

**UNIT – V****DISPOSAL OF SEWAGE AND  
SLUDGE****1. Define the term “Dilution Factor”?**

The ratio of the quantity of the diluting water to that of the sewage is known as the Dilution Factor.

**2. What are the methods adopted for sewage disposal?**

1. Dilution is disposal in water.
2. Effluent Irrigation or Broad Irrigation or Sewage farming is disposal on land.

**3. What are the conditions adopted for disposal by dilution?**

1. When sewage is comparatively fresh (4 to 6 hr old) and free from floating and settleable solids.
2. When the dilution water has a high dissolved oxygen (D.O.) content.
3. When the outfall sewer of the city or the treatment plant is situated near some natural waters having large volumes.

**4. What are the natural forces of purification?**

1. Dilution and dispersion.
2. Sedimentation
3. Oxidation – reduction in sun-light.
4. Oxidation
5. Reduction

**5. What are the factors affecting self purification of polluted streams?**

- a) Temperature
- b) Turbulence
- c) Hydrography such as the velocity and surface expanse of the river stream.
- d) Available dissolved oxygen and the amount and type of organic matter.
- e) Rate of reaeration.

**6. What are the types of self purification?**

The self purification divided into four zones.

1. Zone of degradation.
2. Zone of active decomposition.
3. Zone of recovery

#### 4. Zone of Cleaner water

### 7. What is meant by “Self purification phenomenon”?

When sewage is discharged into a natural body of water, the receiving water gets polluted due to waste products, present in sewage effluent. The natural forces of purification such as dilution, sedimentation, oxidation – reduction in sun light go on acting upon the pollution elements and bring back the water into its original condition. This automatic purification of polluted water, in due course is called the self purification phenomenon.

### 8. What is meant by photo synthesis?

The sun light has a bleaching and stabilizing effect of bacteria. It also helps certain micro organisms to derive energy from it and convert themselves into food for other forms of life, thus absorbing  $\text{CO}_2$  and releasing  $\text{O}_2$  by a process known as Photo synthesis.

### 9. What do you mean by Oxidation?

The oxidation of the organic matter present in sewage effluents, will start as soon as the sewage out falls into the river water containing dissolved oxygen. The deficiency of oxygen so created will be filled up by the atmospheric oxygen. The process of oxidation will continue till the organic matter has been completely oxidized. This is the most important action responsible for effecting self purification of rivers.

### 10. What do you understand by Reduction?

Reduction occurs due to hydrolysis of organic matter settled at the bottom either chemically or biologically. An aerobic bacteria will help in splitting the complex organic constituents of sewage into liquids and gases and thus paving the way for their ultimate stabilization by oxidation.

### 11. Define the term Re-oxygenation curve.

In order to counter – balance the consumption of D.O. due to de-oxygenation, atmosphere supplies oxygen to the water and the process is called re-oxygenation.

### 12. What is meant by “Oxygen sag curve”?

The amount of resultant oxygen deficit can be obtained by algebraically adding the de-oxygenation and re-oxygenation curves. The resultant curve so obtained is called the oxygen sag curve or the oxygen deficit curve.

### 13. Write the equation for find out the B.O.D. of the diluted water.

B.O.D. of the diluted mixture

$$C = C_0 \left( \frac{Q_s}{Q_s + R} \right)^f$$

Where  $\frac{Q_s}{Q_R}$

$C_s$  B.O.D. of sewage

$C_R$  B.O.D. of river

$Q_s$  Sewage discharge

$Q_R$  Discharge of the river

#### 14. Define the term “limnology”.

A study of the lake systems is essential to understand the role of phosphorous in lake pollution. The study of lakes is called limnology.

#### 15. What is meant by epilimnion zone?

The water of a lake gets stratified during summers and winters. Since such turbulence extends only to a limited depth from below the water surface, the top layers of water in the lake become well mixed and aerobic. This warmer, well mixed and aerobic depth of water is called epilimnion zone.

#### 16. What is meant by hypolimnion zone?

The lower depth of water in the lake which remains cooler, poorly mixed and an aerobic, is called hypolimnion zone.

#### 17. What do you understand by monoclinal? Give example.

The water of a lake gets stratified during summers and winters. The change from epilimnion to hypolimnion can be experienced while swimming in a lake. When you swim in top layers horizontally you will feel the water warmer and if you dive deeper, you will find the water cooler. The change line will represent monoclinal.

#### 18. What are the classification of biological zones in lakes?

The most important biological zones are

- (i) euphotic zone
- (ii) Littoral zone
- (iii) benthic zone

#### 19. What do you understand by “Euphotic Zone”?

The upper layer of lake water through which sunlight can penetrate is called the euphotic zone. All plant growth occurs in this zone. In deep water, algae grow as the most important plants, while rooted plants grow in shallow water near the shore.

#### 20. Define the term secchi disk? Draw a neat sketch

The depth of the euphotic zone can be approximated and measured by a sample device called the secchi disk as shown in figure.

**21. What do you understand by “Littoral zone”?**

The shallow water near the shore in which rooted plants grow, is called the littoral zone. The extent of the littoral zone depends on the slope of the lake bottom, and the depth of the euphotic zone.

**22. What is meant by Benthic zone? Give example**

The bottom sediments in a lake comprises what is called the benthic zone. As the organisms living in the overlying water die, they settle down to the bottom, where they are decomposed by the organisms living in the benthic zone. Bacteria are always present on this zone.

**23. Define the term “productivity of a lake”?**

The productivity of a lake is defined as a measure of its ability to support a food chain. Since the algae forms the base of this food chain, which is required by the other forms of living organisms to thrive. Its presence measures the lake productivity.

**24. What are the types of lakes?**

Depending upon the increasing level of its productivity the lakes may be classified as

1. Oligotrophic lakes
2. Mesotrophic lakes
3. Eutrophic lakes
4. Senescent lakes

**25. What are the requirements for disposal of solid waste?**

1. It should be located away from the building, on the leeward side.
2. Its floor should be at least 1.2 m above the general level.
3. Its floor should be of impervious material.
4. It should be well ventilated.

