Ministry of Higher Education and Scientific Research
Southern Technical University
Basrah Engineering Technical College

Water Pollution Control

For

Students of forth class
Department of Environment and Pollution Engineering
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By

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AEROBIC BIOLOGICAL OXIDATION

Six modular unit

Rationale :-

The amount of organic matter which can be assimilated by a stream is limited by the availability of dissolved oxygen. In industrialized areas where large volumes of wastewater are discharged to relatively small rivers, natural self-purification cannot maintain aerobic conditions and waste treatment additional to the removal of suspended matter by physical means is essential. Removal of soluble and colloidal organic matter can be achieved by the same reactions as occur in self-purification, but more efficient removal can be achieved in a treatment plant by providing optimum conditions.

The Text :-

Definition

Aerobic biological oxidation process is used to removal of soluble and colloidal organic matter.

Biological Oxidation

a- Principles of biological oxidation:

It is possible to achieve a rapid rate of removal of organic matter from solution by providing a large population of micro- organisms in the form of a slime or sludge. The large microbial surface permits initial adsorption of colloidal and soluble organics together with synthesis of new cells so that after a relatively short contact time the liquid phase contains little residual organic matter. The adsorbed organic matter is then oxidized to the aerobic and products.

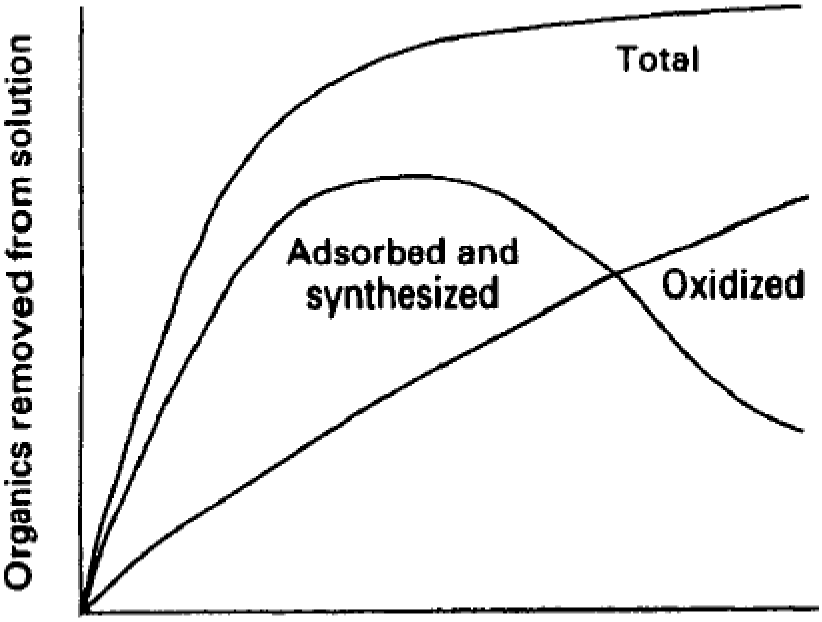


Figure (1) Removal of soluble organics in biological treatment

The rate of removal of organic matter depends on the phase of the biological growth curve.

