POSTAL Book Package 2021

CIVIL ENGINEERING

Environmental Engineering

Conventional Practice Sets

Contents

MADE EASY Publications

7 CHAPTER

Disposing of Sewage Effluents

Q.1 A waste water stream (flow = 2 m^3/s, ultimate BOD = 90 mg/*l*) is joining a small river (flow = 12 m^3/s, ultimate BOD = 5 mg/l). Both water streams get mixed up instantaneously. Cross-sectional area of the river is 50 m^2. Assuming the de-oxygenation rate constant, K' = 0.25/day, find the BOD (in mg/*l*) of the river water, 10 km downstream of the mixing point

Solution:

Flow of waste water stream,

$$Q_w = 2 \text{ m}^3\text{/sec}$$

Ultimate BOD,

$$Y_w = 90 \text{ mg}/l = 90 \text{ gm/m}^3$$

Flow of river,

$$Q_R = 12 \text{ m}^3\text{/sec}$$

Ultimate BOD of river,

$$Y_R = 0.5 \text{ mg}/l = 5 \text{ gm/m}^3$$

BOD of mixture,

$$Y_0 = \frac{(2 \times 90) + (12 \times 5)}{2 + 12}$$

$$= \frac{180 + 60}{14} = \frac{240}{14}$$

$$= 17.143 \text{ gm/m}^3$$

$$k_D = 0.434 \text{ K}$$

$$= 0.434 \times 0.25 = 0.1085$$

$$Y_t = Y_0\left[1 - (10)^{-k_D t}\right] \quad \text{...(i)}$$

$$\text{Area of river} = 50 \text{ m}^2$$

$$\text{Flow of river} = 12 \text{ m}^3\text{/sec}$$

$$\text{Stream velocity} = \frac{14}{50} = 0.28 \text{ m/sec}$$

Time taken,

$$t = \frac{10\text{km}}{0.28\text{m/s}} = 0.4133 \text{ days}$$

∴ From eq. (i) ,

$$\text{BOD}_{\text{left}} = Y_0 - Y_t = Y_0 \times 10^{-kt}$$

$$= 17.143 \times 10^{-0.1085 \times 0.4133}$$

$$= 15.46 \text{ mg}/l$$

Q.2 What are different zones of pollution in river stream? Explain the importance of re-oxygeneration, deoxygeneration and oxygen deficit in problems of stream sanitation.

Solution:

Zones of pollution in a river stream: A river/stream undergoing self purification can be divided into following four zones of pollution viz.

(i) **Zone of degradation:** This zone exists upto a certain length beyond the point just below the sewage out fall.

Here in this zone, water becomes dark and turbid along with foundation of sludge deposits at the bottom. Dissolved oxygen gets reduced to about 40% of the saturation value ($\simeq$ 7.6 mg/lit at 30°C).

Rate of de-oxygenation is much higher than re-oxygenation rate.

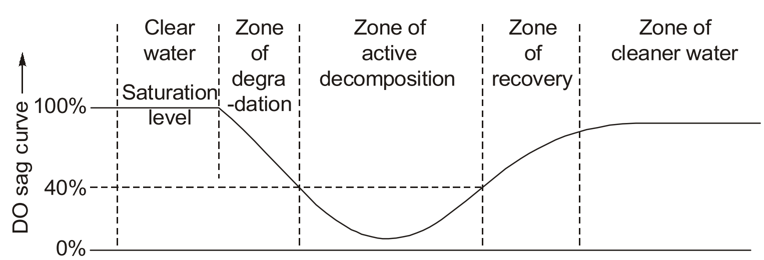
Due to such un-favourable conditions, aquatic life such as algae etc. dies out.

(ii) **Zone of active decomposition:** This is the highly polluted zone.

Here water becomes greyish and much darker. Dissolved Oxygen (DO) level falls down to almost zero. Anaerobic conditions get set in thereby resulting in evolution of gases like CH_4, CO_2, H_2S etc. Due to decomposition of organic matter, the upper part of this zone is dominated by anaerobic bacteria while the lower part is dominated by aerobic bacteria.