**26. Give examples for solid waste?**

1. garbage
2. ashes
3. rubbish
4. dust

**27. What are the methods adopted for disposal of waste?**

Waste or solid waste can be finally disposed of the following methods.

1. Controlled tipping
2. Filling of low lying areas. (Land filling)
3. Dumping into sea
4. Pulverization

5. Incineration
6. composting

**28. What are the advantage of land filling methods of disposal?**

1. It is simple and economical
2. No plant / equipment is required
3. There are no by products and hence there is no problem of the disposal of the by-products.
4. Separation of various materials of the refuse is not required.

**29. What are the disadvantages of land filling methods of disposal?**

1. Proper site may not be available near by
2. Wind direction may not be favourable.
3. Large land areas are required.
4. It may be difficult to get large quantities of covering material.

**30. What do you understand by pulverization?**

In this method, the dry refuse is pulverized into powder form, without changing its chemical form. The powder can either be used as a poor quality manure, or else be disposed of by land filling.

**31. What are the factors considered during incineration?**

1. The refuse charging should be carefully observed during incineration.
2. Each batch of refuse entering furnace should be well mixed.
3. Auxiliary burners are usually installed above the refuse to ignite it and to establish the draft at the beginning of the cycle. This is all the more necessary when the moisture content of air is high.

**32. What are the advantages of incineration method of disposal?**

1. This is most hygienic method, since it ensures complete destruction of pathogens.
2. There is no odour trouble or dust nuisance.
3. The heat generated can be used for saving steam power.
4. Clinker produced can be used for road purposes.

**33. What are the disadvantages of incineration method of disposal?**

1. Large initial expenditure.
2. Improper operation results in air pollution problems and incomplete reduction of the waste materials.
3. Disposal of the remaining residue is required.
4. High stacks needed for natural draft chimneys present safety problems.

**34. What do you understand by composting?**

Composting is a method in which putrescible organic matter in the solid

waste / refuse is digested anaerobically and converted into humus and stable mineral compounds.

It is a hygienic method which converts the refuse into manure through the bacterial agencies.

**35. What are the methods adopted for composting?**

1. Composting by trenching.
2. Open window composting.
3. Mechanical composting.

**36. What is meant by “humus”?**

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. **37. Describe the term open window composting.**

In this method, a large proportion of mineral matter like dust, stone, broken glass pieces etc. are first removed from the refuse. The refuse is then dumped on the ground in the form of 0.6 to 1 m high, 6 m long and 1 to 2m wide piles at about 60% moisture content. The pile is then covered with high Boon, cow dung, cattle urine etc. through which the organisms or germs that are necessary for fermentation are added after which compost is ready for use as manure when the temperature falls considerably.

**38. What do you understand by mechanical composting?**

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 composting in which the process of stabilization is expedited by mechanical devices of turning the compost.

**39. What are the operations involved in mechanical composting?**

The operations involved in a large scale composting plant as follows:-

1. Reception of refuse
2. Segregation
3. Shredding or pulverizing
4. Stabilization
5. Marketing the humus

**40. Give three important methods of disposal of sludge.**

1. Sludge disposal into water.
2. Sludge disposal by application on land.
3. Sludge disposal by clogging.
4. Sludge disposal by composting.

**41. What are methods adopted for sludge drying?**

1. Drying the sludge on prepared sand beds.
2. Drying the sludge on centrifuges.
3. Drying the sludge by heat dryers

**42. What is meant by house refuse?**

This consists of vegetable and animal waste matters, ashes, cinders, rubbish, debris from cleaning and demolition of structures.

**43. What is meant by organic waste?**

It includes dry animal and vegetable refuse, cow dung, excreta of birds, tree leaves, sticks, plastic bottles, paper waste, rags. This waste is subject to decay with time and evolve highly offensive odour and gases which are highly detrimental to health.

**44. What do you understand by inorganic waste?**

This consists of non-combustible materials such as grit, dust, mud, metal pieces, metal containers, broken glass and crockery, tiles waste building material. It is not subjected to decay and is therefore not harmful to public health.

**45. Define the term "Sewage sickness".**

When sewage is applied continuously on a piece of land, the soil pores or voids may get filled up and clogged with sewage matter retained in them. The time taken for such a clogging will, of course depend upon the type of soil and the load present in sewage.

The organic matter will thus, of course, be mineralized, but with the evolution of four gases like  $H_2S$ ,  $CO_2$ ,  $CH_4$ . This phenomenon of soil getting clogged is known as sewage sickness.

**46. What are the types of preventive measure in adopted for sewage sickness?**

1. Primary treatment of sewage
2. Choice of land
3. Under-drainage of soil.
4. Giving rest to the land.
5. Rotation of crops
6. Applying shallow depths.

**47. Define the term “Raw sludge”?**

The sludge, which is deposited in a primary sedimentation tank is called Raw sludge. Raw sludge is colourous, contains highly putrescible organic matter, and is thus, very very objectionable.

**48. Define the term “secondary sludge”?**

The sludge, which is deposited in a secondary clarifier is called secondary sludge. It is also putrescible, though a little less objectionable.



**49. What are the unit operation / process on the sludge treatment?**

Sludge treatment may include all or a combination of the following unit operations and processes

1. Thickening or concentration
2. Digestion
3. Conditioning
4. Dewatering
5. Drying
6. incineration

**50. What is the purpose of thickening?**

The purpose of thickening is to reduce moisture content of the sludge, and consequently to increase the solids concentration. **51. What are the types of thickening?**

1. Gravity thickening
2. Air Floatation.
3. Centrifugation.

**52. What do you mean by “Digestion”?**

The principle objectives 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.

**53. What is meant by “conditioning”?**

Conditioning improves the drainability of digested sludge. Prior conditioning of sludge before application of dewatering methods renders it more amenable to dewatering.

**54. What are the purpose of dewatering?**

The purpose of dewatering is to further reduce the volume of sludge and thereby increase the solids concentration.

