0 + 1600 \times 9.2}{125 + 1600} = 8.53 \text{ mg/l}$$

Initial D. O deficit $(D_o) = D_S - D$

$= 9.2 - 8.53$

$= 0.67$ mg/l

BOD_5 of the river at the mixing point after disposal of sewage (y_5)

[As per given in assumption (iii)]

$= 1.25 \times 21.74$

$= 27.17$ mg/l

We have

$$BOD_5 = L\left[1 - (10)^{-k_D \times 5}\right]$$

$$\text{Or } 21.74 = 27.17\left[1 - (10)^{-k_D \times 5}\right]$$

$$\text{Or } 0.8 = \left[1 - (10)^{-5k_D}\right]$$

$$\text{Or } (10)^{-5k_D} = 0.20$$

$$\text{Or } -5k_D \log 10 = \log 0.20$$

$$\text{Or } k_D = 0.14$$

The coefficient of DO or BOD (k_D) is given in assumption No. (ii) to be 0.11, as against its values of 0.14 computed above on the basis of assumption (iii). Eventually, there is some inconsistency in the given data, and the examiner should have given only one of the two assumptions, i.e., either (ii) or (iii) which would have sufficed the question. Under such a difficult situation, we may solve the question by both the values of K_D i.e 0.11 as well as 0.14. The k_D value 0.14 will, however give more D.O deficit and will displace the point upstream, and will thus provide more conservative design values,

Case (1): When $k_D = 0.11$. Using eqn.

$$t_c = \frac{1}{K_D(f-1)} \log\left[\left\{1 - (f-1)\frac{D_o}{L}\right\} f\right]. \text{ We get}$$

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$$t_c = \frac{1}{0.11(4-1)} \log\left[\left\{1 - (4-1)\frac{0.67}{27.17}\right\} 4\right]. \text{ We get}$$

$= 1.723$ days.

The distances along the river, where the critical D.O deficit will occur

S = velocity × Time

$= 0.12$ m/sec × (1.723 × 24 × 3600 sec)

$= 17.86$ km ~ Say 18km

Hence, critical D.O deficit will occur at 18km downstream of the wage disposal point. Ans.

case (2): When $k_D = 0.14$

$$t_c = \frac{0.11}{0.14} \times 1.723 = 1.354 \text{days}$$

$$S = 17.86 \times \frac{1.354}{1.723} = 14.04 \text{km}$$

Hence, critical D.O deficit will occur at 14km downstream of sewage disposal point.

Question 43

A wastewater treatment plant disposes of its effluents into a stream at a point A. characteristics of the stream at a location fairly upstream of A and of the effluent are as below

Item	*Units*	*Effluent*	*Stream*
Flow	m^3/s	*0.20*	*0.50*
Dissolved oxygen	*mg/1*	*2.00*	*8.00*
Temperature	*°C*	*26*	*22*
BOD_5 *at 20°C*	*mg/1*	*40*	*3*

Assume that the reoxygenation content k_1 at 20°C (basee) = $0.20d^{-1}$ and the re-aeration constant k_2 at 20°C (base e) = $0.40-d^{-1}$ for the mixture. Equilibrium concentration of dissolved oxygen C_s for the fresh water is as follows:

Temperature °C	*18*	*20*	*22*	*23*	*24*	*25*	*26*
C, (mg/l)	*9.54*	*9.17*	*8.99*	*8.83*	*8.53*	*8.38*	*8.22*

The velocity of the stream downstream of the point a is 0.2 m/s determine the critical oxygen deficit and its locations.

[Use temperature coefficients of 1.04 for k_1 and 1.02 for k_2.

Ans. k_1 at 20°C (base e) = $0.2d^{-1}$

$= 0.2$ per day

$\therefore k_D$ at 20°C (base 10)

$$= \frac{k_1}{2.3} = 0.434k_1$$

$= 0.434 \times 0.2$ per day

$= 0.087$ per day

Similarly, k_R at 20°C

$= 0.434 \times 0.4d^{-1}$

$= 0.174$ per day

The formulas to be used in this question for converting k_D and k_1 at any other temperature (T°C) will be

$$k_D(T°) = k_D(20°)[1.04]^{T°-20°}; \text{ and}$$
$$k_D(T°) = k_R(20°)[1.02]^{T°-20°}$$

(As per the give values)

(i) We will now determine DO, BOD and temperature of mixture as below,

$$\text{DO of mixture} = \frac{\text{D. O. of sewage} \times Q_S + \text{DO of river} \times Q_R}{Q_S + Q_R}$$
$$= \frac{2 \times 0.20 + 8 \times 0.50}{0.20 + 0.50}$$
$$= 2.29 \text{ mg/l}$$

BOD_5 of mixture (i.e. 5 day BOD at 20°C)

$$= \frac{40 \times 0.20 + 3 \times 0.50}{0.20 + 0.50}$$
$$= 13.57 \text{ mg/l}$$

Temperature f mixture

$$= \frac{26 \times 0.20 + 22 \times 0.50}{0.20 + 0.50}$$
$$= 13.14°C$$

(ii) Ultimate BOD of mixture (L)

$$L = \frac{y_5(\text{i. e 5 day BOD of mixture at 20°C})}{1 - (10)^{-k_D \times 5}}$$

where k_D is at 20°C = 0.087 per day

$$= \frac{13.57}{1 - (10)^{-0.087 \times 5}}$$
$$= \frac{13.57}{0.633} = 21.45 \text{ mg/}l.$$

(iii) Initial D.O. Deficit of mixture,

D. O. of mixture = 6.29 mg/l

Saturation D.O at mixture temperature of 23.14°C = 8.79 (interpolated from given values)

$$\therefore \quad D_o = \text{D. O. deficit}$$
$$= 8.79 - 6.29$$
$$= 2.50 \text{ mg/}l$$

(iv) Corrected values of k_D and k_R are,

$$k_{D(23.14°)} = k_{D(20°)}[1.04]^{T-20}$$
$$= 0.087[1.04]^{3.14}$$
$$= 0.098$$
$$= 0.17[1.02]^{3.14}$$
$$= 0.185$$

(v) The time (t_c) after which critical D.O. deficit (D_o) occurs is given by eqn.

$$t_c = \frac{1}{k_D(f-1)} \log 10 \left[\left\{1 - (f-1)\frac{D_o}{L}\right\} f\right]$$

where $k_R = 0.185$

$k_R = 0.098$

$$\therefore \quad f = \frac{k_R}{k_D}$$
$$= \frac{0.185}{0.098} = 1.888$$
$$L = 21.45 \text{ mg/l}$$
$$D_o = 2.5 \text{ mg/l}.$$
$$\therefore \quad = \frac{1}{0.098(1.888-1)} \log 10 \left[\left\{1 - \frac{0.888 \times 2.5}{21.45}\right\} 1.888\right]$$
$$= \frac{1}{0.098(0.8888)} \times 0.228$$
$$= 2.625 \text{ days.}$$

(vi) Now, Distance = velocity × travel time 0.2 m/s × (2.625 × 24 × 60 × 60sec)
= 45.36 km/Ans.

(vii) D_c is now giving by eqn.

$$\left(\frac{L}{D_{c.f}}\right)^{f-1} = f\left(1 - (f-1)\frac{D_o}{L}\right)$$
$$\text{Or} \left(\frac{21.45}{D_c \times 1.888}\right)^{0.888} = 1888\left(1 - \frac{0.888 \times 2.5}{21.4}\right)$$
$$\text{Or} \quad \frac{21.45}{1.8888 D_c} = (1.692)^{\frac{1}{0.888}}$$
$$= (1.692)^{1.126} = 1.808$$
$$\text{Or } D_c = \frac{21.45}{1.888 \times 1.808}$$
$$= 6.28 \text{ mg/}l$$

Hence, the critical D.O deficit equal to 6.28 mg/l occurs at 45.36 km downstream of A, after 2.625 day.

CSVTU, APRIL-MAY 2013

(a) A coastal city produces MSW with high moisture content, organic materials, low calorific value and low inorganic material? The most effective option for MSW management is 2

(i)Composting (ii)Incineration (iii)Land Filling (iv) Ocean Dumping

Ans. ***Land filling***

(b) Draw and explain dexoygenation, reoxygenation, oxygen sag curve and BOD removal curve for a stream subject to waste water disposal. 7

Ans. ***Refer Question 17 Unit - 4***

(c) Explain the solid waste management scheme adopted for a city. 7

Ans. ***Refer Question 1 Unit - 5***

(d) Explain the treatment mechanism in a septic tank and soak pit with sketches. What are the precaution that should be taken while constructing the septic tank to ensure its efficiency?

