KEY for AS-4211

B.TECH. (Seventh Semester) Examination-2013
(Civil Engineering Branch)
ENVIRONMENTAL ENGINEERING – II
(CE41T02)

Max. Marks 60 Time Allowed: 3 Hrs.

Note :i) Section- A is compulsory ii) Answer any one part from each question /unit under Section B.
iii) Each question carries equal 8 marks. Iv) Assume suitable data (if required)

SECTION – A

Q.1) Fill up the blanks with appropriate answer:

i) The solubility of oxygen in sewage, when compared to its solubility in distilled water, is **90%**

ii) A drop manhole may be provided along a sewer line **option b as below**

a) When the sewer drops from a height of more than 0.6m or so.

b) When a branch sewer outfalls into it from a height of more than 0.6 m or so

c) To provide inspection chambers in the sewer line

d) For non of the above

iii) The relative stability of a sewage sample whose dissolved oxygen is same as the total oxygen required to satisfy BOD is **100%**

iv) If the sewage contains grease & fatty oils, these are removed in **skimming** tank.

v) The term sludge age is associated with **option b as below**

a) sedimentation b) aeration c) sludge drying d)none of these

vi) Lower F / M value in a conventional activated treatment plant will mean **option b as below**

a) lower BOD removal b) higher BOD removal

c) No effect on BOD removal d) nothing can be said

vii) The required area for the sludge drying beds normally ranges between **option a as below**

a) 0.05 to 0.2 Sq. m. per capita b) 0.005 to 0.02 Sq. m. per capita

c) 0.5 to 2.0 Sq. m. per capita d) 5.0 to 20.0 Sq. m. per capita

viii) The acidity in the sludge digestion tank increases with **option a as below**

a) overdosing of raw sludge b) optimal withdrawal of digested sludge

c)gradual design admission of industrial wastes d) aerating the tank

ix) The anaerobic method of mechanical composting, as practiced in India, is called

option c as below

a)Indore method b) Manglore method c) Banglore Method d) None of these

x) Leachate is a coloured liquid, that comes out of **option b as below**

a) septic tank b) Sanitary Landfills c) compost plants d) aerated lagoons

SECTION – B

UNIT-I

Q.2) 125 cumecs of sewage of a city is discharged in a perennial river which is fully saturated with oxygen and flows at a minimum rate of 1600 cumecs with a minimum velocity of 0.12 m/sec. If the 5 day BOD of 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 of sewage and river water.

Solution) **Assume the value of saturation DO of river water as 9.2 ppm**

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 $(D_0) = D_s - D$

$= 9.2. - 8.53 =$ **0.67 mg/l.**

BOD_5 of the river at the mixing point after disposal of sewage (Y_5)

$$= \frac{125 \times 300 + 1600 \times 0}{125 + 1600} = \mathbf{21.74 \text{ mg/l}}$$

The *ultimate BOD of river (mix) at mixing point (L)*

$= 125\%\ BOD_5$ [as per given in assumption (*ii*)]

$= 1.25 \times 21.74 =$ **27.17 mg/l.**

Now, using eqn. (7.16), we have

$$BOD_5 = L\left[1-(10)^{-K_D \times 5}\right]$$

or $$21.74 = 27.17\left[1-(10)^{-K_D \times 5}\right]$$

or $$0.8 = \left[1-(10)^{-5K_D}\right]$$

or $$(10)^{-5K_D} = 0.20$$

or $$-5K_D \log 10 = \log 0.20$$

or $$K_D = \mathbf{0.14}.$$

Now, using eqn. (8.8) as

$$t_c = \frac{1}{K_D(f-1)} \log\left[\left\{1-(f-1)\frac{D_0}{L}\right\} f\right], \text{ where } f = 4.0 \text{ (given)}$$

$\therefore$ $$t_c = \frac{1}{0.14(4-1)} \log\left[\left\{1-(4-1)\frac{0.67}{27.17}\right\} 4\right] = \mathbf{1.354 \text{ days.}}$$

The distance along the river, where the critical D.O. deficit will occur

$= S =$ Velocity $\times$ Time

$= 0.12$ m/sec $\times$ $(1.354 \times 24 \times 3600$ sec$)$

= 14.04 km ; Say 14 km

Hence, critical D.O. deficit will occur at 14 km downstream of the sewage disposal point. **Ans.**

OR

a) Find the relation between the side of a square section of one sewer and the diameter of a circular section of another sewer when both are hydraulically equivalent.

b) Self Purification of natural streams.