**55. What are the characteristics of sources of sludge?**

1. Sludge from primary settling tanks
2. Chemical precipitation
3. Trickling filter huming.
4. Activated sludge

**56. Write the formula for determining the volume of sludge?**

$$V_{sl} = \frac{W_s}{P_s P_w}$$

Where

$V_{sl}$  □ volume of sludge

$W_s$  □ wt of dry solids

$S_{s1}$  □ sp. Gravity of sludge  $P_s$  □ percent solids expressed as a decimal

$P_w$  □ density of water

( $10^3 \text{ kg/m}^3$  at  $5^\circ \text{C}$ )

### 57. Define the term dissolved air floatation?

Air floatation units employ floatation of sludge by air under pressure or vacuum the former process more commonly used is known as dissolved air floatation or pressure type floatation.

### 58. What is meant by centrifugal thickening?

Centrifuges are used both to thicken and to dewater sludge. Their application in thickening is normally limited to waste activated sludge.

Thickening by centrifugation involves the setting of sludge particles under the influence of centrifugal forces.

### 59. What are the basic types of centrifugal thickening?

The three basic types of centrifuges currently available for sludge thickening

1. Nozzle disc
2. Solids bowl
3. Basket centrifuges.

### 60. What are the types of digester? Sludge digesters can be of two types

1. Conventional or low rate digester
2. High rate digester

### 61. What are the elements involved in the design of digester?

1. Number of unit
2. Tank shape and size
3. Water depth and F
4. Roofing
5. Mixing of digester contents

### 62. What do you mean by Aerobic digestion?

The function of aerobic digestion is to stabilize waste sludge by long term aeration, thereby reducing the BOD and destroying volatile solids. Aerobic digestion is generally defined as a process in which micro-organisms obtained

energy by endogenous or auto-oxidation of their cellular protoplasm.

**63. What are the factors considered for design of aerobic digestion?**

The factors that should be considered on designing an aerobic digester include

1. Detention time
2. Loading criteria
3. Oxygen requirement

**64. What are the advantages of aerobic digestion?**

1. Lower BOD concentration in digester supernatant
2. Production of odourless and easily dewaterable biologically stable digested sludge.
3. Lower capital cost

**65. What are the disadvantages of aerobic digestion?**

1. Higher power costs generate higher operating costs comparable with anaerobic digestion.
2. No methane gas is produced for recovery as a by-product.

**66. What is meant by "Elutriation"?**

Elutriation is literally a "washing" of the sludge. It is a unit operation in which a solid or a solid-liquid mixture is intimately mixed with a liquid for the purpose of transferring certain components to the liquid.

**67. What are the purposes of dewatering?**

1. Cost of trucking sludge to ultimate disposal site is reduced, because of reduced sludge volume consequent to dewatering.
2. Ease in handling dewatering sludge.

**68. What are the methods of "elutriation"?**

1. Single stage elutriation
2. Multi stage elutriation
3. Counter current washing

**69. What are the advantages of "two stage digestion"?**

1. Two stage digestion is an effective method of preventing any tendency for the sludge to short-circuit.
2. Two stage digestion offers the freedom from large slum formations in any other digestion tanks.

**70. What is meant by lagoon?**

The raw sludge is kept at rest in a large shallow open pond, called a lagoon.

**71. Define what is meant by sludge concentrator unit?**

Since the sludge obtained in a sludge digestion plant contains too much of moisture (98% to 99%) and is therefore very bulky, may sometimes be reduced in its moisture content by first sending it to a sludge thickener unit also called a sludge concentrator unit. **72. Define the term “high rate digestion”?**

The process of sludge digestion using a sludge thickener before the digestion tank, helps in reducing the capacity of the digestion tank which further reduces their capacity and the rate of digestion is also made high. Such a digestion which is used in modern large sized plants is called high rate digestion.

**73. Define the term “Sludge bulking”?**

The settled sludge may contain more moisture and thus resulting in the swelling of the sludge volume. This phenomenon is known as sludge bulking.

**74. What are the factors assist on the development of sludge bulking?**

- 1) Presence of harmful industrial waste waters, especially those containing high carbohydrate content antiseptic or other such properties.
- 2) Accumulation of sludge at the bottom of the aerofuon tanks.'

**75. What are the disadvantages of sludge bulking?**

1. When sludge bulking occurs, the sludge does not readily settle down, and is, remains in suspension in secondary clarifier is even seen in the effluent of the secondary clarifier.
2. When sludge bulking occurs, naturally large volume of sludge will have to be handled.

**76. What are the remedial measures adopted for controlling the bulking of sludge?**

1. by heavily chlorinating the sewage
2. by increased aeration
3. by reducing the suspended solids in the sewage

**77. Define the term MLSS?**

The total microbial mass in the aeration system (M) is computed by multiplying the effluent concentration of solids in the mixed liquor of the aeration tank called Mixed Liquor suspended solids (MLSS)

**78. Explain the following term**

1. SRT

2. MLSS
3. MCRT
4. F/M

1. SRT → Solids Retention Time
2. MLSS → Mixed liquor suspended solids
3. MCR → Mean cell Residence time
4. F/M → Food / Micro organisms

**79. Define the term “sludge age”?**

It is defined as the ratio between mass of suspended solids (MLSS) in the system (M) to Mass of solids leaving the system / day. It is denoted as  $Q_c$

Mass of suspended solids (MLSS)

$Q_c = \frac{\text{Mass of solids leaving system / day}}{\text{Mass of solids in the system (M)}}$

**80. What are the methods adopted for disposal of wet digested sludge?**

1. Disposed by Dumping into the sea
2. Disposed by Burial in the trench
3. Incineration.

**81. What do you understand by ‘dumping’?**

Dumping in an abandoned mine clearly can be resorted to only for sludges and solids that have been stabilized so that no decomposition or nuisance conditions will result. Thus method can be safely adopted for digested sludge, clean frit and incinerator residue. **82. What do you understand by “Vacuum filtration”?**

Vacuum filtration is the most common mechanical method of dewatering. It is used to dewater raw or digested sludges preparatory to heat treatment by vacuum filtration because the waste solids are rendered fine during digestion.