Ans. ***Refer Question 59, 60 Unit – 2***

CSVTU, NOV-DEC 2012

(a) Define MCRT. 2

Ans. ***Refer Question 26 Unit - 3***

(b) 5-day 20°C BOD of a wastewater is 150 mg/L, what would be its 8-day 15°C BOD? Assume k = 0.23 at 20°C. 7

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Ans. *Similar to Question 32 Unit - 2*

(c) *Draw a schematic diagram of a domestic wastewater treatment plant showing various unit processes and operations and the purpose served each one of these.* 7

Ans. ***Refer Question 39 Unit - 2***

(d) *Describe the characteristics of waste generated from a sugar factory and also mention the treatment methodology to be adopted for such waste.* 7

Ans. ***Refer Question 28 Unit - 4***

CSVTU, APRIL-MAY 2012

(a) *Write the NRC formula for efficiency of trickling filter.* 2

Ans. ***Refer Question 4 Unit - 3***

(b) *Differentiate with neat sketches the difference in SRTF and HRTF.* 7

Ans. ***Refer Question 13 Unit - 3***

(c) *Write notes on:* 7

(i) *SVI & F/M Ratio* ***Refer Question 26 Unit - 3***

(ii) *Extended Aeration Process* ***Refer Question 28 Unit - 3***

(d) *With a neat sketch explain working, advantages and disadvantages of an oxidation ditch.* 7

Ans. ***Refer Question 35, 36 Unit - 3***

CSVTU, NOV-DEC 2011

Part - A

(a) *(i) Main gases generated during anaerobic digestion of sewage sludge.*

(1) CO_2 & CH_4 (2) CH_4, H_2S

(3) CO_2 & H_2S (4) None

Ans. ***Refer Question 12 Unit - 4***

(ii) Correct relationship given in as:

(1) TOD>BOD>COD (2) TOD>COD>BOD

(3) COD>BOD>TOD (4) BOD>COD>TOD

Ans. ***Refer Question 12 Unit - 4***

(b) *Write short notes on:* 7

i. *Stream standards & Effluent Standards.*

ii. *Equalization & Proportioning*

Ans. ***Refer Question 23, 24 Unit - 4***

(c) *The sewage discharge of a town is 1.72 m³/sec. If the sewage is discharged into a river, whose minimum discharge is 7240 lps. If the minimum DO to be maintained in the river is 4.4 mg/l, determine the degree of sewage treatment to be done. Temperature of sewage and river = 20°C.*

$k_1 = 0.1$ $k_2 = 0.5$ BOD_5 (S) = 225 mg/l BOD_5(R) = 1.2 mg/l

[at T = 20°C]

DOR = 80% DO_{sat} DO_{sat} 20°C = 9.17 mg/l

Ans. ***Refer Question 33 Unit - 4***

(d) *Write short notes on:* 7

i. *DO Sag Curve.* ***Refer Question 17 Unit - 4***

ii. *Zones of Pollution in a Stream.* ***Refer Question 18 Unit - 4***

iii. *TOC and THOD* ***Refer Question 14 Unit – 4***

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CSVTU, APRIL-MAY 2011

(a) *What is sewage sludge?* 2

Ans. ***Refer Question 1 Unit - 4***

(b) *Discuss the effect of pH and temperature on sludge digestion.* 7

Ans. ***Refer Question 7 Unit - 4***

(c) *Explain in brief various methods of final disposal of sludge.* 7

Ans. ***Refer Question 19 Unit - 4***

(d) *The domestic sewage of a town is to be discharged into a stream after treatment. Determine the maximum permissible effluent BOD and the percentage purification required in the treatment plant, given the following particulars:* 7

(i) *Population of town : 50, 000*

(ii) *D.W.F. of sewage : 150 litres/capita/day*

(iii) *BOD contribution per capita : 0.075 kg/day*

(iv) *Minimum flow of stream : 0.20 m³/s*

(v) *BOD of stream : 3 mg/l.*

(vi) *Max. BOD of stream on downstream: 5 mg/l.*

Ans. ***Refer Question 32 Unit - 4***

CSVTU, NOV-DEC 2010

(a) *What do you mean by stream standards?* 2

Ans. ***Refer Question 15 Unit - 4***

(b) *Discuss the anaerobic digestion of the sludge.* 7

Ans. ***Refer Question 10 Unit - 4***

(c) *Describe the characteristics of waste generated from a distillery and also mention the treatment methodology to be adopted for such waste.* 7

Ans. ***Refer Question 29 Unit - 4***

CSVTU, APRIL-MAY 2010

(a) *Explain disposal by dilution in brief.* 2

Ans. ***Refer Question 19 Unit - 4***

(b) *Differentiate between aerobic and anaerobic digestion. Explain the biological mechanism and its various stages for anaerobic digestion.* 7

Ans. ***Refer Question 8 & 11 Unit - 4***

(c) *Discuss various standards applicable to waste water treatment in brief. What are the general logic behind these standards?* 7

Ans. ***Refer Question 24 Unit - 4***

(d) *Describe the characteristics of waste generated from a sugar factory and also mention the treatment methodology to be adopted for such waste.* 7

Ans. ***Refer Question 28 Unit - 4***

CSVTU, NOV-DEC 2009

(a) *What is self purification of a river?* 2

Ans. ***Refer Question 15 Unit - 4***

(b) *Differentiate between aerobic and anaerobic digestion. Explain the biological mechanism and its various stages of anaerobic digestion.* 7

Ans. **Refer Question 8 & 11 Unit - 4**

(c) *The rate of flow in river is 3 cum/sec and has a BOD_5 of 2mg/L. The river is saturated with D.O. of 9.2 mg/L at 20°C. Waste water having BOD_5 of 120 mg/L and D.O. content zero with a flow rate of D. 30 cum/sec is discharged into river. Assuming temperature of 20°C throughout and deoxygenation coefficient as 0.1 day and reoxygenation coefficient of 0.3/day. Find out the degree of treatment required if the minimum DO to be maintained in the river is 4 mg/L.* 7

Ans. **Refer Question 34 Unit - 4**

(d) *Why there is need to adopt effluent standards for waste water disposal in surface water bodies? Why these standards differ for disposal into a public sewer? What are stream standards?* 7

Ans. **Refer Question 24 Unit - 4**

CSVTU, April-May 2009

(a) *What do you understand by digestion of sludge?* 2

Ans. **Refer Question 4 Unit - 4**

(b) *Explain the factors affecting the sludge digestion.* 7

Ans. **Refer Question 7 Unit - 4**

(c) *The sewage discharge of town 1.72 cum/sec. If the sewage is discharged into river whose minimum discharge is 7240 litres/sec. If the minimum dissolved oxygen to be maintained in the river ip 4.4 mg/litre, determine the degree of sewage treatment to be done with the following data:* 7

(i) *Temperature of sewage = Temperature of river = 20°C*
(ii) *Value of k_1 = 0.1 and value of k_2 = 0.5*
(iii) *5 days BOD at 20°C of sewage = 225 mg/l*
(iv) *5 days BOD at 20°C of river = 1.2 mg/l*
(v) *Dissolved oxygen in sewage = zero*
(vi) *Dissolved oxygen at saturation in river = 80%*
(vii) *Saturation D.O. at 20°C = 9.17 mg/l*

Ans. **Refer Question 33 Unit - 4**

(d) *Explain the characteristic of Industrial waste water.* 7

Ans. **Refer Question 21 Unit - 4**

CSVTU, Nov-Dec 2008

(a) *What do you understand by digestion of sludge?* 2

Ans. **Refer Question 4 Unit - 4**

(b) *Explain the important factors which affect the process of sludge digestion.* 7

Ans. **Refer Question 7 Unit - 4**

(c) *A town discharges 80 cumecs of sewage into a stream having a rate of flow of 1200 cumecs during lean days, at a 5 day BOD of sewage at given temperature is 250 mg/l. Find the amount of critical deficit and is location in downstream portion of stream. Assume de-oxygenation coefficient k as 0.1 and coefficient of self purification (f_s) as 3.5. Assume saturation DO at given temperature as 9.2 mg/l.* 7

Ans. **Refer Question 35 Unit - 4**

(d) *A sedimentation tank treat 6 MLD containing 250 mg/l of suspended solid. The tank removes 60% of the suspended solids. Compute the weight and volume of sludge produced daily it the moisture content of sludge is (i) 97.5% (ii) 95%.* 7

Ans. **Refer Question36 Unit - 4**

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Unit - 5

Solid Waste Management

Solid waste also known as dry refuse includes house refuse, trade refuse and street refuse.

Question 1

Define solid waste. Write a brief note on solid waste management and explain what the 3-R strategy for waste management is? *(CSVTU, April-May 2011)*

Or

Define solid waste management.

Or

Explain 4R's of Solid Waste Management in detail. *(CSVTU, Nov-Dec 2012)*

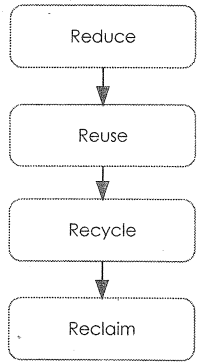
Ans. **Solid Waste**

Solid waste also known as dry refuse includes house refuse, trade refuse and street refuse. Reduce, Reuse, Recycle and Reclaim are the 4R's of solid waste management.

Solid Waste Management

Solid waste management is defined as the discipline associated with the control of generation, storage, collection, transfer and transport, processing, and disposal of solid waste in a manner that is in accord with the best principles of public health, economic, engineering, conservation, aesthetics and other environment considerations.