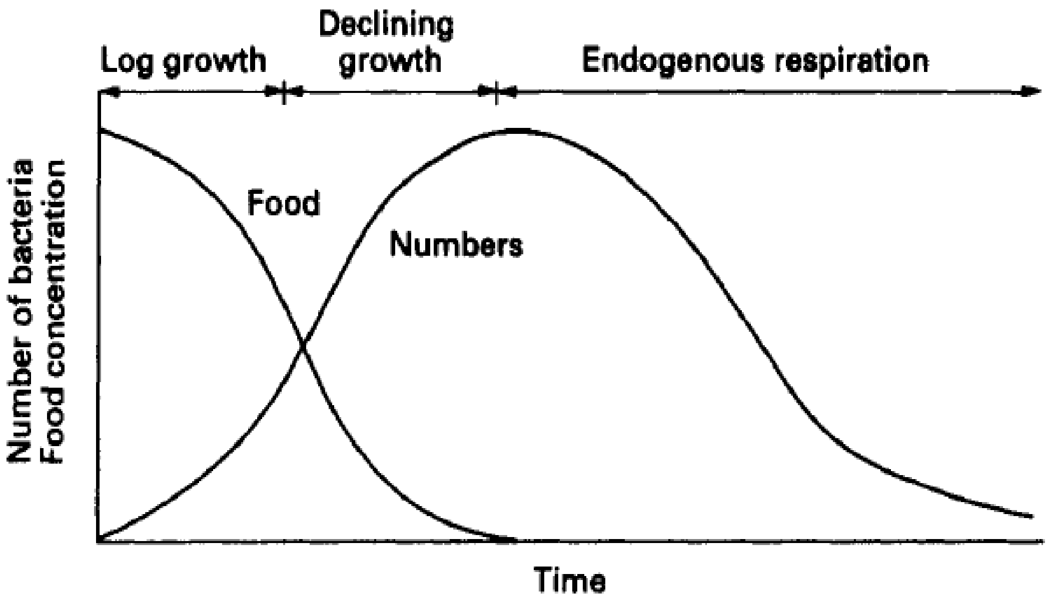
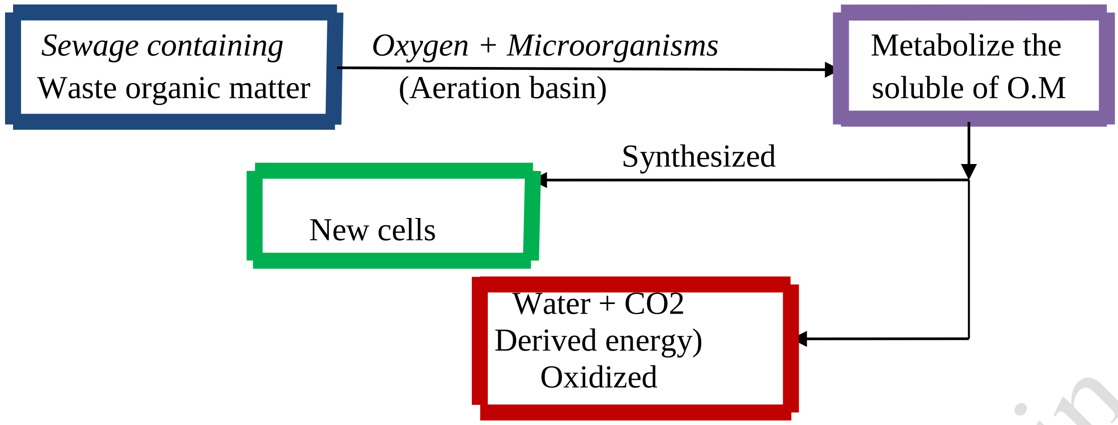


Figure (2) The Biological Growth Curve

To maintain aerobic conditions in the reactor, oxygen must be supplied, since it is utilized for oxidation reactions and for basic cell maintenance.



$\frac{1}{3}$ COD of waste is used for energy.

$\frac{2}{3}$ COD of a waste utilized for synthesis of new cells.

b- Types of aerobic oxidation plant:

Biological treatment reactors provides the high population of microorganisms in the form of either a fixed film on a suitable support surface or as a dispersed growth kept in suspension by an appropriate level of mixing.

There are four basic types of aerobic reactor:

i. Biological filter, trickling filter or bacteria bed-fixed films systems.

ii. **Activated sludge-dispersed growth systems.**

iii. Oxidation ponds-dispersed growth systems.

iv. Land treatment-complex system.

Activated Sludge

This process depends on the use of a high concentration of microorganisms present as a floc kept suspended by agitation, originally with air of high rates of oxygen.

The effluent from the aeration is again low in dissolved organics but contain high SS which must be removed by sedimentation. The effective use of the process depends on the return of the separated sludge (living microorganisms) to the aeration zone to recommence stabilization.

a- Activated sludge process variables

An activated sludge plant is essentially consists of the following:

i. Aeration tank (containing micro- organisms in suspension).
ii. Activated sludge recirculation system.
iii. Excess sludge wasting and disposal facilities.
iv. Aeration system to transfer oxygen.
v. Secondary sedimentation tank to separate and thick activated sludge.