**83. What do you mean by “sludge drying beds”?**

This method of dewatering and drying the sludge is specially suitable for those locations where temperature are higher, similar to the one prevailing in our country. The method consists of applying the sludge on specially prepared open beds of sand. **84. Give Brief notes on sludge Lagooning ?**

A Lagoon is a shallow earth basin into which untreated or digested sludge is deposited. Untreated – sludge lagoons stabilize the organic solids by an aerobic and anaerobic decomposition, which may give rise to objectionable odours. Hence the lagoons should be located away from the town.

**85. What do you understand by “chemical conditioning”?**

Chemical conditioning is the process of adding certain chemicals to enable coalescence of sludge particle facilitating easy extraction of moisture.

Exp: Alum, ferric, chloride, lime.

### **86. What do you understand y temp of digestion?**

Digestion of sludge is temperature dependent. Here, rate of digestion increases with increase in temp upto a temp of 40°C the digestion is brought about by a particular type of organisms.

While a totally different type of organisms establish in the digester at temp higher than 45°C. The former range is called the mesophilic range and the latter is known as Thermophilic range.

### **87. What are the factors depends upon the capacity of digester?**

The capacity of digester, depends on

- (i) Daily volume and moisture content of input sludge and digested sludge
- (ii) Temperature of digestion
- (iii) Desired degree of destruction of volatile solids
- (iv) Storage capacity of for digested sludge.

### **88. What do you understand by Daily volume and moisture content of sludge?**

The volume of daily sludge varies depending upon degree of removal of suspended solids in primary and final settling tanks, moisture content and spreading of sludge.

### **89. What are the purpose of sludge concentration?**

1. To permit increased loadings to sludge digesters
2. To increase feed solids concentration of vacuum filters
3. To economize on transport costs as in ocean barging in case of raw sludge.

## **UNIT – B**

### **1. Enumerate the two general methods adopted for sewage disposal and explaining the conditions favourable for their adoption.**

There are two general methods of disposing of the sewage effluents.

- a. Dilution is disposal in water.
- b. Effluent Irrigation or Broad Irrigation or sewage

farming is disposal on land.

**Disposal by dilution:-**

Disposal by dilution is the process whereby the treated sewage or the effluent from the sewage treatment plant is discharged into a river stream, or a large body of water, such as a lake or sea. The discharged sewage in due course of time, is purified by what is known as self purification process of natural waters. The degree and amount of treatment given to raw sewage before disposing it of into the river stream in question, will definitely depend not only upon the quality of raw sewage but also upon the self purification capacity of the river stream and the intended use of its water. **Conditions favouring Disposal by dilution.**

The dilution methods for disposing of the sewage can favourably be adopted under the following conditions.

1. When sewage is comparatively fresh (4 to 5 hr old) and free from floating and settleable solids.  
(or are easily removed by primary treatment)
2. When the diluting water (is the source of disposal) has a high dissolved oxygen (0-0) content.
3. Where diluting waters are not used for the purpose of navigation or water supply for at least some reasonable distance on the downstream from the point of sewage disposal.
4. Where the flow currents of the diluting waters are favourable, causing no deposition, nuisance or destruction of aquatic life.
5. When the out fall sewer of the city or the treatment plant is situated near some natural water having large volumes.

**Disposal on land:-**

Disposal of Sewage Effluents on land for Irrigation:

In this method, the sewage effluent (treated or diluted) is generally disposed of by applying it on land. The percolating water may either reach the water table or is collected below by a system of under drains. This method can then be used for irrigating crops.

This method, in addition to disposing of the sewage may help in increasing crop yields (by 33% or so) as the sewage generally contains a lot of fertilizing minerals and other elements.

However, the sewage effluent before being used as irrigation water, must be made safe. In order to lay down the limiting standards for sewage effluents, and the degree of treatment required, it is necessary to study as to what happens when sewage is applied on to the land as irrigation water.

The pretreatment process may be adopted by larger cities which can afford to conduct treatment of sewage when sewage is diluted with water for disposal for irrigation, too large volumes of dilution water are generally not needed, so as not to require too large areas for disposal.



2. The sewage of a town is to be discharged into a river stream. The quantity of sewage produced per day is 8 million litres, and its BOD is 250 mg/l. If the discharge in the river is 200 l/s and if its BOD is 6 mg/l. find out the B.O.D. of the diluted water.

**Solution:-**

Sewage discharge =  $Q_s$

Discharge of the river =  $Q_R$

$$= 200 \text{ l/s}$$

B.O.D. of sewage =  $C_s = 250 \text{ mg/l}$ .

B.O.D. of river =  $C_R = 6 \text{ mg/l}$ .

B.O.D. of the diluted mixture

$$C = \frac{C_s Q_s + C_R Q_R}{Q_s + Q_R}$$

$$20 = \frac{250 Q_s + 6 Q_R}{Q_s + Q_R}$$

$$92.59 Q_s = 200 Q_R$$

$$Q_R = 83.21 \text{ mg/l}$$

**3. In the above problem, what should be the river discharge, if it is desired to reduce the B.O.D. of diluted water to 20 mg/l.**

**Solution:-**

Here  $C = 20 \text{ mg/l}$

B.O.D. of the diluted mixture

$$C = \frac{C_s Q_s + C_R Q_R}{Q_s + Q_R}$$

$$20 = \frac{250 Q_s + 6 Q_R}{Q_s + Q_R}$$

$$92.59 Q_s = 20 Q_R$$

$$20 (92.59 Q_s) = 250 Q_s + 6 Q_R$$

$$20 \cdot 92.59 Q_s = 250 Q_s + 6 Q_R$$

$$Q_R = 1521 \text{ l/s}$$

**4. A treated waste water is discharged at the rate of  $1.5 \text{ m}^3/\text{s}$  into a river of minimum  $710$  to  $5 \text{ m}^3/\text{sec}$ . The temperature of river flow and waste water flow may be assumed at  $25^\circ\text{C}$ . The BOD removal rate constant  $k$  is  $0.12/\text{d}$  (base 10). The  $\text{BOD}_5$  at  $25^\circ\text{C}$  of the waste water is  $200 \text{ mg/l}$  and that of the river water upstream of the waste water out fall is  $1 \text{ mg/l}$ . the efficiency of waste water treatment is  $80\%$ . Evaluate the following.**