Solution. Let D be the diameter of the circular sewer and b be the side of the equivalent square sewer.

The discharging capacity of circular sewer while running full* at a gradient of 1 in S

$$= \frac{1}{N}\left(\frac{\pi}{4}D^2\right)\left(\frac{D}{4}\right)^{2/3}\sqrt{S} \qquad ...(i)$$

The discharging capacity of the rectangular section while running full* at a gradient of 1 in S

$$= \frac{1}{N} \cdot b^2 \cdot \left(\frac{b^2}{4b}\right)^{2/3}\sqrt{S} \qquad ...(ii)$$

$\therefore$ Equating (i) and (ii), we have

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

or $$\frac{\pi}{4}\cdot\frac{D^{8/3}}{2.52} = \frac{b^{8/3}}{2.52}$$

or $$D^{8/3} = 1.272\, b^{8/3}$$

or $$D = 1.094b.$$

This is the required relation, where b is the side of a square and D is the dia of the circular section. **Ans.**

Q.4) A rectangular grit chamber is designed to remove particles with a diameter of 0.2 mm, gravity 2.65. Settling velocity for these particles has been found to range from 0.016 to 0.022m/sec, depending on their shape factor. A flow through velocity of 0.3 m/sec will be maintained by proportioning weir. Determine the channel dimensions for a maximum wastewater flow of 8,000 cu.m./day.

Solution. Let us provide a rectangular channel section, since a proportional flow weir is provided for controlling velocity of flow.

Now,

Horizontal velocity of flow = V_h = 0.3 m/sec.

Settling velocity is between 0.016 to 0.022 m/sec, and hence let it be 0.020 m/sec.

Now, Q = velocity × cross-section

or $Q = V_h \times A$

where Q = 10,000 cu m/day

$$= \frac{10000}{24 \times 60 \times 60} \text{ m}^3/\text{s} = 0.116 \text{ m}^3/\text{s}$$

$\therefore$ $0.116 = 0.3.\,A$

$$A = \frac{0.116}{0.3} \quad \text{or} \quad A = 0.385 \text{ m}^2.$$

Assuming a water depth (H) of 1 m above the crest of the weir, which is kept at 0.3 m above the channel bottom, we have the width (B) of the basin as

$1 \times B = 0.385$

or B = 0.385 m ; **say 0.4 m.**

Overall depth of grit chamber (D)

= Water depth above the crest of weir + 0.3 m

+ Free board of 0.45 m

= 1.0 m + 0.3 m + 0.45 m = **1.75 m**

Now, settling velocity

V_s = 0.02 m/sec

$$\therefore \quad \text{Detention time} = \frac{\text{Water depth in the basin}}{\text{Settling velocity}} = \frac{1}{0.02} = 50 \text{ secs}$$

$\therefore$ Length of the tank = V_h × Detention time = 0.3 × 50 m = 15 m.

The length of the channel is increased beyond theoretical value by a factor of 10—50% to account for non-idealities in the flow and settling of particles. Hence, using about 30% (say) increased length, we get L = 20 m.

Hence, use a rectangular tank, with dimensions :

Length (L) = 20 m
Width (B) = 0.4 m
Depth (D) = 1.75 m

Ans.

OR

a) The BOD 5-day of a waste water has been measured as 600 mg/l. If k = 0.23/day (base e) , what is the ultimate BOD of the waste? What proportion of this ultimate BOD would remain un-oxidized after 20 days ?

ii) What is Relative Conductivity ? Calculate the population equivalent of a city given, i) the average sewage from the city is 95×10^6 l/day, and ii) the average 5 day BOD is 300 mg/l

Solution:

$$Y_t = L\left[1-(10)^{-K_D \cdot t}\right]$$

Here $K = k_1 = 0.23$/day (given)