Reduce, reuse, recycle and reclaim (4R's)



4 R's of Solid Waste Management

The 4R's represent, in order of priority, the steps for responsible waste management: reduce at the source, reuse, recycle and reclaim. These steps help reduce waste of natural resources, while cutting down greenhouse gas emissions generated by transport and land filling.

A. Reduce at the source

Source reduction is the most effective step of the 4R's because it encourages people to think about their consumption. The following principle should always be borne in

mind: *the easiest waste to manage is waste that it is not generated in the first place.* Reducing consumption automatically creates less waste, and reduces use of natural resources and energy to produce new goods and products. There are a number of ways to achieve reductions at the source, for example, by avoiding single-use products. An effective strategy for achieving this goal involves setting clear and measurable targets, implementing appropriate measures and periodically assessing progress. This approach makes it easier to target efforts and measure their outcomes.

Example: Reducing paper use

Ways to reduce paper use include:

- Programming automatic double-sided printing or setting up a dedicated printer using paper already printed on one side
- Using single spacing
- Reducing margins
- Printing as little as possible

B. Reuse

Reusing means finding a second life for a product or using it repeatedly without necessarily transforming its appearance or properties. Repairing an item, using used goods or finding other uses for an item are various examples of reuse. According to Recyc-Québec, reuse has impacts on the three areas of sustainable development (the economy, society and the environment) since it helps create jobs, helps preserve natural resources and redistributes goods through resale at second-hand stores.

C. Recycle

Recycling means transforming waste in order to create new products rather than using virgin material. For example, plastic bottles are used to make polar fleece garments and aluminum from cans is melted down to make new cans.

D. Reclaim

Reclaiming means deriving value that would otherwise go to waste from an item that has reached the end of its useful life; it means using some of the properties of waste through conversion or transformation. Biological treatments such as composting and anaerobic digestion as well as heat treatment (such as gasification and pyrolysis) are examples of waste reclamation.

The breakdown of organic matter, usually table and garden waste, causes acidification of the environment and generates biogas. When this waste is land-filled, the acid solution created travels via runoff and contaminates groundwater and surface water. In addition, land-filled organic matter, decomposing without oxygen, generates biogas composed primarily of carbon dioxide and methane that contributes to the greenhouse effect. Various other elements present in small quantities contribute to acid rain as well as releasing volatile organic compounds (VOCs).

Reclaiming this organic matter is therefore an important tool for controlling climate change. Depending on the size of your organization, whether or not it provides food services and the number of visitors and employees, you can opt for on-site backyard composting, vermicomposting or, for larger volumes, hiring a company that runs a large-scale composting operation.

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Measures to Reduce 4R's

1. All residents should be asked to reduce generation of food waste as far as possible. They should be asked to hand over food waste to animal breeders for feeding animals, if possible.
2. Usage of hard to recycle packaging material like PET bottles, metalized plastic films and multi film packs should be discouraged.
3. Usage of thin polythene bags (less than 20 micron) should be prohibited.
4. All floating population should be instructed not to liter any waste and minimize waste generation in the city to keep it clean and green. Such instructions may be given at bus stands, railway stations and other public places through display boards.
5. All vendors and shops should be asked to request customers to use carry bags and they should resist from providing plastic bags, if the weight of purchases is less than 1 kg. Even for purchases weighing more than 1 kg, provision of free plastic bags should not be there. Each plastic bag should be charged up to 50 paisa.

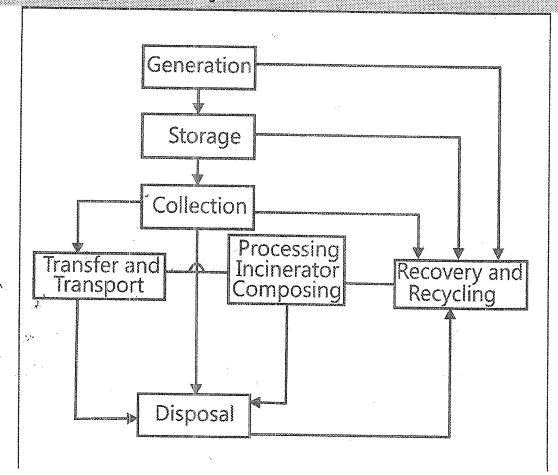
Question 2

What is municipal solid wastes management? Define and explain.

Ans. **Solid wastes management** - It involves management of activates associated with generation, storage, collection, transfer & transport, processing and disposal of solid wastes which is environmentally compatible considering principal of economy, aesthetics, energy & conservations.

Municipal Solid Wastes (MSW) - Municipal solid wastes includes wastes generated in residential & commercial areas, whereas wastes from industrial & agricultural operations are separately considered.

Solid Waste Management System



Reduce the waste generation at source, reuse it by making some other useful product out of the waste or in the same form but with different application or hand it over to recyclers for recycling. The Solid Waste Management Committee should emphasize on spreading awareness in general public on this account.

Waste management system is integration of services like collection, transport, processing, recycling or disposal, and monitoring of waste materials. Operations strategy can be viewed as part of a planning process that coordinates operational goals with those of the larger organization. Since the goals of the larger organization change over time, the operations structure must be designed to anticipate future needs.

Functional elements of management:

(1) **Generation** - Wastes differ in the rate of generations, quantity & quality depending upon the area of generation. This will affect selection of method for its collection, processing & disposal.

(2) **Storage** - The generated waste is stored within the premises for the short period & then transfer to community storage bin or directly to the treatment or disposal site.

(3) **Collection** - Waste produced from individual households i removed initially by the owner or an employee & later by municipal staff. Wastes from the streets are collected & removed by the conservancy staff.

(4) **Transportations** - The material collected in community dust bins is transferred to transport vehicles for transport to the processing or disposal site. In big cities the material is conveyed to a transfer station from where another set of vehicles transport it further to the disposal site.

(5) **Processing (Treatment) & recovery** - A large quantity of wastes has to be processed before suitable disposal to reduce its potential nuisance value. Occasionally recovery of useful constituents is also carried out as an independent process.

(6) **Disposal** - The wastes may come for disposal either directly after its transpiration or after processing, disposal could be on land or water logged areas for reclamation.

Question 3

Solids present in sewage are mainly in the form of:

i. Settled Solids.
ii. Dissolved Solids.
iii. Suspended Solids.
iv. Colloidal Solids. *(CSVTU, Nov-Dec 2011)*

Ans. Dissolved Solids

Question 4

Give details about the average composition of municipal solid waste of an Indian city. *(CSVTU, Nov-Dec 2010)*

Or

Write the percentage composition of various components in a domestic waste in an average Indian city? *(CSVTU, April-May 2013)*

Ans. The quantity and composition of refuse varies from place to place and also varies from season. Ashes increase in winter and in Northern latitudes while these are less in summer and in hot tropical countries. The quantity of garbage depends upon the food available food habits and standard of living. It also depends upon whether the town is residential, commercial or industrial. For an average Indian city, quantity of refuse

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varies from 0.4 to 0.5 kg per capita per day. The average composition of refuse by weight is about 25% cinder, 27% fine dust 15% ashes, 4% empty tins and cans, 14% putrescible matter, 2% glass and crockery, 2% rags, 1% bone and 8% miscellaneous matter. Organic wastes are generally 55% while inorganic wastes are 45%. Following table gives an average composition of refuse (by weight) for an average Indian city and average American city, at the disposal site.

S. No	*Constituent*	*Average Composition % by weight at disposal site Typical Indian City*	*Typical U.S.A.*
1.	Garbage	55	25
2.	Rubbish	15	55
3.	Ashes	10	10
4.	Dust, silt sand	20	10
	a) Unit weight (Kg/m^3)	350-600	250-300
	b) Calorific value (Kilo cal /Kg.)	1500-1800	3000

Question 5

Give a general idea about the per capita per day quantity of solid waste generated in India and some western countries. *(CSVTU, Nov-Dec 2010) (CSVTU, April-May 2010)*

Ans. In India, the per capita generation of the solid waste is about 0.4- 0.5 /kg /capita where as in USA is 0.69 kg/capita/day and china it varies from 1.2 to 1.42 kg/capita /day.

Question 6

Explain the term 'refuse' and give its composition and classification. *(CSVTU, April-May 2010) (CSVTU, Nov-Dec 2009)*

Ans. Refuse is a general term used to indicate what is rejected or left out as worthless. It may be in liquid, semi-solid or solid form. Refuse is classified into three classes.

1. **House refuse:** It mainly consist of vegetable and animal waste matters, ashes, cinders, rubbish, debris from cleaning and demolition of structures.
2. **Street Refuse:** This consist of empty packets and bottles, empty matches and cigarette boxes, fruit peels, tree leaves street sweepings etc.
3. **Trade Refuse:** This mainly consist of solid waste from the factories, commercial and business centers slaughter house etc.

The composition of the refuse is as given in the table below.