**i)  $\text{BOD}_5$  at  $25^\circ\text{C}$  if river water received untreated waste water.**

**ii)  $\text{BOD}_5$  at  $25^\circ\text{C}$  if river water receives treated waste water.**

**Solution:**

Discharge of waste water =  $Q_w = 1.5 \text{ m}^3/\text{s}$

Discharge of river =  $Q_r = 5 \text{ m}^3/\text{s}$

Temperature =  $T = 25^\circ\text{C}$

$K_D(25^\circ) = K_1 = 0.12/\text{d}$

CW-conc of  $\text{BOD}_5$  for untreated water =  $200 \text{ mg/l}$

$C_R$ -conc. Of  $BOD_5$  for river water =1/mg/l

- (i) conc of  $BOD_5$  of the mixture if untreated waste water is discharged into the river

$$C = \frac{C_w Q_w + C_R Q_R}{Q_w + Q_R}$$

$$= \frac{200 \times 1.5 + 1 \times 5}{1.5 + 5}$$

$$= 46.92 \text{ mg/l}$$

- (ii)  $BOD_5$  of the treated waste water is given by  $C_w = 20\%$  of the  $BOD_5$  of untreated waste water

(If efficiency of waste water treatment is 80%)

$$C_w = 20\% \times C_R$$

$$= 20\% \times 200 \text{ mg/l}$$

$$= 40 \text{ mg/l}$$

$BOD_5$  of mixture if treated waste water is discharged into the river

$$C_1 = \frac{C_{TW} Q_w + C_R Q_R}{Q_w + Q_R}$$

$$= \frac{40 \times 1.5 + 1 \times 5}{1.5 + 5}$$

$$= 10 \text{ mg/l}$$

**5. In impervious prob(40) found out the ultimate  $BOD$  of the river water after it receives treated waste water.**

$BOD_5$  of river water after it receives treated waste water

$$= 10 \text{ mg/l (as computed above prob (10))}$$

ultimate  $BOD$  of this mixture

$$= y_u = C = ?$$

Using equ

$$Y_t(\text{day}) = L[1 - (10)^{-k_p \cdot t}]$$

$$Y_5 = L[1 - (10)^{-0.12 \times 5}]$$

$$10 = L[1 - (10)^{-0.6}]$$

$$L = 13.35 \text{ mg/l}$$

**6. A town having population of 40,000 disposes sewage by land treatment. It gets a per capita assured water supply from water works at a rate of 130 l/c/d. assuming that the land used for sewage disposal can absorb  $80 \text{ m}^3$  of sewage per ha per day, determine the land area reqd and (t) cost at the rate of Rs./ 25,000 per ha make suitable assumptions where needed.**

**Solution:**

Population = 40,000

Rate of water supply = 130 c/d/per

Total water supplied per day

$$= 40,000 \times 130 \text{ l} = 52,00,000 \text{ l} = 5,200 \text{ cu.m.}$$

Assuming that 80% of this water appears as sewage, we have

The quantity of sewage produced per day

$$= 0.8 \times 5200$$

$$= 4160 \text{ cu.m}$$

Area of land reqd for disposing sewage

$$\frac{4160}{80}$$

$$\square 52 \text{ hect}$$

providing 50% extra land for rest and rotation, we have the total land area reqd.

$$= 1.5 \times 52 = 78 \text{ hect.}$$

Cost of land involved = Rs 25,000 x 78

$$= \text{Rs. } 19,50,000$$

**7. A Town disposes sewage by land treatment. It has a sewage farm of area 150 hect. The area included an extra provision of 50% for rest and rotation the population of the town being 50,000 and rate of water supply 140 lit/ capita / day. If 75% of the water is converted into sewage determine the consuming capacity of the soil.**

**Solution:**

Quantity of water produced per day

$$= 50,000 \times 140 \text{ lit/d} = 70,00,000 \text{ l/d}$$

$$= 7,000 \text{ cu. m/d.}$$

Quantity of sewage produced

$$= 0.75 \times 7000$$

$$= 5,250 \text{ cu. m/d.}$$

Area of farm land provided

$$= 150 \text{ hect} \text{ with } 50\% \text{ additional reserve}$$

Area provided for immediate need

$$\frac{150}{1.5}$$

$$\square 100 \text{ hect}$$

100 hect is capable of passing 5250 cum/d

□

consuming capacity of 800%

$$\frac{5250}{100} = 52.5 \text{ cu.mhe/d}$$

### 8. Write short notes on

- i) Efficient irrigation and sewage farming.
- ii) sewage sickness.

#### Efficient irrigation and sewage for morning:

Although, outwardly, both these terms are used as synonyms to each other, yet there is one basic difference b/w the. This difference is that : in "efficient irrigation" (or broad irrigation), the chief consideration is the successful disposal of sewage, while in sewage farming, the chief consideration is the successful growing of the crops.

Hence in broad irrigation, the raw or settled. Sewage is discharged on vacant land which is provided underneath with a system of properly laid under-drains. These under-drains basically consist of 15 to 20 cm river process tile pipes, laid open founded at a spacing of 12 to 30m. The effluent collected in these drains after getting filtered through the 5001 pores is a generally small (as a large quantity gets evaporated) and well stabilized, and can be early disposal into some natural water courses, without any further treatment.

In case of sewage farming, however the stress is laid upon the use of sewage effluent for irrigation crops and increasing the fertility of the soil. The pre-treatment of sewage in removing the ingredients which may prove harmful and toxic to the plant is therefore, necessary in this case.