(iii) **Zone of recovery:** Here the stream recourse from its degraded condition. Water becomes clear and algae reappears. Dissolved Oxygen (DO) level rises and organic matter gets mineralized to form nitrates, sulphates, phosphates and carbonates.

(iv) **Zone of cleaner water:** Here the river attains its original condition, DO level reaches to saturation value and usual aquatic life prevails.



De-oxygeneration: Due to decomposition of organic matter in a polluted stream, DO level goes on decreasing. Rate of de-oxygenation follows the first order kinetics w.r.t. amount of organic matter remaining to be oxidized at prevalent temperature.

Re-oxygenation: In order to make-up the uses of DO in de-oxygenation process, atmosphere supplies oxygen to water and this process is referred to as re-oxygenation. Rate of re-oxygenation depends on the water body condition i.e., running on static water body, oxygen deficit and depth of receiving water.

Oxygen Deficit: In an running polluted stream, both de-oxygenation and re-oxygenation process goes simultaneously.

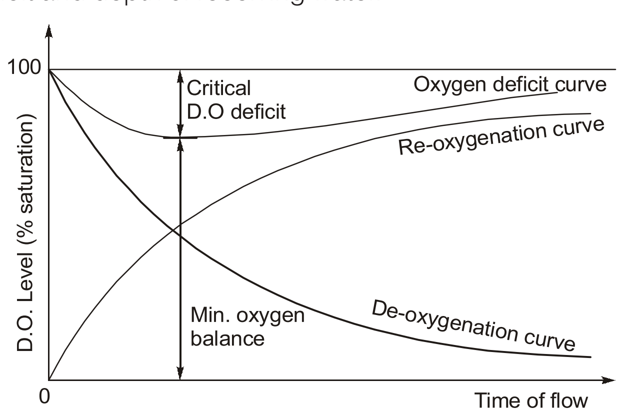
If R_D = rate of deoxygenation

and R_R = rate of reoxygenation

Then oxygen deficit occurs if

$$R_D > R_R$$

Net oxygen deficit = Algebraic sum of deoxygenation and reoxygenation curves.



Q.3 The treated domestic sewage of a town is to be discharged in a natural stream. Calculate the percentage purification required in the treatment plant with the following data:
(i) Population = 50000
(ii) *BOD* contribution per capita = 0.07 kg/day
(iii) *BOD* of stream on *U/S* side = 3 mg/L
(iv) Permissible maximum BOD of stream on *D/S* side = 5 mg/L
(v) Dry weather flow of sewage = 140 litres per capita per day
(vi) Minimum flow of stream = 0.13 m^3/s
Explain graphically the process of self purification of natural waters when sewage is discharged therein.

Solution:

$$\text{Total } BOD \text{ of raw sewage} = \text{Population} \times BOD \text{ contribution per capita}$$
$$= 50000 \times 0.07 = 3500 \text{ kg/day}$$

Sewage discharge, $$Q_s = \frac{50000 \times 140}{10^3 \times 24 \times 60 \times 60} = 0.081 \text{ m}^3\text{/s}$$

River discharge, $$Q_r = 0.13 \text{ m}^3\text{/sec}$$

$$BOD \text{ of the mix} = 5 \text{ mg/L}$$

$$BOD \text{ of the river stream} = 3 \text{ mg/L} = C_r$$

Let *BOD* of treated sewage be C_s.

We know that, $$\boxed{BOD \text{ of mix} = \frac{C_s \times Q_s + C_r \times Q_r}{Q_s + Q_r}}$$

$$\Rightarrow \quad 5 = \frac{C_s \times 0.081 + 3 \times 0.13}{0.081 + 0.13}$$

$$\Rightarrow \quad C_s = \frac{5 \times 0.211 - 0.39}{0.081} = 8.21 \text{ mg/L}$$

$$BOD \text{ of untreated sewage} = \frac{3500 \times 10^6 \text{ mg/d}}{50000 \times 140 \text{ L/d}} = 500 \text{ mg/L}$$