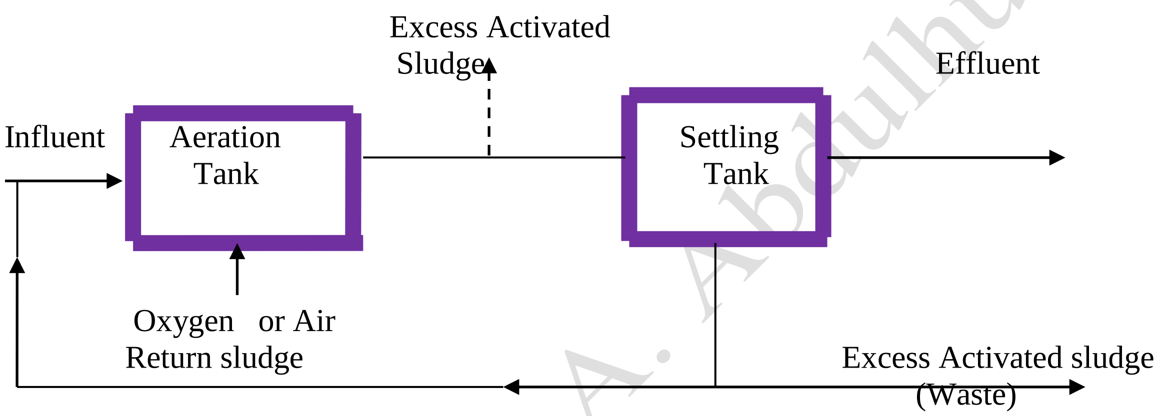


Figure (3) Conventional Activated sludge (Typical A.S process)

b- Classification of Activated sludge process:

This process is classified into three main groups depending on the method of aeration:

1- Diffused Aeration tanks (i) Ridge and furrow type
(ii)Spiral flow tanks

2- Mechanical Aeration (i) Simplex type aerator
(ii)Link belt system

3- Combined mechanical and diffused air unit.

c- Mixing Regime:

∗ Plug flow (PF): In this system the sewage moves down progressively along the aeration tank.

∗ Complete mixed flow (CMF): In this system the sewage fed to the aeration tank at multiple points and complex mixed flow involves the rapid dispersal of the incoming sewage throughout the tank.

d- Definitions:

∗ The mixed liquor suspended solids (MLSS)
MLSS content is generally taken as index of the mass of active and dead cells of organisms in the aeration tank.

MLSS $\Longrightarrow$ 1500- 3000 mg/l (PF)
MLSS $\Longrightarrow$ 3000- 6000 mg/l (CMF)

∗ The mixed liquor volatile suspended solids (MLVSS):

MLVSS is a better indicator of activate microbial concentration. (Eliminate the dead cells of O.M). The ratio of MLVSS/MLSS is taken as (0.7- 0.8).

∗ F/M Food to Microorganisms Ratio:

It is the organic loading rate is defined as the ratio of kg BODs applied per day (representing microbial feed) to kg MLSS in aeration tank (representing microorganisms).

(PF) $\longrightarrow$ (F/M ratio) and (BODs) very high in inlet and reduce progressively.
(CMF) $\longrightarrow$ Uniform (F/M) and (BOD) $\longrightarrow$ More efficient
More effective

Thus, volume and detention time reduced.
* Oxidation- addition of Oxygen or removal of Hydrogen
*Reduction- addition of Hydrogen or removal of Oxygen.
*Hydrolysis- addition of water.
*Dehydrolysis- removal of water.
*Deamination- removal of NH2 group.

e- Types of process and Modifications:

1- Conventional system: (Figure 3)

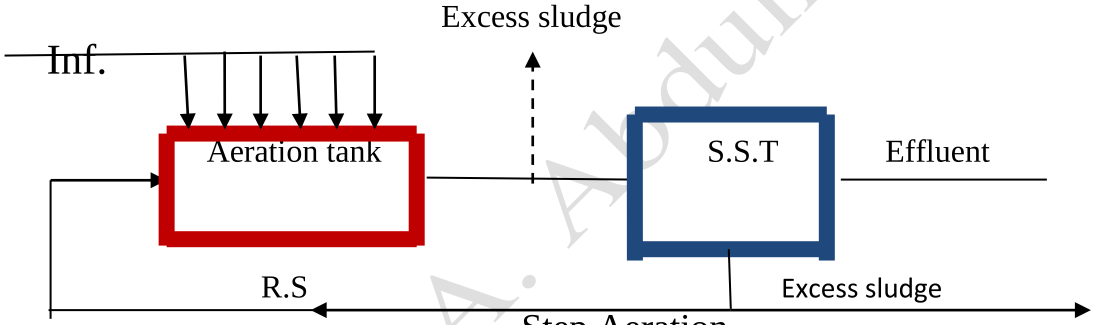
P.F; BOD removal 85-92%

2- Tapered Aeration: (Figure 3)