#### Sewage sickness:

When sewage is applied continuously once. Piece of land, the soil pores or void may get filled up and clogged with sewage matter retained in them. The time taken for such a clogging will, of course depend upon the type of soil and the load present in sewage. But when once these voids are clogged, free circulation for air will be prevented and anaerobic conditions will develop clogging the pores. Due to these the aerobic decomposition of organic matter will stop, and anaerobic decomposition will start. The organic matter will therefore, of course, be mineralized but with the evolution of foul gases like  $\text{H}_2\text{S}$ ,  $\text{CO}_2$ ,  $\text{CH}_4$ . this phenomenon of soil getting clogged is known as sewage sickness of land.

### 9. What are the preventive measures of sewage sickness by the land disposal? Describe it.

In order to prevent the sewage sickness of a land, the following preventive measures may be adopted.

1. Primary treatment of sewage.

2. Choice of land
3. under drainage of soil
4. Giving rest to the land.
5. Rotation of crops
6. Applying shallow depths. **Primary treatment of sewage.**

The sewage should be disposed of, only after primary treatment, such as screening, grit removal and sedimentation. This will help in removing settleable solids and reducing the B.O.D load by 30% or so. And as such, soil pores will not get clogged, quickly.

#### **Choice of land:**

The piece of land used for sewage disposal should normally be sandy or loamy, clayey lands should be avoided.

#### **Under – drainage of soil:**

The channel on which sewage is being disposed of, can be better drained if a system of under – drains (ie open joined proper ) is laid below, to collect the effluent; and those will also minimize the possibilities of sewage sickness.

#### **Giving rest to the land:**

The land which the sewage being used for disposal should be given rest, periodically by keeping some extra land as reserve and stand-by for diverting the sewage during the period the first land is at rest more over, during the rest period, the land should be thoroughly planned so that it gets broken up and aerated.

#### **Rotation of crops;**

Sewage sickness can be reduced by planting different crops in rotation instead of growing single type of a crop. This will help in utilizing the fertilizing elements of sewage and help on aeration of soil.

#### **Applying shallow depths:**

The sewage should not be filled over the area in large depth, but it should be applied in thin layers. Greater depth of sewage on a land does not allow the soil to receive the sewage satisfactorily and ultimately results in clogging.

Sewage –sick land can be improved and made useful by thoroughly ploughing and treating the soil, and exposing it to the atmosphere.

**10. A sedimentation tank is treating 4.5 million lit of sewage per day containing 275 ppm of suspended solids. The tank removes 50% of suspended solids. Calculate the quantity of sludge produced per day in bulk and find (a) moisture content of sludge is 98%**

#### **Solution:**

Volume of sewage treated  
= 4.5 M.Lit / day

Since suspended solids amount to 275 mg / l, we have that wt of suspended solids present in sewage

$$\frac{275 \times 4.5}{10^6} = 1237.5 \text{ kg/d}$$

Since 50% of solids are removed in sedimentation tank, we have the wt of solids removed in sedimentation tank

$$\frac{1237.5 \times 50}{100} = 618.75 \text{ kg/d}$$

(a) When moisture content of sludge is 98% then 2 kg of solids (dry sludge) will make  
= 100 kg of wt sludge

618.75 kg of solids (dry sludge) will make

$$\frac{100}{2} \times 618.75 = 30937.5 \text{ kg} \approx 30940 \text{ kg}$$

Hence wet sludge or sludge produced per day

$$= 30,940 \text{ kg} \approx 30.94 \text{ ton}$$

Assuming the specific gravity of wet sludge (sludge) as 1.02, we have unit wt. of sludge

$$1.02 \text{ t/m}^3$$

$$1.02 \text{ t/m}^3$$

$$\frac{1.02}{1.02} \text{ unit wt of water} = 1 \text{ t/m}^3$$

volume of wet sludge produced per day

$$= \frac{30.94}{1.02} = 30.33 \text{ m}^3 \text{ unit wt } 1.02$$

Vol. of sludge (when its m.c. is 98%)

$$= 30.33 \text{ cu.m}$$

**11. In the same prob (1) Finding out the moisture content of sludge is 96%.**

When moisture content is 96% then

4 kg of solids will make  
= 100 kg of wet sludge

□ 618.75 kg of solids will make (Refer previous prob)

$\frac{100}{4}$  □ 618.75 kg of wet sludge  
□ 15468.75 kg of wet sludge

□ 15,470 kg say of wet sludge □ □  
= 15.47 tonnes of wet sludge

Hence, wt. of, sludge (when its m,c, is 96%)

= 15.47 tonnes if sp – gravity of sludge

is 1.02 then

Volume of sludge (when its m,c, is 96%)

$\frac{15.47}{1.02}$  m<sub>3</sub>  
□ 15.17 m<sup>3</sup>

Hence, the vol. of sludge at 96% m.c.

= 15.17 cu.m

**12. Raw waste water is entering a treatment plant and contains 250 mg / l suspended solids. It 55% of these solids are removed in sedimentation.**

**(a) Find the volume of raw sludge produced permillion litre of waste water. Assume that the sludge has a moisture content of 96% and specific gravity of solids is 1.2.**

**(b) Find the unit weight of raw sludge**

**(c) If 45% of raw sludge is changed in liquid and gas in the digestion tank, find the volume of digested sludge per million litre of waste water. Assume that the moisture constant of the digested sludge is 90%.**

**Solution:**

(a) Suspended solids in waste water = 250 mg / l

Since 55% of these solids are removed in sedimentation, we have

The solid removed in sedimentation as sludge



$$= 55\% \times 250 \text{ mg / l}$$

$$= 137.5 \text{ mg / l}$$

If volume of waste water is 1 million litre, then solids removed as sludge

$$\frac{10^6 \text{ kg}}{137.5 \text{ kg}}$$

Sludge produced will, thus, have 137.5 kg solids, and rest will be water. Now, since the moisture constant of sludge is 96%, we have 4 kg of solids will produce 100 kg of wet sludge, by joining with 96 kg of water.