S. No	*Constituent*	*Average Composition % by weight at disposal site Typical Indian City*	*Typical U.S.A.*
1.	Garbage	55	25
2.	Rubbish	15	55

3.	Ashes	10	10
4.	Dust, silt sand	20	10
	a) Unit weight (Kg/m^3)	350-600	250-300
	b) Calorific value (Kilo cal /Kg.)	1500-1800	3000

Environmental and health implications:

When solid waste is disposed off on land in open dumps or in improperly designed landfills (e.g. in low lying areas), it causes the following impact on the environment.

a) Ground water contamination by the leachate generated by the waste dump.
b) Surface water contamination by the run-off from the waste dump.
c) Bad odor, pests, rodents and wind-blown litter in and around the waste dump.
d) Generation of inflammable gas (e.g. methane) within the waste dump.
e) Bird menace above the waste dump which affects flight of aircraft.
f) Fires within the waste dump.
g) Erosion and stability problems relating to slopes of the waste dump
h) Epidemics through stray animals.
i) Acidity to surrounding soil.
j) Release of green house gas.

5.1 Classification of Solid Waste

Question 7

Explain the classification of solid waste.

Or

Differentiate between "Garbage" and "Refuse". *(CSVTU, April-May 2012)*

Ans.

1. **Domestic/Residential Waste:**
This category of waste comprises the solid wastes that originate from single and multi-family household units. These wastes are generated as a consequence of household activities such as cooking, cleaning, repairs, hobbies, redecoration, empty containers, packaging, clothing, old books, writing/new paper, and old furnishings. Households also discard bulky wastes such as furniture and large appliances which cannot be repaired and used.
2. **Municipal Waste:**
Municipal wastes include wastes resulting from municipal activities and services such as street waste, dead animals, market waste and abandoned vehicles. However, the term is commonly applied in a wider sense to incorporate domestic wastes, institutional wastes and commercial wastes.
3. **Commercial Waste:**
Waste included in this category are solid wastes that originate in offices, wholesale and retail stores, restaurants, hotels, markets, warehouses and other commercial establishments. Some of these wastes are further classified as garbage and others as rubbish.

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4. **Institutional Waste:**
Institutional wastes are those arising from institutions such as schools, universities, hospitals and research institutes. It includes wastes which are classified as garbage and rubbish as well as wastes which are considered to be hazardous to public health and to the environment.
5. **Garbage:** *(CSVTU, Nov-Dec 2012) (CSVTU, April-May 2012)(CSVTU, Nov-Dec 2009)*
Garbage is the term applied to animal and vegetable wastes resulting from the handling, storage, and sale, preparation, cooking and serving of food. Such wastes contain putrescible organic matter, which produces strong odors and therefore attracts rats, flies and other vermin. It requires immediate attention in its storage, handling and disposal.
Refuse: *(CSVTU, April-May 2012) (CSVTU, April-May 2009) (CSVTU, Nov-Dec 2008) (CSVTU, Nov-Dec 2012)*
Refuse is a general term used to indicate what is rejected or left out as worthless. It may be in liquid, semi-solid or solid form. Examples include waste from residential sources like old broken furniture. The difference between garbage and refuse is that a refuse can be recycled or reused whereas garbage cannot be recycled.
6. **Rubbish:**
Rubbish is a general term applied to solid wastes originating in households, commercial establishments and institutions, excluding garbage and ashes.
7. **Ashes:**
Ashes are the residues from the burning of wood, coal, charcoal, coke and other combustible materials, for cooking and heating in houses, institutions and small industrial establishments. When produced in large quantities at power generating plants and factories these wastes are classified as industrial wastes. Ashes consist of a fine powdery residue, cinders and clinker often mixed with small pieces of metal and glass.
8. **Bulky Wastes:**
In this category are bulky household wastes which cannot be accommodated in the normal storage containers of households. For this reason they require special collection. In developed countries bulky wastes are large household appliances such as cookers, refrigerators and washing machines as well as furniture, crates, vehicle parts, tyres, wood, trees and branches. Metallic bulky wastes are sold as scrap metal but some portion is disposed of at sanitary landfills.
9. **Street Sweeping:**
This term applies to wastes that are collected from streets, walkways, alleys, parks and vacant lots. In the more affluent countries manual street sweeping has virtually disappeared but it still commonly takes place in developing countries, where littering of public places is a far more widespread and acute problem. Mechanized street sweeping is the dominant practice in the developed countries. Street wastes include paper, cardboard, plastic, dirt, dust, leaves and other vegetable matter.

10. **Dead Animals:**
This is a term applied to dead animals that die naturally or accidentally killed. This category does not include carcass and animal parts from slaughterhouses which are regarded as industrial wastes. Dead animals are divided into two groups, large and small. Among the large animals are horses, cows, goats, sheep, hogs and the like. Small animals include dogs, cats, rabbits and rats. The reason for this differentiation is that large animals require special equipment for lifting and handling during their removal. If not collected promptly, dead animals are a threat to public health because they attract flies and other vermin as they putrefy. Their presence in public places is particularly offensive and emits foul smell from the aesthetic point of view.
11. **Construction and Demolition Wastes:**
Construction and demolition wastes are the waste materials generated by the construction, refurbishment, repair and demolition of houses, commercial buildings and other structures. It mainly consists of earth, stones, concrete, bricks, lumber, roofing materials, plumbing materials, heating systems and electrical wires and parts of the general municipal waste stream, but when generated in large amounts at building and demolition sites, it is generally removed by contractors for filling low lying areas and by urban local bodies for disposal at landfills.
12. **Industrial Wastes:**
In the category are the discarded solid material of manufacturing processes and industrial operations. They cover a vast range of substances which are unique to each industry.
13. **Hazardous Wastes:**
Hazardous wastes may be defined as wastes of industrial, institutional or consumer origin which, because of their physical, chemical or biological characteristics are potentially dangerous to human and the environment.
14. **Sewage Wastes:** The solid by-products of sewage treatment are classified as sewage wastes.

5.2 Characteristics of Solid Waste

Question 8

Explain the characteristics of Municipal Solid Wastes. *(CSVTU, April-May 2012)*

Ans. The composition and characteristics of municipal solid wastes vary throughout the world. Even in the same country it changes from place to place as it depends on number of factors such as social customs, standard of living, geographical location, climate etc.

A. **Physical Characteristics:**

1. **Density:** knowledge of the density of a waste i.e. its mass per unit volume (kg/m³) is essential for the design of all elements of the solid waste management system viz. Community storage, transportation and disposal. For example, in high income countries, considerable benefit is derived through the use compaction vehicles on collection routes, because the waste is typically of low density. However, in India due to higher initial density the compaction ratio obtained rarely exceeds 1.5.

2. **Moisture Content:** Moisture content is a critical determinant in the economic feasibility of waste treatment and processing methods by incineration since energy (e.g. heat) must be supplied for evaporation of water and in raising the temperature of the water vapor. A considerable amount of energy is used before the waste is incinerated. Climatic conditions apart, moisture content is generally higher in low income countries because of the higher proportion of food and yard waste.
Moisture content of solid wastes is usually expressed as the weight of moisture per unit weight of wet material.

$$\text{Moisture Content (\%)} = \frac{wet\ weight - dry\ weight}{wet\ weight} \times 100$$

3. **Particle Size:** The size distribution of waste constituents in the waste stream is important because of its significance in the design of mechanical separators and shredder and waste treatment process.
4. **Calorific Value:** Calorific value is the amount of heat generated from combustion of a unit weight of a substance, expressed as kcal/kg. The calorific value is determined experimentally using Bomb calorimeter in which the heat generated at a constant temperature of 25 °C from the combustion of a dry sample is measured.

B. **Chemical Characteristics:** Knowledge of chemical characteristics of waste is essential in determining the efficacy of any treatment process. Chemical characteristics include (i) chemical; (ii) bio-chemical; and (iii) toxic Chemical characteristics include pH, Nitrogen, Phosphorus and Potassium (N-P-K), total Carbon, C/N ratio, calorific value. The Nitrogen, Phosphorus and Potassium content of municipal solid waste ranges between 0.5 -0.7%, 0.5 - 0.8 % and 0.5 -0.8 % respectively. The calorific value ranges between 800-100 kcal /kg.

5.3 Collection of Solid Waste

Question 9

Describe briefly the various methods employed for the collection and disposal of the refuse. *(CSVTU, Nov-Dec 2012)*
(CSVTU, Nov-Dec 2011) (April-May 2011) (CSVTU, April-May 2010)

Or

Discuss the methods being adopted in India for collection and disposal of refuse. *(CSVTU, Nov-Dec 2009)*

Or

Detail the methods of collection and conveyance method of Solid Waste. *(CSVTU, April-May 2013) (CSVTU, Nov-Dec 2008)*

Ans. Primary collection of waste is the second essential step of Solid Waste Management activity. Primary collection system is necessary to ensure that waste stored at source is collected regularly and it is not disposed of on the streets, drains, water bodies, etc. However, step has to synchronize well with the first step i.e. Storage of Waste at source.