The application of air to aeration tank shall be at a higher rate near the influent end. The varying oxygen demand supply ratio has led to controlled aeration. (Attempt to supply air to match oxygen demand along the length of the tank).

3- Step Aeration:

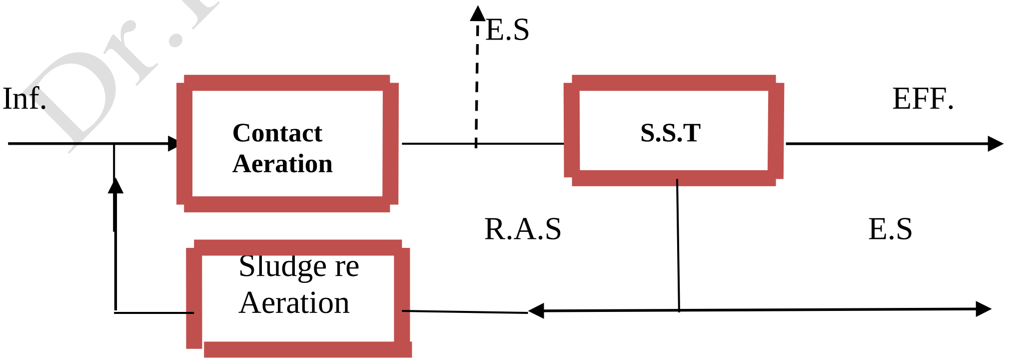
Settled sewage is introduced at several points along the tank length which produced a more uniform oxygen demand throughout.



Step Aeration

4- Contact stabilization:

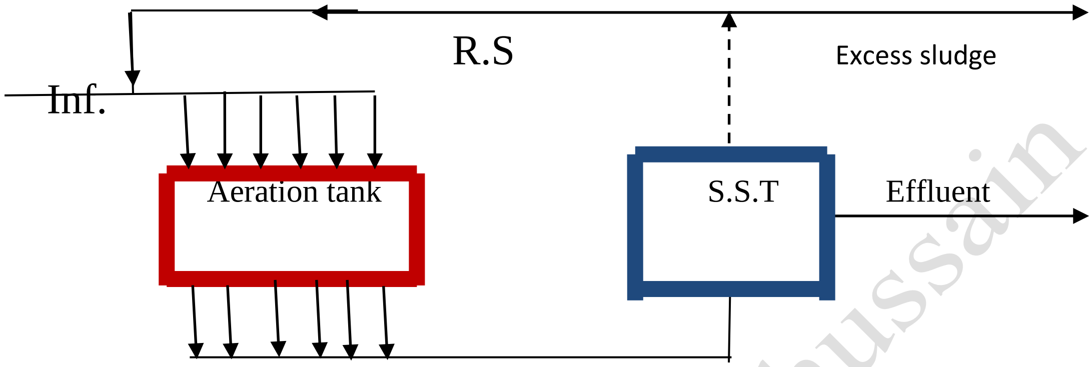
C-S- Provides for reaction of returns activated sludge from the final clarifier, which allows a smaller aeration or contact tank.



Contact Stabilization

5- Complete Mix Process:

In this process, the complete mixing is achieved by distributing the sewage and the return sludge uniformly along one side of the tank and withdrawing the aerated sewage uniformly along the opposite side.



Complete Mix Process

Design Consideration

1-Volume of Aeration tank:

a- Diffused aeration method

$$V = Q \times T$$

Where, V= volume of the tank, m^3

Q= Rate of sewage flow, m^3/hr.

T= Detention period (HRT) in hrs.