□ Water contained in 4 kg of solids

$$= 96 \text{ kg}$$

□ Water contained in 137.5 kg of solids

$$\frac{96}{4} \times 137.5$$

$$= 3300 \text{ kg}$$

Hence volume of sludge produced per million litre of water

□ Weight of solids □ wt. of water

$$\frac{\text{unit wt. of solids}}{\text{unit wt. of water}}$$

$$= \frac{1.2 \times 1000}{3300} \times 1000 \text{ cu.m}$$

□ □ unit weight of solids □

□ □ = sp. gravity of solids □ unit wt. of water □

$$\square = 1.2 \times 1000 \text{ kg/ m}^3 \quad \square$$

$$\square 0.115 \times 3.3$$

$$\square 3.415 \text{ cu.m}$$

Hence, vol. of sludge produced per million litre of waste water.

$$= 3.415 \text{ cu. M}$$

(b) unit wt of raw sludge

□ wt. of solids + wt. of water volume of sludge

$$1007 \text{ kg/m}^3$$

© 45% of raw sludge is changed into liquid and gas, means that 45% of solids are consumed (digested). wt. of dry solids left in the digested sludge

$$= (100 - 45) \% \text{ of total solid}$$

$$= 137.5 \text{ kg}$$

$$= 75.625 \text{ kg}$$

since digested sludge contains 90% m.c. we have The volume of digested sludge

$$\square \square \square \text{ wt. of solids left in digested sludge} \div \text{unit weight of solids} = \text{unit wt.}$$

$$\text{water} \div \text{wt. of meter} = 0.744 \text{ cu. m}$$

Hence, the volume of digested sludge per million litre of waste water = 0.744 cu.m

**13. The sewage of a certain town contains 600 ppm of suspended matter. Assuming that 55% of this settled down in plain sedimentation tank, and the sludge collected has a water content of 95% calculate its quantity per million litre, both in bulk and weight. Assume sp. Gravity 1.2**

**Solution:-**

Suspended matter in sewage

$$= 600 \text{ ppm}$$

$$= 600 \text{ mg / l}$$

For 1 million litre of sewage, we have the suspended matter.

$$\begin{aligned} & \frac{600}{1000000} \\ &= 10^{-6} \text{ kg} \\ &= 600 \text{ kg.} \end{aligned}$$

Now, 55% of this matter is settled as sludge, and therefore quantity of sludge solids.

$$= 0.55 \times 600 = 330 \text{ kg.}$$

The sludge is having 95% m.c. which, means 5 kg of dry solids will make 100 kg of wet sludge.

$$\square 5 \text{ kg of dry solid make} = 100 \text{ kg of sludge}$$

□ 330 kg of dry solids make

$$\frac{100}{5}$$

$$\square 5 \square 330$$

□ 6600 kg of sludge

Hence, the wt. of sludge formed per million litre of sewage = 6600 kg.

$$\text{Volume of sludge} = \frac{\text{wt. of sludge}}{\text{unit wt. of sludge}}$$

$$\square 1020 \frac{6600 \text{ kg}}{\text{m}^3}$$

[□ unit wt. of sludge

= sp. Gravity □ unit wt. of water.

$$= 1.02 \square 1000$$

$$= 1020 \text{ kg / m}^3]$$

$$= 6.47 \text{ m}^3$$

Hence, the vol. of sludge formed per million litre of sewage.

$$= 6.47 \text{ cu.m}$$

**14. Design a sludge digestion tank for 40,000 people. The sludge content per capita per day is 0.068 kg. The moisture of the sludge is 94% The sp. Gravity of the wet sludge is 1.02 and 3.5 percent of the digester vol. is daily filled with the fresh sludge, which is mixed with the digested sludge.**

**Solution:-**

Dry sludge content produced by 40,000 persons

$$= 0.068 \times 40,000 \text{ kg}$$

$$= 2,720 \text{ kg / day}$$

94% moisture content means that 6 kg of dry sludge will produce 100 kg of wet sludge.

□ 6 kg of dry sludge produces wet sludge = 100 kg

2720 kg of dry sludge produces wet sludge

$$6. \frac{2720}{100}$$

$$\square 45333 \text{ kg}$$

45.3 t/day

Volume of wet sludge produced

□ wt. of sludge

unit.wt. of sludge

□ 45.3 m<sup>3</sup>/day  
1.02

□ Unit wt. of sludge in 6 / m<sup>3</sup> sp. gravity unit wt. of water i.e 1 t  
/ m<sup>3</sup> □<sup>3</sup> □

□ 1.02 t □

$$\square 1.02 \text{ t/m}^3$$

$$\square 44.4 \text{ m}^3/\text{day}$$

44.4 m<sup>3</sup> of fresh sludge is added to the tank daily, to fill 3.5% of the digester capacity.

$$\frac{3.5}{100} \square \text{capacity of digester} \\ = \text{volume of fresh sludge produced daily}$$

$$\square = 44.4 \text{ m}^3$$

or capacity of digester required

$$\frac{44.4 \times 100}{3.5} \\ \square 1268.9 \text{ cu.m}$$

Providing 30% additional capacity for fluctuations, we have,

The required digester capacity,

$$= 1268.9 \times 1.3 \\ = 1650 \text{ cu. M (say)}$$

Now, providing 6 m depth of the cylindrical digestion tank, we have

The cross sectional area of the tank

$$\frac{1650}{6} \\ \square 275 \text{ m}^2 \\ \square \text{Dia of tank} = \sqrt{\frac{275 \times 4}{\pi}} \\ = \sqrt{\frac{275}{0.785}} \\ = 18.7 \text{ m.}$$

Hence, provide a cylindrical sludge digestion tank, 6m deep and 18.7 in diameter, with an additional hoppers bottom of 1:1 slope for collection of digested sludge.

**15. A sewage containing 200mg/l of suspended solids is passed through primary setting tanks, tricking filters, and secondary settling tanks, how much gas will probably be produced in the digestion of sludge from one million litre of sewage?**

**Solution:**

Total suspended solids in sewage = 200 mg/l

Assuming 90% removed of suspended solids in complete treatment, we have.

The suspended solids removed =  $90\% \times 200 \text{ mg/l}$   
 = 180 mg/l.