$\therefore \quad K_D = 0.434\, K = 0.434 \times 0.23 = 0.1.$

Using $t = 5$ days, we have

$$Y_5 = \text{BOD of 5 days}$$

$$= 600 \text{ mg/l} = L\left[1-(10)^{-0.1\times 5}\right]$$

or $$600 \text{ mg/l} = L\left[1-(10)^{-0.5}\right] = L\left[1-\frac{1}{(10)^{0.5}}\right]$$

$$= L\left[1-\frac{1}{3.16}\right] = L\,[1-0.316] = 0.684\, L$$

$\therefore \quad 0.684\, L = 600$ mg/l

$\therefore \quad L = \dfrac{600}{0.684}$ mg/l $= 877.5$ mg/l.

Hence, the ultimate BOD = 877.5 mg/l. **Ans.**

Now $$Y_{20} = L\left[1-(10)^{-0.1\times 20}\right] = Y_u\left[1-\frac{1}{(10)^2}\right]$$

$$= Y_u\,[1-0.01] = Y_u\,[0.99]$$

$\therefore \quad Y_{20} = 0.99\, Y_u$

It means that 99% of BOD_u is utilised in 20 days, and hence only 1% of ultimate BOD would be left unoxidised after 20 days. **Ans.**

b)

Calculate the population equivalent of a city given (i) the average sewage from the city is 95 × 10⁶ l/day, and (ii) the average 5 day BOD is 300 mg/l.

Solution. Average 5 day BOD = 300 mg/l.

Average sewage flow = 95×10^6 l/day

$\therefore$ Total BOD in sewage

$= 300 \times 95 \times 10^6$ mg/day

$= 300 \times 95$ kg/day $= 28500$ kg/day

Population equivalent

$$= \frac{\text{Total 5 day BOD in kg/day}}{0.08}$$

[assuming the domestic sewage quantity to be 0.08 kg/person/day]

$$= \frac{28500}{0.08} = 3{,}56{,}250. \textbf{ Ans.}$$

Q.5) Discuss about: i) Rotating Biological Contactor
ii) Principle of oxidation Pond iii) Sewage farming

Answer :

i) Rotating Biological Contactor :

The Rotating Biological Contractor's method of secondary waste-water treatment has been recently developed and does not fit precisely in to either the trickling filter or the activated sludge categories, but does employ principle common to both of them.

A **rotating biological contactor** (RBC) is a cylindrical media made of closely mounted thin flat circular plastic sheets or discs of 3 to 3.5 m in diameter, 10 mm thick, and placed at 30 to 40 mm spacings mounted on a common shaft.

The R.B.C.'s are usually made in up to 8 m length, and may be placed in series or parallel in a specially constructed tank(s), through which the wastewater is allowed to pass. The RBC's are kept immersed in wastewater by about 40% of their diameter. The RBC's are rotated around their central horizontal shaft, at a speed of 1—2 rpm by means of power supplied to the shaft. Approximately 95% of the surface area is thus alternately immersed in the wastewater and then exposed to the atmosphere above the liquid.

In this process, the attached growths are similar in concept to a trickling filter, except that here the microorganisms are passed through the wastewater, rather than the wastewater passing over the microbes, as happens in a trickling filter. This method realises some of the advantages of both the trickling filter and the activated sludge process.

ii) Principle of oxidation Pond

The term **oxidation pond** was originally referred to that stabilisation pond which received partially treated sewage ; whereas the pond that received raw sewage was used to be called a **sewage lagoon** ; but in recent years, the term *oxidation pond* has been widely used as a collective term for all types of ponds, and most particularly the *facultative stabilisation ponds*.

The results of the oxidation pond treatment are : the oxidation of the original organic matter and the production of algae, which are discharged with the effluent. This results in a net reduction in BOD, since the algae are more stable than the organic matter in wastewater, and degrade slowly in the river stream into which the effluent is discharged.