Detention period for diffused aeration method is given by formula:

$$B.O.D = 20\,(T+1)$$

Where, B.O.D = BOD in mg/l to be removed

b- Mechanical aeration method.

$$T = (BOD)^{3/4}/10 \Longrightarrow V = Q.T$$

c- Based on organic loading.

$$\frac{F}{M} = \frac{Q*La}{V*MLSS}$$

$\frac{F}{M}$= Food to microorganism's ratio — (P.F)= 0.2 to 0.4 ; C.M.F =0.2to0.6

La= Influent B.O.D, mg/l

d- Rational method:

$$\frac{V*(MLSS)d}{100} = \frac{Total\ B.O.D}{(B.O.D)d}$$

Where, (MLSS)d=Design MLSS to maintain in reactor
Total B.O.D= Influent B.O.D to reactor
(B.O.D) d= B.O.D loading/100 gm. of solids

2- Hydraulic Retention time in reactor

Or

$$T=\frac{V}{Q} \Longrightarrow T=\frac{La*MLSS}{F/M}$$

3-Excess sludge production

M_w= y. F-K_d. M

Where; M_w =Excess solids produced (kg/day) = Q_w. X_s
Y= maximum yield coefficient= 0.5-0.7
F= BOD to be removed (gm/day) =Q*La
K_d= endogenous respiration rate constant
=0.05-0.075d^{-1}
M= Total MLSS in the reactor=V.X

4-Sludge Retention Time (SRT) [sludge Age]

$$SRT=\frac{M}{Mw} \Longrightarrow SRT=\frac{V.X}{Qw.Xs}$$

5-Sludge Recycle:

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

X=MLSS in reactor (gm/m^3)
X_R= MLSS in returned sludge (gm/m^3) =10000 gm/m^3 (max) Q
Q_R= Return sludge= Sludge recirculation rate (m^3/day)
Q= Flow rate m^3/day

6-Oxygen Requirements:

O_2 required $\frac{g}{day}=\frac{Q*La}{f}$-1.42 Q_w. Xs (for carbon)

Where, f= ratio of BODs to ultimate BOD
O_{nit}= Oxygen required for nitrification
= 4.6 gm of O_2 for NH_3 to NO_3

OR: 1m^3 of air should be supplied for each 15 gm of B.O.D

7-Sludge Volume Index: (SVI)

It is the ratio of the volume of the activated sludge in m^3 for one gram of dry weight of sludge.

$$SVI=\frac{Settled\ volume\ of\ sludge\ in\ 30\ \text{min}\ \%}{MLSS}$$

SVI
- 55 → 150(in diffused aeration)
- 200 → 300 (in Mechanical aeration)

A higher value of SVI indicates a light and fluffy sludge which is not easily settable. Such conditions of sludge bulking shows inefficient operation of the plant. This condition may be overcome by increasing the proportion of return sludge or lowering excess aeration.

8- In activated sludge process, when the soluble BOD in the effluent is restricted to a desired limit and it can be given by the following expression:

$$\frac{1}{SRT} = \frac{Q.\left(\frac{F}{M}\right).\ (La - Ls)}{V \text{x} MLSS} - K_d$$

Where L_s= Soluble BOD in the effluent in kg/m^3

K_d= endogenous rate constant,d^{-1}

And other terms as already stated earlier in m and kg units.

The following example will illustrate the application of the formula.

Illusterated Problems

Problem 1: A complete mixed activated sludge plant having discharge of 10000 m^3/day and influent BOD of 150 mg/l should have not more than 5 mg/l effluent soluble BOD. F/M=0.5; $(MLSS)_{A.T}$=3000 mg/l; $(MLSS)_{w.s}$ =10000 mg/l; K_d=0.05 d^{-1} ; SRT=10 days.

Determine the following:

(a) Volume of the reactor

(b) The mass and volume of solids that must be wasted/ day.

(c) The recirculation ratio.