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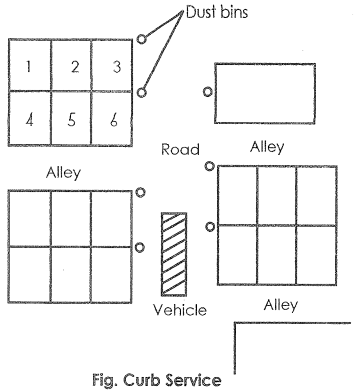


Fig. Curb Service

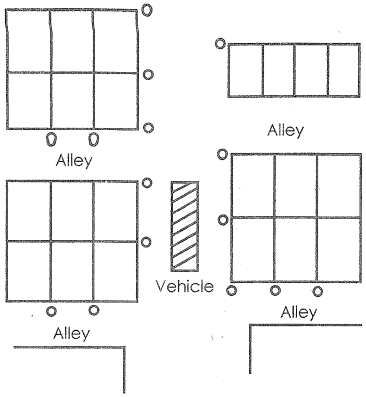


Fig. Alley Service

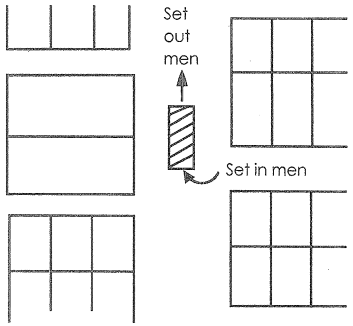


Fig. Set-out, Set-back service

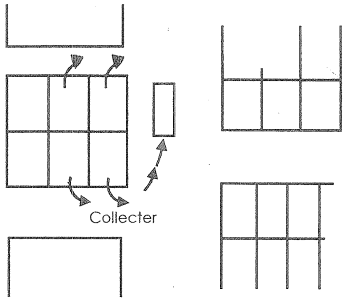


Fig. Back yard

Following are the methods of collection of solid waste.

1. **House to house collection:** In the house to house collection, refuse generated and stored in the individual premises is collected by several methods which are as follows:
2. **Curb Services:** The house owner is responsible for placing the refuse containers at the curb at the scheduled day. When the workmen from solid waste collection vehicles collect and empty the containers in the collection vehicle and place them back at the curb. The house owner is required to take back the empty containers to their house.
3. **Alley service:** The Containers are placed at the alley line from where they are picked up by workmen from solid waste collection vehicles who deposit back the empty containers.
4. **Set Out and Set back Service:** Set men go to individual houses, collect the containers and empty them in the solid waste vehicle. Another group of persons return them to house owner's yard.
5. **Set out service:** The workers of solid waste collection vehicles collect the containers from individual houses and empty them in the collection vehicles. The house owner is required to take back the empty containers.

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6. **Back yard service:** solid waste worker carry a bin, handcart or sack or cloth to the yard and empty the solid waste container in it. The handcart or bin is subsequently taken to solid waste collection vehicles where it is emptied.
7. **Community bin systems:**
   This system is commonly adopted in India where in community bins are located at street corners and at specific frequencies along the straight roads. The residents are expected to bring the waste and deposit in the community bins.
8. **Bell Ringing systems:**
   It is observed in some cities, in this system the collection vehicle is provided bell and on reaching specific points it is rung. Residents from adjoining areas come to the vehicle and deposit the waste in the vehicle. This system can work efficiently if the movement of the vehicle is appropriately and continuously controlled.

5.4 Transportation of Solid Waste

Question 10 (a)

Explain the transportation technique adopted in solid waste management. *(CSVTU, April-May 2012)*

Ans. The refuse collected in the public dust bins located by the sides of roads, is transport to the disposal site by means of following vehicles.

1. Auto-rickshaws 2. Trailers and 3. Trucks.

1. **Auto rickshaws:** These having three or four wheels, have covered bodies. Since their capacity is limited to ½ to ¾ tones, these are used only for those narrow localities where other heavy vehicles cannot go.
2. **Trailors:** Trailors have slightly larger capacity (2 to 3 tones) they are also used for localities where trucks cannot go. Loading of trailors is done manually. However, they are of tilting-tipping type and hence their unloading is done automatically with the help of hydraulically operated jacks.
3. **Trucks:** Trucks have larger capacity (5-10 tonnes). They are generally of tilting-tipping type so that unloading is automatic. Special types of trucks, capable of bodily lifting covered skip boxes (in place of ordinary dust bins) are now available, and should be used so as to avoid nuisance of files.

The vehicles employed for the transport of refuse should be of such pattern and design that collected garbage does not fall once again on the road during the transport. The vehicle should be strong durable and water tight. They should be made of steel with smooth interior surface and round edge and corners, so that they can be kept clean.

Processing of solid waste

The organic content of Municipal Solid Waste (MSW) tends to decompose leading to various smell and odor problems. It also leads to pollution of the environment. To ensure a safe disposal of the MSW it is desirable to reduce its pollution potential and several processing methods are proposed for this purpose.

5.5 Composting

Question 10 (b)

Explain the term composting. *(CSVTU, April-May 2011)*

Ans. Composting process is quite commonly used and results in production of a stable product - compost which depending upon its quality can be used as a low grade manure and soil conditioner

Question 11

Explain the transportation routes. How is it planned? *(CSVTU, April- may 2012)*

Ans. Presently in most of the cases, the routes of refuse vehicles are not properly designed but left to the vehicle operator or supervision to use his opinion. It is observed that out of total expenditure spent in solid wastes management, about 60-80% cost contributed to transportation of refuse itself. Therefore, if the routes of refuse vehicles are properly planned, the expenditure can be reduced & better service can be provided.

Following are the various method used for planning the refuse vehicle routes.

(1) **Heuristic Methods** - This is an old system of assigning the routes of refuse vehicles. The routes of refuse vehicles are determined on the basis of experience, and some simple rules. However, their efficiency depends upon the experience of the user. The macro routing is to be done first followed by route balancing & micro routing. In the macro routing, collection area are assigned to disposal facilities. A fair day's work has to be determined in terms of km to be travelled, trips made & tonnage to be hauled per day. Micro routing is then carried out by using heuristics. The factors to be considered in micro routing are:

i) Routes should not be fragmented or overlapped.
ii) Collection & transport time should be reasonably constant for each route so as to equalize the work load.
iii) The collection route should start as close to the garbage as possible taking into consideration heavily travelled routes.
iv) Routes having heavy traffic should be served before or after rush hours only
v) Sources where large waste quantities are-generated should be serviced during the first part of the day.
vi) Collection routes should be so arranged that the last bin, emptied is nearest to the disposal site in the route.

(2) **Deterministic Methods** - These methods use advanced mathematical techniques for obtaining the optimum route for, refuse vehicles. This method is widely used in developed countries. In this method the various information regarding location of collection bins, quantity collected in each individual bin, processing and disposal sites should be made available. This method also consists of macro scale studies. Macro scale studies involves the study & planning the system in order to evaluate alternate solution to the entire solid wastes problems involving generations, collection, processing & economic planning of the whole system. For these cases specific models have also been prepared. The various models prepared for this purposes are:-

i) Models for uniform and continuous generation of solid waste along the street.
ii) Models for use of transfer stations.

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Microscale studies are then carried out which consists of location and allotment of transfer stations to different processing & disposal sites. Preparing computer program for the various models & obtaining optimum routes for refuse vehicles.

(3) **Modi Methods** - The models so prepared in deterministic method are used in developed countries. But the models used in developed countries cannot be used directly in developing countries because the wastes collection along the street is not regular & continuous. The collection is not form house to house but from community bin. Also transfers stations are nearly used & refuse vehicles proceed directly to disposal site.

Therefore, NEERI prepared a suitable model for India condition for deciding the vehicles routes, such a model prepared by NEERI are called Modified Distribution (MODI) method.

In this method, it is assumed that the cost of transportation is directly proportional to the route length. Hence optimization is carried out for the length of route. In this method it is also assumed that every community bin visited at least once in a day an the quantity collected in a route should be equal to the cap city of the vehicle. As the number of collection points & vehicles are quite large in cities and towns, the above method can be used by preparing a computer program which will help to reduce the requirement & give optimum results.

In this study, macro scale studies consist of study of location of community bin, quantity collected in each community bin, different processing and disposal sites etc. Micro scale studies is then carried out which consist of preparing computer program and obtain optimum routes for refuse vehicles.

Question 12

State the requirements of transportation vehicle & list various types of transportation vehicles.

Ans.. **Requirements of transportations vehicles:**

Following are the various requirements of transportations vehicle:

i) It should have low loading height which in any case should not exceed 1.5 meters.
ii) It should have a facility for taking portable/exchangeable containers for house to house collection.
iii) It should have a covered body.
iv) It should have a tipping gear for quick unloading.
v) It should be reliable & economic in operation.
vi) It should have a sufficient carriage capacity.

Types of Transportation Vehicles:

Following vehicles are used for transpiration of refuse to the disposla site.

(1) **Animal Carts** - Carts driven by bullocks. Buffaloes are used in small towns & cities. The capacity of bullock cart is about 1m3 and due to, its slow speed, it tends to obstruct traffic on main roads.

(2) **Short Range Diesel Vehicles** - As a substitute for bullock carts for short haul small capacity transport vehicles of a number of designs have recently been introduced.

These are provided, with a small (5-7.5kP) diesel engine to carry 1-1.5 tonnes of material with low lading height (< 105m).

(3) **Tractor Trailer** - These are used in medium sized towns and cities. It has low initial cost & easy to operate. It consists of a trailer which hauled by a tractor. Sometimes two trailers can also be hauled by one tractor for economic operation.