The oxidation ponds, throwing their effluents in rivers, just upstream of some lakes or reservoirs, are therefore, generally not preferred, as the discharged algae may settle in the reservoirs, and cause anaerobic decomposition and other water quality problems. *However, the effluents from oxidation ponds can be easily used for land irrigation,* particularly at places, where they cannot be discharged into river streams.

iii) Sewage Farming :

Although, outwardly, both these terms are used as synonyms to each other, yet there is one basic difference between them. This difference is that : *in 'effluent 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 a vacant land, which is provided underneath, with a system of properly laid under-drains. These under-drains, usually, consist of 15 to 20 cm dia porous tile pipes, laid open jointed at a spacing of 12 to 30 m. The effluent collected in these drains after getting filtered through the soil pores is generally small (as a large quantity gets evaporated) and well stabilised, and can be easily disposed into some natural water courses, without any further treatment.

In case of *sewage farming*, however, the stress is laid upon the use of sewage effluents for irrigating 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 plants is, therefore, necessary in this case.

However, in general, for all practical purposes, both these terms are used as synonyms, and both means : use of sewage effluents for irrigating crops.

A single stage filter is to treat a flow of 3.79 Mld of raw sewage with BOD of 240 mg/l It is to be designed for a loading of 11086 kg of BOD in raw sewage per hectare meter, and the recirculation ratio is to be unity. What will be the strength of the effluent, according to the standard recommendations.

Solution. Total BOD present in raw sewage

$$= 3.79 \text{ Ml} \times 240 \text{ mg/l} = 909.6 \text{ kg}$$

Now, filter volume required

$$= \frac{\text{Total BOD in raw sewage in kg}}{\text{Given BOD loading rate of 11,086 kg / ha-m}}$$

$$= \frac{909.6}{11086} \text{ ha-m} = 0.082 \text{ ha-m.}$$

Now, assuming that 35% of BOD is removed in primary clarifier, we have

The amount of BOD applied to the filter

$$= 0.65 \times 909.6 \text{ kg} = 591.24 \text{ kg.}$$

Now, using equation (9.34), we have

$$\eta = \frac{100}{1 + 0.0044 \sqrt{\dfrac{Y}{V \cdot F}}}$$

where Y = Total BOD applied to the filter in kg

= 591.24 kg

∴ V = Vol. of the filter in ha-m. = 0.082 ha-m.

$$F = \frac{1 + \dfrac{R}{I}}{\left(1 + 0.1\dfrac{R}{I}\right)^2}; \quad \text{where} \quad \frac{R}{I} = 1$$

$$\therefore \quad F = \frac{1+1}{(1+0.1)^2} = \frac{2}{1.21} = 1.65.$$

$$\therefore \quad \eta = \frac{100}{1 + 0.0044\sqrt{\dfrac{591.24}{0.082 \times 1.65}}} = 77.47\%.$$

∴ The amount of BOD left in the effluent

$$= 591.24\ [1 - 0.7747] \text{ kg.} = 133.21 \text{ kg.}$$

∴ BOD concentration in the effluent

$$= \frac{\text{Total BOD}}{\text{Sewage volume}} = \frac{133.21 \times 10^6}{3.79 \times 10^6} \text{ mg}/l = 35.15 \text{ mg}/l. \quad \textbf{Ans.}$$

Q.6) Design a septic tank for the following data: No. of people=150; Sewage/capita/day=125litres; de-sludging period=one year; length : width = 3:1; Assume any other data if required.

Ans-6 → The quantity of sewage produced
= 125 litres/capita/day

Population = 150 persons.

Total quantity of sewage produced $= 125 \times 150$ lit/day
$= 18750$ lit/day

Assuming the detention time to be 1 day = 24 hours

The quantity of sewage produced during the detention period (i.e. the capacity of the tank) $= 18750 \times \frac{24}{24} = 18750$ lit

Assuming the rate of deposited sludge is 30 lit/cap./day.
and given that period of cleaning/de-sludging = 1 year

The volume of sludge deposited $= 30 \times 150 \times 1 = 4500$ lit.

Total required capacity of the tank =
= Capacity of sewage + Capacity of sludge
$= 18750 + 4500 = 23250$ lit
$= 23.25\ m^3$

Assuming 1.5 m as the depth of the tank

The surface area of the tank $= \frac{23.25}{1.5} m^2 = 15.5 m^2$

If the ratio of the length to width is kept (given) as 3:1

$3 \times B^2 = 15.5 \Rightarrow B = 2.273\ m \simeq 2.3\ m$

$L : B = 3:1$ so $L = 3 \times 2.3 = 6.9 \simeq 7\ m$

Provide width = 2.3 m, Length = 7 m.