Solution:

(a) $$\frac{1}{SRT} = \frac{Q * (\frac{F}{m}) * BOD\ removed}{V * MLSS} - K_d = \frac{Q.\left(\frac{F}{M}\right).\ (La - Ls)}{V * MLSS} - K_d$$

$$\frac{\mathbf{1}}{\mathbf{10}} = \frac{\mathbf{10000 * 0.5 * (0.15 - 0.005)}}{\boldsymbol{V * 3}} - 0.05 \qquad Solve\ for\ V = 1611\ m^3$$

(b) At equilibrium conditions:

$$SRT = \frac{M}{M_w} = \frac{Mass\ of\ the\ solids\ in\ reactor}{mass\ of\ the\ solids\ wasted}$$

$$10 = \frac{V * (MLSS)A.T}{Qw * (MLSS)w.s}$$

$$10 = \frac{1611 * 3}{Qw * (MLSS)w.s}$$

Or $M_w = Qw * (MLSS)_{w.s} = \frac{1611 * 3}{10}$ = 483.3 kg/day

The concentration of solids in the under flow

$Q_w * 10000\ \frac{mg}{l} * (10^3/10^6)$= 483.3 kg/day

$\therefore$ $Q_w = 48.33\ m^3/day$

(c) $Qr = \frac{Q.(MLSS)A.T - Qw.(MLSS)W.S}{(MLSS)w - (MLSS)A.T}$

$Qr = \frac{(10000*3)-(48.33*10)}{10-3} = 4217\ m^3/d$

$\frac{Qr}{Q} = 4217/10000 = 0.42$

Problem 2: Calculate the sludge volume index for mixed liquor with 2500 mg/lit of suspended solids having settled volume of 190 ml. with a liter sample. Is this sludge volume index good or poor?

Solution:

2500 mg settles to 190 C.C

$\therefore$ 1 gm settles to $\frac{190\ c.c}{2.5 gm}$ = 76 ml/gm.

Hence S.V.I =76 cc/gm.

If this from diffused aeration plant, S.I.V value (between 55 to 150) is good.

In case of mechanical aeration this is too low a value.

Problem 3: Compute the volume and air required for an aeration tank of an activated sludge plant of 10,000 persons and the sewage flow equal to 300 liters per head per day. Given BOD /capita /day equal to 0.077 kg and return sludge 30 per cent. Detention period= 6 hours and 35% of BOD being removed in the primary settling tank.

Solution:

Q=10,000x300 liter/day

Return sludge = 30%

Detention period = 6 hr.

$\therefore$ Total volume = Q*T= $\frac{10,000x300x1.3x6}{24x1000}$ = $975\ m^3$

Provide 50mx5.5mx3.5, deep tank

B.O.D= 10,000*0.077*(1-0.35)*1000/(24*60) =348 gm. /min.

$\therefore$ Air supply = $\frac{348}{15}$ = $23\ m^3$/ min.

Problem 4: Design a conventional activated sludge plant to treat 5000 m^3/day of domestic sewage having B.O.D of 350 mg/lit. B.O.D of treated waste should be 30 mg/lit. Assume: F/M = 0.6 kg B.O.D. / kg. of MLSS and the B.O.D. loading is to be 60 gm. of suspended solids to be maintained.
MLSS concentration in aeration tank= 2500 mg/lit.
Aeration requirement= 0.8 kg O_2 /kg. of B.O.D removed.
Aerator capacity = 1.6 kg O_2/h.p.hr.
Assume 25% return sludge

Solution: Total B.O.D $=\frac{350x5000x1000}{1000}$= 1,750,000 gm.

MLSS= 2500 mg/lit. = 2.5 gm./lit.

Let the tank volume = V liters.

∴Solid content in the tank =2.5V

$$\frac{V*(MLSS)d}{100}=\frac{Total\ B.O.D}{(B.O.D)d} \qquad \frac{2.5V}{100}=\frac{1,750,000}{60}$$

∴ V=1,165,000 lit= 1166 m^3

For 25% return sludge

∴ Volume provided = 1165+0.25x1165=1456m^3

Provide 50mx7mx4m deep tank

B.O.D to be removed per liter of sewage= (350-30) =320 mg/lit

Total B.O.D to be removed

$$=\frac{320*5000*1000}{10^6*24}=66.67 = 67 \text{ kg/hr.}$$

Air supply required= 0.8x67=54 kg/hr.

Aerator capacity = $\frac{54}{1.6}$ = 33 .7 h.p.hr.