(4) **Three Wheeler Auto Rickshaws** - Such type of vehicles with closed body are in use where the transportation distance is not very large. These vehicles can move in narrow lanes and bylanes. These are mostly petrol operated therefore the cost of transportation will be high.

(5) **Electric Vehicles** - These are in use in some developed countries & can operate over short radius of about 2km. The battery has to be charged overnight. These vehicles are available in India only to a limited extent due to its high capital cost.

(6) **Dumper Placer** - These unit are used for lifting of heavy materials specially demolition wastes. The vehicle is provided with winch mechanisms with the aid of which the bin is hoisted & placed on the body of the truck

(7) **Container Carrier system** - In this system, special types of containers are placed at the collection points. When It is full, the container are removed by a tractor prime-mover which has a hydraulically powered frame chassis. The chassis lifts the container & grips it firmly & transport it to the disposal site.

(8) **Special Municipal Vehicle** - It consists of a truck provided with special hydraulic arrangement for lifting, placing as well as unloading 8-10 cum container on a truck chassis. The container has low loading height with a number of flaps which are kept open for loading refuse. The prim-mover lifts & locks the container on the body for transpiration to processing/disposal site.

(9) **Trucks** - Various types of trucks have been commonly in use in most of the cities in India for transportation of refuse. These trucks make 2-4 trips per day covering about 20kms per tarp.

(10) **Compaction Vehicles** - In developed countries the compaction types of vehicles are in use which accept refuse having an initial density of 150-20 kg/m^3 & compact it by nearly 2-4 times. Such vehicles are costly & hence will not be economically viable. These are either of the hydraulically operated pressure plate type of mechanically driven screw impeller type.

Question 13

Explain the different methods of composting of municipal solid wastes.

(CSVTU, April-May 2012)

Or

Describe the Indore Method and the Bangalore Method of composting techniques.

(CSVTU, Nov-Dec 2011)

Or

Explain the term "composting". Give the different type of composting in use, and describe any one.

(CSVTU, April-May 2011)(CSVTU, April-May 2009) (CSVTU, Nov-Dec 2008)

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Ans. Composting process is quite commonly used and results in production of a stable product - compost which depending upon its quality can be used as a low grade manure and soil conditioner. The process results in conservation of natural resources and is an important processing method, especially in agricultural and horticultural areas. Composting is an organized method of producing compost manure by adopting this natural phenomenon. Compost is particularly useful as organic manure which contains plant nutrients (Nitrogen, Phosphorous and Potassium) as well as micro nutrients which can be utilized for the growth of plants.

Composting can be carried out in two ways i.e., *aerobically* and *anaerobically*. During aerobic composting, aerobic micro-organisms oxidize organic compounds to Carbon dioxide, Nitrite and Nitrate. Carbon from organic compounds is used as a source of energy while nitrogen is recycled. Due to exothermic reaction, temperature of the mass rises. During anaerobic process, the anaerobic micro organisms, while metabolizing the nutrients, break down the organic compounds through a process of reduction. A very small amount of energy is released during the process and the temperature of composting mass does not rise much. The gases evolved are mainly Methane and Carbon dioxide. An anaerobic process is a reduction process and the final product is subjected to some minor oxidation when applied to land.

Methods of Composting

There are three methods of composting.

(i) Composting by trenching

(ii) Open window composting

(iii) Mechanical Composting

Composting by trenching:

1. In this method, trenches 4 to 10 m long, 2 to 3 m wide and 0.7 to 1 m deep are excavated with a clear spacing of 2 m.
2. The trenches are then filled with refuse/garbage in layers of 15cm.
3. On the top of each layer, 5 cm thick sandwiching layer of night soil/animal dung is spread in semi-liquid form.
4. On the top layer, protruding 0.3 m above the original ground surface, a 10 cm layer of good earth is spread so that flies do not get access to the refuse and at the same time, the refuse does not get blown off by wind.
5. Within 2-3 days, intensive biological action starts to destroy/reduce organic matter present in the refuse.
6. In this process, considerable heat is generated and the temperature of the composting mass rises to about 75°C. Due to this reason, the breeding of flies does not take place.
7. The refuse gets stabilized in about 4-5 months period, and gets changed into a brown coloured odourless innocuous powdery form known as *humus*, which has high manure value because of its nitrogen content.
8. The stabilized mass is removed from the trenches, sieved through 12.5 mm sieve to

exclude coarse inert materials like stones, brick bats, broken stone etc.

9. The sieved material is then sold out as a manure.

Open Window Composting:

1. In this method, a large proportion of mineral matter like dust, stone, broken glass pieces etc. are first removed from the refuse.
2. The refuse is then dumped on the ground in the form of 0.6 to 1 m high, 6 m long and 1 to 2 m wide piles at about 60% moisture content.
3. The pile is then covered with night soil, cow dung, cattle urine etc. through which the organisms or germs that are necessary for fermentation are added.
4. Due to biological activity through aerobic bacteria, heat starts developing up to about 75°C in the refuse piles. Due to this, the microbial reaction shifts from mesophilic to thermophilic stage.
5. After this, the pile is turned up for cooling and aeration to avoid anaerobic reactions. The temperature of pile again rises to 75°C, and the process of turning, cooling and aeration is repeated.
6. The complete process may take about 4-6 weeks, after which the compost is ready for, use as manure when the temperature falls considerably.

Mechanical Composting:

1. The open window method of composting is very laborious and time consuming process. Also, it requires large area of land which may not be available in big cities. These difficulties are overcome by adopting *mechanical compositing* in which the process of stabilization is expedited by mechanical devices of turning the compost. The mechanical met nod stabilizes the refuse compost only within 3-6 days. The operations involved in a large scale composting plantare as follows:
   (1) Reception of refuse, (2) Segregation, (3) Shredding or pulverising, (4) Stabilisation, (5) Marketing the humus
2. The refuse is *received* at the plant site in quantities of 2 to 6 tonnes per vehicle. Hence the plant site must have a storage capacity of about 25 to, 50% of total daily, arrival, before it can be segregated and shredded/pulverized. *Segregation* is done by hand picking on smaller plants and by mechanical devices on large plants, to remove paper, rags, non-ferrous metals and large objects. Ferrous metals are removed by magnetic separators. Finer material such as ash, particles of garbage etc. are removed by passing the refuse over shaker-screens. The remaining refuse is then shredded and pulverized mechanically.
3. The *prepared refuse* is then decomposed or stabilized under controlled conditions of temperature and moisture content. Mechanical digestors of various types such as *(i))* Pits or cells *(ii)* Windows or stacks and *(iii)* Vertical cylinder, horizontal cylinder, or silo type closed digestors. Closed digestors are most hygienic and occupy less space. In these digestors, the refuse is digested and converted into humus and stable mineral compounds. The digestion period vary between 2 to 5 days for refuse containing low cellulose or low carbon-nitrogen (C/N) ratio, and 7-9 days for refuse having more

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quantities of cellulose or high (C/N) ratio. The stabilized brown mass (humus) is collected, sieved and sold in packets. Sometimes, the stabilized mass is enriched by adding chemical nutrients like phosphorous, nitrogen.

Composting Methods Used in India

1. **Bangalore Method:** This is an anaerobic method conventionally carried out in pits. Formerly the waste was anaerobically stabilized in pits where alternate layers of MSW and night soil were laid. The pit is completely filled and a final soil layer is laid to prevent fly breeding, entry of rain water into the pit and for conservation of the released energy. The material is allowed to decompose for 4 to 6 months after which the stabilized material is taken out and used as compost.
2. **Indore Method:** This method of composting in pits involves filling of alternate layers of similar thickness as in Bangalore method. However, to ensure aerobic condition the material is turned at specific intervals for which a 60 cm strip on the longitudinal side of the pit is kept vacant. For starting the turning operation, the first turn is manually given using long handled rakes 4 to 7 days after filling. The second turn is given after 5 to 10 more days. Further turning is normally not required and the compost is ready in 2 to 4 weeks. In the urban areas, due to extensive provision of water carriage system of sanitation, night soil is not available. Composting of MSW alone is hence often carried out. Aerobic composting of MSW is commonly carried out in windrows.

Question 14

State and explain the factors affecting composting process.

Ans. Factors affecting composting process are as follows:

(1) **Organisms:** Aerobic composting is a dynamic system in which bacteria, actinomycates, fungi and other biological forms are actively involved. It depends upon the constantly changing available food supply, temperature and substate conditions. In this process facultative and obligate aerobic form of bacteria, actinomycates and fungi are most active.

(2) **Use of culture:** When the environmental conditions are appropriate, indigenous bacteria, better adopted to municipal refuse than forms attenuated under laboratory conditions, rapidly and carry out necessary decompositions.

(3) **Moisture:** Moisture replaces air from the interspaces between particles. Too low a moisture content reduces the metabolic activity of organisms, whereas anaerobic conditions would set in if the moisture content is too high.

(4) **Temperature:** Temperature is one of the major factors which affect the compo sting process. In the temperature range of 50°C - 60°C high nitrification and cellulose degradation occur and destruction of pathogens and parasites is also ensured.