Area of cross section $16\ m^2$ which is more than reqd area $= 15.5\ m^2$

The dimensions of the septic tank will be

$7\,m \times 2.3\,m \times (1.5 + 0.3)\,m$ [free board = 0.3 m]

L × B × overall depth

b) Stages of Digestion in Sludge Digester :

Three distinct stages have been found to occur in the biological action involved in the natural process of sludge digestion. These stages are :

(*i*) *Acid fermentation* ;

(*ii*) *Acid regression* ; and

(*iii*) *Alkaline fermentation.*

These stages are briefly summarised here :

(*i*) **Acid Fermentation Stage or Acid Production Stage.** In this first stage of sludge digestion, the fresh sewage-sludge begins to be acted upon by *anaerobic and facultative bacteria,* called **acid formers**. These organisms solubilize the organic solids through *hydrolysis*. The soluble products are then fermented to volatile acids and organic alcohols of low molecular weight like propionic acid, acetic acid, etc. Gases like methane, carbon dioxide and hydrogen sulphide are also evolved. *Intensive acid production makes the sludge highly acidic, and lowers the pH value to less than 6. Highly putrefactive odours are evolved during this stage, which continues for about 15 days or so* (at about 21°C). BOD of the sludge increases to some extent, during this stage.

(*ii*) **Acid-Regression Stage.** In this *intermediate stage,* the volatile organic acids and nitrogenous compounds of the first stage, are attacked by the bacteria, so as to form acid carbonates and ammonia compounds. Small amounts of hydrogen sulphide and carbon-dioxide gases are also given off. The decomposed sludge has a very offensive odour, and its pH value rises a little, and to be about 6.8. The decomposed sludge, also, entraps the gases of decomposition, becomes foamy, and rises to the surface to form scum. *This stage continues for a period of about 3 months or so* (at about 21°C). BOD of the sludge remains high even during this stage.

(*iii*) **Alkaline Fermentation Stage.** In this *final stage* of sludge digestion, more resistant materials like proteins and organic acids are attacked and broken up by anaerobic bacteria, called **methane formers,** into simple substances like ammonia, organic acids and gases. *During this stage, the liquid separates out from the solids, and the digested sludge is formed.* This sludge is granular and stable, and does not give offensive odours. (It has a musty earthy odour). This digested sludge is collected at the bottom of the digestion tank, and is also called **ripened sludge.** Digested sludge is alkaline in nature. The pH value during this stage rises to a little above 7 (about 7.5 or so) in the alkaline range. *Large volumes of methane gas (having a considerable fuel value) alongwith small amount of carbon dioxide and nitrogen, are evolved during this stage. This stage extends for a period of about one month or so (at about 21°C). The BOD of the sludge also rapidly falls down during this stage.*

b) Distinguish between the Refuse and Garbage:

Key:

The municipal solid waste (MSW) is a heterogeneous mixture of various kinds of solid wastes-which are not transported with water as sewage, and may include biodegradable (putrescible) food wastes called *garbage*, and the non-putrescible solid wastes like paper, glass, rags, metal items, etc., called *rubbish*.

The **garbage** includes all sorts of *putrescible (bio-degradable) organic wastes* obtained from kitchens, hotels, restaurants, etc. All waste food articles, vegetable peelings, fruit peelings, etc., are thus, included in this term. These wastes are organic in nature, and thus, likely to decompose quickly, producing foul odours and health hazards. They may also result in breeding of flies, mosquitoes, insects, etc. Hence, garbage must be disposed of, properly and quickly. When it is scientifically processed and *composted,* then it is possible to obtain valuable products, like grease, hog wood, fertiliser, etc. from the garbage. The density of garbage usually varies between 450 to 900 kg/m^3.

The **rubbish** can include a variety of materials, which may either be *combustible* (such as paper, plastic, textile, etc.) or *incombustible* (such as broken glass, crockery, metal, masonry, etc.). Most of these types of wastes are discarded on a regular basis from homes, offices, and small commercial establishments. The density of rubbish usually varies between 50 to 400 kg/m^3.