Problem 5: An aeration tank with the diffused air system is to treat 6.8 MLD of settled sewage having a B.O.D. of 200 mg/lit. The final effluent is to have a B.O.D. of 10 mg/lit. Find the (i) Volume of the aeration tank, if the design criterion is 1 m^3 for 535 gm. of B.O.D. in the effluent sewage to the tank. (ii) Volume of the aeration tank, if the suspended solid content of the mixed liquor is 2500 mg/lit and the B.O.D. loading is to be 40 gm of suspended solids; (iii) Period of aeration, if the sludge occupies 25% of the aeration tank.

Solution:

(i) B.O.D.= $200 x 6.8 x 10^6/1000$ =1,360,000 gm./day

For 535 gm. B.O.D. tank volume = $1 m^3$

$\therefore$ 1,360,000 B.O.D. tank volume=2542 m^3

(ii) Suspended solids=2500 mg/lit=2.5 gm./lit

Let the tank capacity = V liters.

$\therefore$ Solid content of the tank=2.5xV gm.

From allowable loading conditions

$$\frac{2.5xV}{100}=\frac{1,360,000}{40}$$

$\therefore$ V= $1.36 x 10^6$ liters=1360 m^3

(iii) Given return sludge 25% $\therefore$ Tank volume

V=1.25x1360 m^3

$\therefore$ Detention period T=$\frac{V}{Q}$= $1.25 x 1360 x 24/6.8 x 10^3$= 6.0 hrs.

Problem 6: A sedimentation tank receives sewage of 0.3 m^3/s having suspended solids of 300 mg/l. The suspended solids removal is 60%.Calculate,

(i) SS. In $kg/d/m^3$ the effluent and

(ii) Kg of sludge per day, if the moisture content is 96%.

Solution:

Sewage flow Q=0.3 m^3/s= 25920 m^3/d

S.S. in the influent = 300 mg/l.

$\therefore$ S.S in the effluent = (1- 0.6)x300= 120 mg/l/d

=$120 x 1000/10^6$=0.12 $kg/m^3/d$

(i) S.S. =0.12x25920=3110 kg/d.

(ii) Sludge =$\frac{(3110)(0.96)}{(1-0.96)(1.1)}$ =67855 kg/d.

Problem 7: Indicate the approximate size of the activated sludge unit (diffused air unit) of 4 MLD capacity. Assume B.O.D. of raw sewage is 300 mg/lit., the B.O.D removal in the previous units are 40%, A.S efficiency=90%, return sludge is 20%.

Solution:

B.O.D to A.S. Unit= (1- 0.4)x300=180 mg/lit.

The B.O.D. removal of A.S. Unit

=0.9x180=162 mg/lit.

∴Detention period T is given by

162=20(T+1)

Or T=7 hours

∴Tank capacity C= 7x($4x10^6/10^3$x24)=470 m^3

Rate of aeration will be done 1m^3 for 15 gm. of B.O.D.

Total B.O.D. =($180x4x10^6$)/(10^3x24x60x60)=8.33 gm./sec

Hence free air required = $\frac{8.33}{15}$=0.5 m^3/sec.

Actual tank volume provided=470+0.2x470=564 m^3

=40mx5mx3m deep.

Problem 8: Calculate the sludge volume index for mixed liquor with 2000 mg/lit suspended solids having settled volume of 200 ml with a liter sample. Is this sludge volume index good or poor?

Solution:

S.V.I. =$\frac{ml.of\ settled\ volume\ of\ sludge}{1\ gm.of\ dry\ wt.of\ solid}$

2000 mg settling gives 200 ml.

Or 1 gm. Settling gives $\frac{200}{2.0}$

Hence S.V.I = 100

This is a good sludge volume index for diffused aeration.

Problem 9: Compare the area requirements for trickling filters (0.14 kg BOD/m^3-d) and activated sludge (0.65 kg BOD/m^3-d) for the flow from town of 30000 populations. Daily water flow (DWF) is 250 liters/c/d with 300 mg/l BOD. Assume a filter depth equal to 2.5 m and 3.5 deep aeration tank. The primary sedimentation removes 40% of the applied BOD.

Solution:

Total DWF=250 * 30000=7.5*10^6 liters/d

=(7.5*10^6) / (24*3600)=86.6 say 87 liters/sec.