(5) **C/N ratio:** The progress of decomposition in a composting mass is greatly influenced by C/N value. C/N ratio is the ratio of available carbon to available nitrogen. Optimum value of C /N ratio lies between 26 and 31.

(6) **Addition of sewage and sewage slides:** When initial C/N ratio is high, sewages sludge C/N of 5 to 8 is added to keep C/N ratio of mixture at optimum levels.

(7) **Aeration:** Aeration by natural process occurs in the superficial layers of the composting mass. While the inner layers tend to progressively turn anaerobic as the rate of oxygen replenishment cannot keep pace with utilization. Hence necessary to bring the inner layers in content with oxygen which is accomplished by aeration by turning the material or by supplying compressed air.

Question 15

Write a short note on incineration of refuse. What are its advantages and disadvantages? *(CSVTU, April-May 2009)*

Ans. **Incineration:** It is the thermal processing of solid waste. It involves the direct burning of wastes in the presence of excess air (oxygen) at temperatures of about 800°C and above, liberating heat energy, inert gases and ash. Incineration of solid waste involves controlled combustion of the waste with specific amount of air to ensure that complete combustion occurs in a specific range of temperature in an enclosed space.

Products of incineration:

1. **Gaseous products:** The gases are formed during the process of combustion. If the combustion is complete CO_2, H_2O and SO_2 and N_2 will escape in the atmosphere through chimney.
2. **Solid Residue:** This contains the non –combustibles of the solid waste and ash resulting from combustion of waste. The residue is taken out through ash pit door located below the grates.
3. **Fly ash:** The fly ash mixed with the combustion gases due to the turbulence must be removed from the gases to avoid air pollution. Suitable air pollution control equipment must be provided for this purpose.

Question 16

Explain the three T'S of the incineration.

Ans. Time, Temperature and Turbulence are the three T's of the incineration.

1. **Time:** The volume of the combustion chamber should be so designed that the waste is retained inside for sufficient time to ensure complete combustion.
2. **Temperature:** Temperature has to be maintained at such values as to ensure complete combustion. If the calorific value of the waste is low, auxiliary fuel has to be added to attain the desired temperature for combustion.
3. **Turbulence:** The charge of the air has to be thoroughly mixed for ensuring complete combustion. It is normally achieved by creating necessary turbulence through changes in direction of flow and addition of the air at some point.

Feasibility of incineration:

The feasibility of incineration can be tested through three component diagram. The percentage of moisture in a sample of solid waste is found out. Then the combustible matter and ash for dry sample is calculated by normal procedure. These values are then plotted in the three component diagram. If the plotted point lies in the indicated zone the reaction is self sustaining. However this is the first approximation to assess the feasibility of the incineration and needs to be confirmed after detailed calculation.

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Question 17

Explain the advantages and disadvantages of incineration.

Ans. **Advantages of incineration**

1. This is the most hygienic method, since it ensures complete destruction of pathogens.
2. There is no odor trouble or dust nuisance.
3. The heat generated can be used for raising the steam power.
4. Clinker produced can be used for road purposes.
5. Less space is required for the disposal of residues.
6. Adverse weather condition has no effect on the incinerators capacity.
7. Disposal site can be located at convenient distance.

Disadvantages of incineration

Following are the disadvantage of incineration.

1. The cost of installation is very high.
2. Improper operation results in air pollution problems and incomplete reduction of the waste materials.
3. It is not suitable for the waste having high moisture content and low calorific value.
4. For small capacity plant overall efficiency is less.
5. It requires skilled supervision.

Question 18

Describe the various methods used for the ultimate disposal of the refuse. *(CSVTU, Nov-Dec 2011) (CSVTU, Nov-Dec 2009)*

Or

What are the different methods of disposal of solid refuse? Which one most popular in India? Explain the process in detail. *(CSVTU, April-May 2009)*

Or

Describe briefly method of refuse disposal by sanitary land filling? *(CSVTU, Nov-Dec 2008)*

Ans. Disposal of solid waste: After the collection, transportation and processing the solid waste is directly sent for disposal. Disposal can be made either in water body or in land.

Disposal in water:

Disposal in water can be made in

1. Flowing water
2. A stagnant water body like pond or lake
3. In ocean.

Disposal in water bodies like river, pond or lake is normally not considered as it tends to pollute the receiving water substantially.

Due to high organic content the dissolved oxygen of the receiving water body are depleted rapidly resulting in anaerobic conditions. However the floating materials like paper, plastic etc floats over the surface of water effects the aesthetic appearance of the water body.

Disposal in ocean is only feasible for the urban centers which are in coastal areas.

1. Bulky and lighter matter in the refuse may float spread out and tend to return to the shores during high tides,
2. During stormy weather and monsoons, it is not possible to send barges out into the sea, and
3. In spite of best care, some portion of refuse may return the shores and spoil them. Also the method is possible only in cases of coastal cities.

Controlled tipping:

This method is useful where adequate site for redevelopment is available. The method consists of tipping, coarse material is tipped at the bottom while fine material is tipped on the top. These tips are covered with soil, so as provide a seal under which bacterial decomposition takes place. At the end of about 12 months period, the decomposition is complete, due to which the tip settles down to a height of 30 cm only. Normally, an area of 0.3 to 0.5 m^2 per capita per year is required.

Trenching:

This method is generally adopted when low lying areas are not available. Trenches of size 4 to 10 m long, 2 to 3 m wide and 1 to 2 m deep are excavated with a clear spacing of 2 m. these trenches are then filled with refuse/garbage in layers of 15cm. on the top of each layer, 5 cm think sandwiching layer of night soil/animal dung id spread in semi liquid form. On the top layer producing 0.3 m above ground surface, 10 cm layer of good earth of other non-combustible material is spread to act as seal so that files do not get access and wind does not blow these off. The dumped garbage is converted into a type of compost solid waste disposal.

Pulverization:

In this method the dry refuse is pulverized into power form without changing its chemical form. The disposed of by land filling. In some countries the costly and hence not commonly used in India.

Disposal on land: Disposal of solid waste in low lying area is practiced since ancient time.

Sanitary Land Fill: A method of disposing of refuse on land without creating nuisance or hazard to the public health or safety by utilizing the principle of engineering to confine the refuse to smallest practical area to reduce it to smallest practical volume and to cover it with a layer of earth (Soil) at least at the conclusion of each day's work or at such more frequent intervals as necessary. The garbage is dumped into low lying areas of depressions available nearly. Dumping is done in layer of 1 to 2 m and each layer is covered by 0.2 m thickness of good earth. A rest of 2 to 3 weeks is given before dumping the second layer. If dry refuse is loosely packed, it may give rice to health hazards. Hence each layer should be compacted by movement of dumping vehicles, for its settlement before starting filling the second layer of refuse.

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5.6 Site Selection for the Landfill

Question 19

What points should be kept in mind while selecting site for landfill.

Ans. The following points are to be kept in mind while locating the site for landfills.

1. The site should at least 200 m away from the highway.
2. The site should not be a wet land and should not fall in coastal regular zone.
3. The ecological factors such as possible damage to the bird and animal habitat should also be considered.
4. The boundary of landfill site should be at a distance of at least 500 m from the nearest inhabited area.
5. As birds are often attracted towards the landfill sites posing the danger to aircraft therefore it should be at least 20 km away from the airports.
6. The landfill should not be constructed within 100 m of river.
7. The landfill should not be constructed within 300 m of Public Park.
8. The landfill should be constructed 500m outside of the dug well.

Question 20

Give the advantages and disadvantages of solid waste disposal by land filling.

(CSVTU, April-May 2011)

Ans. **Following are the advantages of land filling.**

1. It's simple and economical.
2. No Plant and equipment required.
3. Separation of various material of the refuse not required.
4. There are no by products and hence there is no problem of the disposal of the by-Product.
5. The low lying area can be and reclaimed and put to better use by this method.

Following are the disadvantages of land filling.

1. Proper site may not be available nearby.
2. Wind direction may not be favorable.
3. Large land areas are required.
4. It may be difficult to get large quantities of covering material.
5. Dumped garbage may be containing carcinogenic non biodegradable matter (such as Plastics, unused medicines, paints insecticides, sanitary napkins etc) cause trouble later because of leach ate coming out of dump during rainy season.
6. Leachate from dumped garbage may pollute surface water as well as ground water.

Question 21

Describe about the health implications of ill managed municipal solid waste.

(CSVTU, Nov-Dec 2010) (CSVTU, April-May 2010) (CSVTU, Nov-Dec 2009)

Ans. Impacts of improperly managed MSW

1. Improper removal and disposal of solid waste is proven cause of health hazards which may spread epidemics like plague, and water born diseases.

2. If proper leachate management system is not provide it will lead to the water contamination due to the leakage of leachate.
3. If proper closure is not provided at sanitary landfill many harmful gases may escape to the atmosphere leading to the air pollution.
4. It also results in the ground water contamination through the percolation of the leachate from the landfill.
5. If the waste is not properly handled it may cause skin diseases.
6. Due to the inhalation of the harmful gases it leads to the respiratory problems in the persons living in the vicinity of the area.
7. It results in the eye and respiratory infection due to exposure of infected dust.
8. Intestinal infection may transmitted by flies feeding on the waste.
9. Material account for an estimated 300 – 500 million cases globally which is an endemic disease in Sub – Saharan Africa.