Assuming volatile solids to be equal to 70% of suspended solids, we have  
 Volatile solids removed

=  $70\% \times 180 \text{ mg/l}$   
 = 126 mg/l

Now, assuming that the volatile solids (matter) is reduced by 65% in the sludge by digestion, we have

Volatile solids reduced

=  $65\% \times 126 \text{ mg/l}$   
 = 81.9 mg/l

□ Volatile matter reduced per million litre of sewage produced per kg of volatile matter reduced, we have the gas produced per million litre of sewage

=  $0.9 \times 81.9 \text{ cu.m.}$   
 = 73.71 cu m.  
 = 73710 litres.

**16. A sewage containing 200 mg/l of suspended solids is passed through primary settling tank. The solids from the primary settling tank are digested to recover the gas. Find the likely volumes of methane and carbon dioxide produced in the digestion of the sludge from 10,000 m<sup>3</sup> of sewage. Calculate the fuel value of the gas produced. State clearly the assumption made.**

**Solution:**

Total suspended solids in sewage = 200 mg/l

Assuming that 60% of suspended solids are removed in the primary settling tank, we have the suspended solids removed as sludge. =  $60\% \times 200 \text{ mg/l}$   
 = 120 mg/l

Now assuming that the volatile solids present are 70% of the suspended solids, we have

□ The volatile solids removed  
 =  $70\% \times 120 \text{ mg/l}$   
 = 84 mg/l

Further, assuming that the volatile matter is reduced by

65% in sludge digestion, we have Volatile matter reduced =  $65\% \times 84 \text{ mg/l}$   
 =  $54.6 \text{ mg/l}$ . Hence, volatile matter reduced in  $10,000 \text{ cu m}$  of sewage

$$\square 54.6 \frac{10,000 \times 1000}{10^6} \text{ kg.}$$

$$\square 546 \text{ kg}$$

Now, assuming that  $0.9 \text{ cu. M}$  of gas is produced per kg of volatile matter reduced, we have Total quantity of gas produced

$$= 0.9 \times 546 \text{ cu m.} = 491.4 \text{ cu. M.}$$

Assuming that the produced gas contains 65% of methoane and 30% of carbon di oxide, we have Methane produced =  $0.645 \times 491.4 \text{ cu m.}$

$$= 319.41 \text{ cu. M.}$$

carbondioxide produced =  $0.30 \times 491.4 \text{ cu m.}$

$$= 147.42 \text{ cu m.}$$

Now assuming that the methane in the sludge gas has a fuel value of  $36,000 \text{ kg/m}^3$ , we have

$$\text{The fuel value} = 36,000 \times 391.41 \text{ kj} = 11.50 \text{ M.kj.}$$

Now, assuming a boiler efficiency of 80% we have the amount of heat that can be furnished by the boiler.

$$= 80\% \times 11.50 \text{ mkj} = 9.2 \text{ mkj}$$

$$= \frac{9.2}{4.18} \text{ mkc}_2$$

$$4.18$$

$$= 2.2 \text{ million kilo calorie.}$$

**26. (a) calculate the area of land required for drying the sludge from the digestion tank for 40,000 population, designed in qn. No. 8.**

**(b) Also design the dimensions of beds.**

**Solutions:**

(b) The volume of wet sludge from the sewage of 40,000 population was worked out as  $44.4 \text{ m}^3/\text{day}$

Let it be spread in  $22.5 \text{ cm}$  thick layer (ie between  $20$  to  $30 \text{ cm}$  thick layer) on under drained said beds, then

The area of beds required

$$\frac{44.40 \text{ m}^3}{0.225} = 225$$

$$\square 197.3 \text{ m}^2/\text{day.}^2$$

Under tropical Indian conditions, the beds get dried out in about 10 days and hence taking 2 weeks as average drying time including wet days of rainy season, we can

$$\text{utilize the same bed} = \frac{52}{2} \square 26 \text{ times in an year}^* \cdot 2$$

□ Area of bed required per year

$$\frac{197.3 \times 365}{26}$$

$$\square 2770 \text{ m}^2 \text{ (say)}$$

Making 100% allowance for space for storage, repairs, and resting of beds, etc, we have

The total area of beds required

$$\begin{aligned} &= 2 \times 2770 \text{ m}^2 \\ &= 5540 \text{ m}^2 \\ &= 0.554 \text{ hectares Ans.} \end{aligned}$$

(b) Now, using 15x30 m sized beds, we have the No. of beds required

$$\begin{aligned} &\frac{5540}{15 \times 30} \\ &\square 12.3 \end{aligned}$$

So let us use 14 nos. of beds, with size as:

$$\begin{aligned} &\text{Area} \\ &= 395.7 \text{ m}^2 \end{aligned}$$

$$\begin{aligned} &\text{using 15m width, length=} \\ &= 26.4 \text{ m.} \end{aligned}$$

Hence, use 14 beds, of size 15mx26.4m in plan. The beds should be provided with under drains and side walls, with typical section and plan as shown in figure.

## 27. Describe the mechanical methods of dewatering sludge?

Dried or dewatered by mechanical means, such as by vacuum filtration or by high speed centrifuges.

In vacuum filtration process, the sludge is first mixed with a coagulant such as ferric chloride and then conveyed to a vacuum filter, consisting of a hollow rotating drum, covered with a replaceable filter cloth. The drum rotates partly submerging into the sludge. The vacuum created by a pump within the drum draws the moisture from the sludge through the cloth. The sludge cake which is formed on the outside of the drum is removed by a scraper as the drum rotates.

**High – speed centrifuges:** are also used for drying of raw or digested sludges, and are becoming more popular because of small area requirements. These methods may remove about 50% moisture. Vacuum filtration or centrifugation of raw sludge is often adopted in situations where sludge is to be disposed of by incineration (i.e. burning). These mechanical methods of



drying are generally used when the available area is less than that required for sludge drying beds, or where the climate is too cold or at places where rains are frequent as not to permit natural drying or as a preliminary to heat drying for making fertilizer.