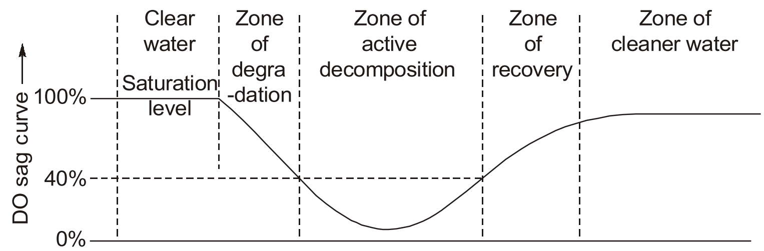
$$\text{Percentage treatment required} = \left(\frac{BOD \text{ of raw sewage} - \text{Maximum permissible } BOD}{BOD \text{ of raw sewage}}\right) \times 100$$

$$= \left(\frac{500 - 8.21}{500}\right) \times 100 = 98.36\ \%$$

A polluted stream undergoing self purification can be divided into the following four zones:

(i) **Zone of degradation:** This zone is characterised by water becoming dark and turbid with formation of sludge deposits at the bottom. *DO* is reduced to about 40% of the saturation value. Reoxygenation occurs but is slower than deoxygenation.

(ii) **Zone of active decomposition:** This zone is marked by heavy pollution which is characterised by water becoming greyish and darker than in the previous zone. *DO* concentration reduces to zero and anaerobic conditions may set in with the evolution of gases like methane and H_2S. As the organic decomposition slackens due to stabilization of organic matter, the reaeration sets in and *DO* again rises to original level i.e. 40%.



(iii) **Zone of recovery:** In this zone, the river stream tries to recover from its degraded condition to its former appearance. The water becomes clearer and so the algae appears while fungi decreases. *BOD* falls down and *DO* content rises above 40% of saturation value.

(iv) **Zone of cleaner water:** In this zone the river attains its original conditions with *DO* rising up to the saturation value. Water becomes attractive in appearance and usual aquatic life prevails.

Q.4 **A city discharge 20 million litres per day of waste water at temperature of 25°C into a stream, whose discharge is 2.0 cumecs and whose temperature is 25°C. The 5 days BOD of waste water is 150 mg/*l* and k_1 (Deoxygenation constant rate/day) Value is 0.1 day and k_2 (Reaeration rate constant/day) is 0.2/day. Determine the critical oxygen deficit and time of occurrence. Assume stream is 90% saturated with oxygen before the waste is added. Take solubility of oxygen in water at 25°C as 9 mg/*l*.**

Solution:

Given: Waste water discharge, $Q_1 = 20$ million litres/day (Given)

$$= \frac{20\times10^6\times10^{-3}}{86400} = 0.231\ \text{m}^3/\text{s}$$

Stream discharge, $Q_2 = 2\ \text{m}^3/\text{s}$ (Given)

Waste water, 5 days BOD = 150 mg/*l* (Given)

Stream dissolved oxygen = **0.9 × 9 = 8.1 mg/*l***

Saturated dissolved oxygen, $DO_{sat} = 9$ mg/*l*

Assuming expansion factor of 1.1

Dissolved oxygen of mixture, $$DO_{mix} = \frac{1.1\times0.231\times0+2\times8.1}{1.1\times0.231+2} = \mathbf{7.187\ mg/l}$$

Initial oxygen deficit, $D_0 = 9 - 7.187 = 1.813$ mg/*l*

5 day BOD of mixture, $$BOD_5 = \frac{1.1\times0.231\times150+2\times0}{1.1\times0.231+2} = \mathbf{16.91\ mg/l}$$

Using, $$BOD_5 = L\left(1-10^{-(k_1\times5)}\right)$$

$$16.91 = L\,(1-10^{-(0.1\times5)})$$

Ultimate BOD of mixture, $L = 24.73$ mg/*l*

Self purification factor, $$f = \frac{k_2}{k_1} = \frac{0.2}{0.1} = 2$$

Using, $$\left(\frac{L}{D_C f}\right)^{f-1} = f\left(1-(f-1)\frac{D_0}{L}\right)$$

$$\Rightarrow \quad \left(\frac{24.73}{D_C\times2}\right)^{2-1} = 2\left(1-(2-1)\times\frac{1.813}{24.73}\right)$$