Question 22

Explain the term refuse derive fuel.

Ans. **Refuse derived fuel (RDF):** As the solid waste form developed countries contains a large paper fraction, it was felt that it could be used as a good fuel. In the plant, the incoming refuse is first subjected to size reduction after which the magnetic metals are removed by a magnetic separation. The remaining material is then passed through a vertical flow air separator where paper is removed. The material is further subjected to size reduction and burnt in a boiler of 125MW plant. The suspension fired boilers are provided with clusters of 5 jet, 4 out of which use coal and the fifth uses refuse derived fuel (RDF).

Question 23

Explain the terms with regard to SWM

(i) Zero Waste
(ii) Mobius Loop Concept
(iii) LCA Studies *(CSVTU, April-May 2013)*

Ans.

Zero Waste

One of the best for environment friendly waste management is the thinking there should be no waste or minimum waste i.e., zero waste generation. Zero waste is a recent concept for reducing the solid waste. In some places of India to set up this process a beginning was made at sarita vihar in Delhi, where 73 % people in colony are participating.

Mobius Loop Concept

What's a möbius?

In 1858, German mathematician August Möbius gave a strip of paper a half twist and joined the ends to create an elegant loop—a mysterious, continuous surface with only one face. The Möbius loop, like solid waste system, has no beginning and no end.

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Is this what people call "zero waste"?

That's a term that means different things to different people. Sometimes it means using a lot and throwing away a lot, but finding novel ways to dispose off waste. In this concept certainly want people to recycle (and compost!)—but as a last resort. More importantly, it wants people to reduce and reuse.

What are the most important things one can do?

First, help make the loop as small as possible. Reduce what you use, and reuse what's left.

Second, think before you throw something away. There really is no "away"—that's just another word for landfill—so we keep making it easier and easier to recycle and compost.

Life Cycle Assessment (LCA) in Solids Waste Management

The LCA methodology is a holistic approach to impact assessment in two senses. Firstly, it attempts to include all known environmental impacts potentially arising from an activity. Secondly, it covers all stages in the life of a product, material or service. The method aims at covering all physical exchanges of a product or material's system, and thereby captures any transfer of impacts from one media to another.

Because of the characteristics mentioned above, LCA is a methodology that is best applied to the analysis of the life cycle of products and services. The mentioned elements are usually not included in other environmental analysis or assessment methods, such as risk assessment, input-output analysis, cost-benefit analysis or environmental impact assessments.

The application of the LCA methodology has been officially standardised in the ISO 14040 series. All steps of a proper LCA are described in detail and preferable solutions are given for common problems, such as the co-products issue.

- LCAs are based on a large amount of background data, and the results should ideally be presented in a transparent form, that is, allowing tracing back the origin of the data and the background for any assumptions and calculations made. LCA experts appreciate the provision of background data, but it often becomes overwhelming for non-experts. Therefore, the available LCA software tools have to strike a balance between user-friendliness and transparency with regard to equations and calculations.
- Together with economic analyses, LCAs of resource and waste management provide a decision-making basis for local, regional and national authorities in such areas as:
  - Quantifying the potential environmental impacts of a given resource and waste management option
  - Providing a basis for identification of resources the use of which has the largest impact, and can be priority areas for policy
  - Providing a basis for comparison of different waste management solutions such as incineration, landfilling, recycling, biodegradation, etc both in environmental and economic terms.

CSVTU, April-May 2013

(a) *Write the percentage composition of various components in a domestic waste in an average Indian city?* 2

Ans. **Refer Question 4 Unit - 5**

(b) *Write the methods of collection and conveyance of solid wastes in an average Indian city?* 7

Ans. **Refer Question 9 Unit - 5**

(c) *Explain in detail the solid waste management tools?* 7

Ans. **Refer Question 1 Unit - 5**

(d) *Explain the terms with regard to SWM:-* 7

(i) *Zero Waste*

(ii) *Mobius Loop Concept*

(iii) *LCA Studies*

Ans. **Refer Question 23 Unit – 5**

CSVTU, Nov-Dec 2012

(a) *Explain the term Garbage.* 2

Ans. **Refer Question 7 Unit - 5**

(b) *Explain the term 'refuse' and give its composition and classification. Describe briefly the various methods employed for collection of the refuse.* 7

Ans. **Refer Question 7, 9 Unit - 5**

(c) *Describe briefly method of refuse disposal employed for sanitary and filling.* 7

Ans. **Refer Question 9 Unit - 5**

(d) *Explain 4R's of Solid Waste Management in detail.* 7

Ans. **Refer Question 1 Unit - 5**

CSVTU, April-May 2012

Part- A

(a) *Differentiate between "Garbage" and "Refuse".* 2

Ans. **Refer Question 7 Unit - 5**

Part – B

(b) *Explain the different methods of composting of municipal solid wastes.* 7

Ans. **Refer Question 13 Unit - 5**

(c) *Explain the characteristics of Municipal Solid Wastes.* 7

Ans. **Refer Question 8 Unit - 5**

(d) *Explain the transportation technique adopted in solid waste management.* 7

Ans. **Refer Question 10 (a) Unit – 5**

CSVTU, Nov-Dec 2011

Part - A

(a) *Solids present in sewage are mainly in the form of:* 2

i. *Settled Solids.*

ii. *Dissolved Solids.*

iii. *Suspended Solids.*

iv. *Colloidal Solids.*

Ans. **Refer Question 3 Unit - 5**

Part – B

(b) *Describe the methods of disposal of solid waste.* 7

Ans. **Refer Question 18 Unit - 5**

(c) *Detail the methods of collection and conveyance method of Solid Waste.* 7

Ans. **Refer Question 9 Unit - 5**

(d) *Describe the Indore Method and the Bangalore Method of composting techniques.* 7

Ans. **Refer Question 13 Unit - 5**

CSVTU, April-May 2011

(a) *Explain the term composting.* 2

Ans. **Refer Question 13 Unit - 5**

(b) *Define solid waste. Write a brief note on solid work management and explain what is the 3-R strategy for waste management?* 7

Ans. **Refer Question 1 & 2 Unit - 5**

(c) *Give the advantages and disadvantages of solid waste disposal by land filling.* 7

Ans. **Refer Question 20 Unit - 5**

(d) *Discuss the methods being adopted in India for collection and disposal of refuse.* 7

Ans. **Refer Question 9 Unit - 5**

CSVTU, Nov-Dec 2010

(a) *Give an idea about the per capita solid waste generated in Indian cities.* 2

Ans. **Refer Question 4, 5 Unit - 5**

(b) *Describe about the health implications of ill managed municipal solid waste.* 7

Ans. **Refer Question 21 Unit - 5**

(c) *Give details about the average composition of municipal solid waste of an Indian city.* 7

Ans. **Refer Question 4 Unit - 5**

CSVTU, April-May 2010

(a) *Give a general idea about the per capita per day quantity of solid waste generated in India and some western countries.* 2

Ans. **Refer Question 4, 5 Unit - 5**

(b) *Explain the term 'refuse' and give its composition and classification.* 7

Ans. **Refer Question 6 Unit - 5**

(c) *Discuss in detail the health hazard of ill managed municipal solid waste of a city.* 7

Ans. **Refer Question 21 Unit - 5**

(d) *Describe briefly the various methods employed for the collection and disposal of the refuse.* 7

Ans. **Refer Question 9 Unit - 5**

CSVTU, Nov-Dec 2009

(a) *What is garbage?* 2

Ans. **Refer Question 7 Unit - 5**

(b) *Explain the term 'refuse' and give its composition and classification. Describe briefly the various methods employed for the collection of the refuse.* 7

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Ans. **Refer Question 7 & 9 Unit - 5**

(c) Describe the various methods used for the ultimate disposal of the refuse. 7

Ans. **Refer Question 18 Unit - 5**

(d) Discuss the health hazard of ill managed municipal solid waste of a city. 7

Ans. **Refer Question 21 Unit – 5**

CSVTU, April-May 2009

(a) Define refuse. 2

Ans. **Refer Question 7 Unit - 5**

(b) Explain the term "composting". Give the different type of composting in use, and describe any one with the aid of sketch. 7

Ans. **Refer Question 17 Unit - 5**

(c) What are the different methods of disposal of solid refuse? Which one most popular in India? Explain the process in detail. 7

Ans. **Refer Question 18 Unit - 5**

(d) Write a short note on incineration of refuse. What are its advantages and disadvantages? 7

Ans. **Refer Question 15 Unit – 5**

CSVTU, Nov-Dec 2008

(a) Explain the term refuse. 2

Ans. **Refer Question 7 Unit - 5**

(b) Describe briefly the various methods employed for collection and disposal of refuse. 7

Ans. **Refer Question 9 Unit - 5**

(c) Describe briefly methods of compositing adopted in India. 7

Ans. **Refer Question 13 Unit - 5**

(d) Describe briefly method of refuse disposal by sanitary land filling? 7

Ans. **Refer Question 15 Unit - 5**

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