BOD of effluent entering SST=(1- 0.4)* 300=180 mg/l
BOD in kg/d= $180*10^{-6}*87*3600*24$= 1353 kg/d

Trickling Filter:
Rate of BOD removal=0.14 kg BOD /m^3-d
Volume required=1353/0.14=9665 m^3
Area required= 9665/2.5=3866 m^2

Aeration Tank:
Rate of BOD removal=0.65 kg BOD /m^3-d
Volume required=1353/0.65=2082 m^3
Area required= 2082/3.5=595 m^2

This shows that the activated sludge plant proves to be more compact unit.

Test 1:-

Circle the correct answer:-

1. **In activated sludge process the F/M ratio should range between:-**

a- 0.2 to 0.6
b- 0.6 to 0.8
c- 0.8 to 1.
d- 1.:1.

2. **In activated sludge process the solid retention time should range between:-**

a- 1 to 2 days
b- 2 to 5 days
c- 5 to 15 days
d- 15 to 50 days

3. **The recommended value of SVI in diffused aeration system should be:**

a- 5 to 10
b- 10 to 25
c- 25 to 55
d- 55 to 155

4. **The recommended value of SVI in mechanical aeration system should be:**

a- 10 to 50
b- 10 to 25
c- 100 to 200
d- 200 to 300

5. **In the treatment by Activated sludge process:**

a- There will be problem from fly
b- Initial cost is higher than Trickling filter
c- Power requirement is higher than Trickling filter
d- The head requirement is higher than Trickling filter

6. **Classification of the activated sludge process depends on:**

a- Aeration method b- Energy method

c- Construction method d- other method

7. **The ratio of mixed liquor volatile S.S to mixed liquor S.S taken as :**

a- 0.7 b- 0.75 c- 0.8 d- 0.85

8. **Food to micro-organism ratio of plug flow ranges from:**

a- 0.2-0.3 b- 0.2-0.4 c-0.2-0.5 d-0.2-0.6

9. **A higher value of (Sludge Volume Index)SVI indicates:**

a- stops the growth of bacteria b- a light and fluffy sludge
c- kill the bacteria d- a heavy and fluffy sludge

10- Attempt to supply air to match oxygen demand along the length of the tank is called:

a- Tapered aeration b- conventional system

c- Step aeration d- contact stabilization

Test 2:-

Design the activated sludge unit (compute the volume and air required) for the following:

(i) Population=50,000
(ii) Average sewage flow= 180 l.p.c.d.
(iii) B.O.D. of raw sewage= 200 mg/lit.
(iv) Suspended solids of raw sewage = 300 mg/lit.
(v) B.O.D. removal in primary treatment = 35%
(vi) Overall B.O.D. reduction desired=80%
(vii) Assume return sludge=20%

key answer :-

1- Test 1:-

1. **a**
2. **c**
3. **d**
4. **d**
5. **c**
6. **a**
7. **c**
8. **b**
9. **b**
10. **a**

If you:-

a. Got 9 or more, go to test2.
b. Got less than 9 you have to study this modular unit well.

2- Test 2:-

Solution:

Flow = 180x50,000 lpd 375 m^3/hr

Overall B.O.D. to be removed

= 0.8x200 = 160 mg/lit (1 Mark)

B.O.D. removed by primary treatment

= 0.35x200=70 mg/lit (1 Mark)

∴ B.O.D to be removed by A.S.P

= 160-70 =90 mg/lit (1 Mark)

Detention period T is given by B.O.D.

=20(T+1)

Or 90=20(T+1)

Or T= 3.5; keep T=4 hours. (1 Mark)

Capacity of the tank

C=Q x T=375x4=1500 m^3 (1 Mark)

Capacity to be provided=1500+0.2x1500=1800m^3 (1 Mark)

Provided two number of tanks each of 50mx6mx3m deep.

B.O.D. applied to A.S.P.=200-70=130 mg/lit. (1 Mark)

Total B.O.D. $=\frac{130x180x50,000}{1,000x24x60x60}$=135 gm/s. (1 Mark)

Assuming 15 gm of B.O.D. needs 1 cu. M free air. (1 Mark)

$\therefore$ 135 gm needs 135/15=0.9 m^3 free air.

Air to be supplied = 0.9 m^3/s (1 Mark)

If you:-

- Got 9 or more, so congratulation for your performance.
- Got less than 9, go back and study the current unit; or any part of it; again, and then do the post test again.

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