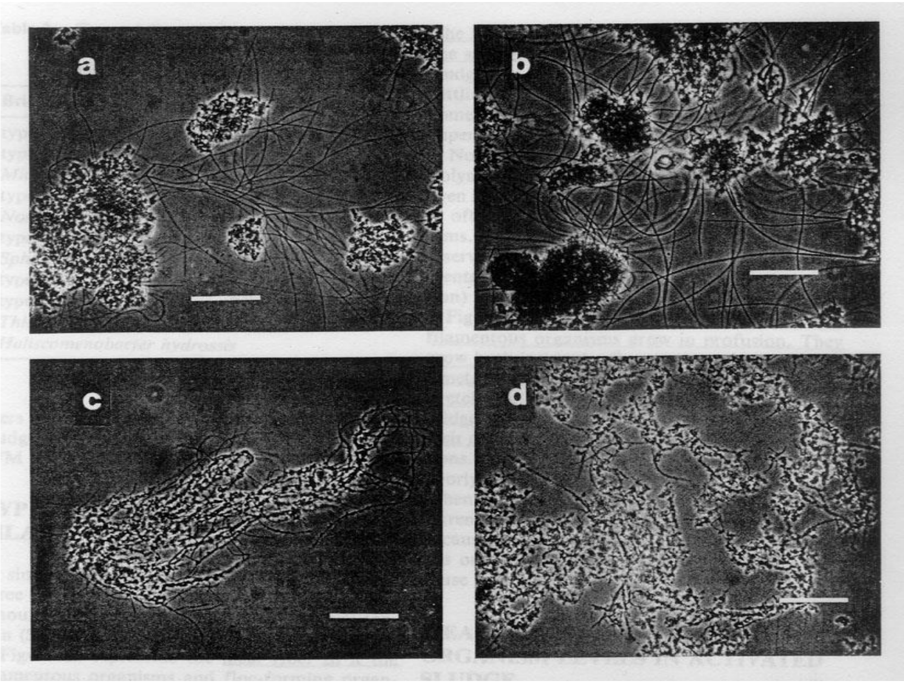
Activated Sludge Process

Suspended growth reactor

In this type of reactor , reaction between organic matter and bacteria takes place in suspension on the surface of the suspended solids (suspended returned sludge particles).

Purpose:

Stabilize organic matter and make it satiable.



A microscopic photo of the reaction between organic matter and bacteria which takes place in suspension solids on the surface of the suspended

Types of activated sludge process:

1- Conventional aeration.
2- Contact stabilization.
3- Step aeration.
4- Extended aeration.
5- Oxidation ditch (orbital aeration).

Conventional aeration

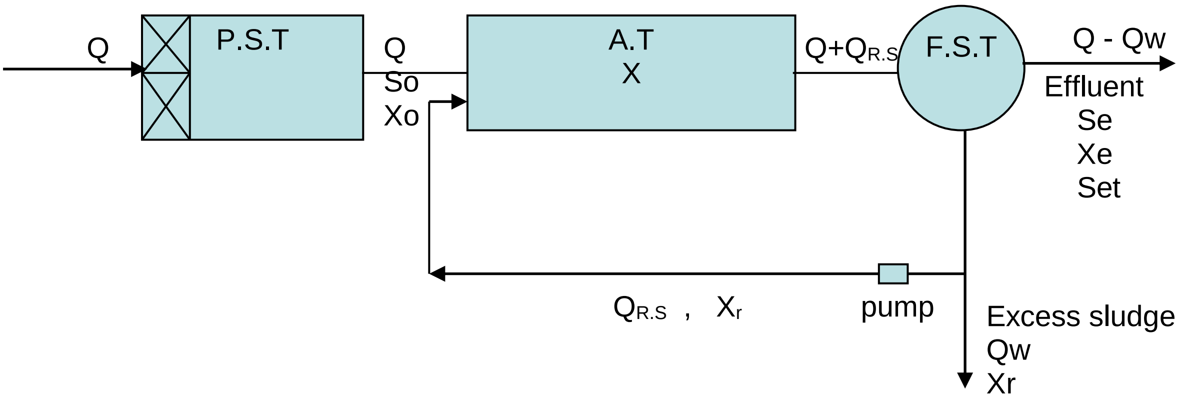
Advantages of aeration tanks :

1- It does not need large land areas.
2- It is more efficient than trickling filters.
3- No fly and odor problems occurs around the trickling filter.

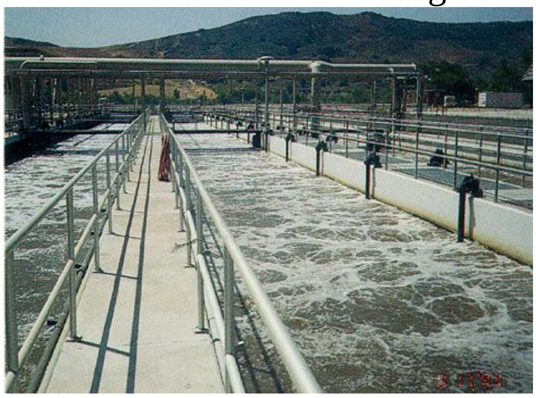
Disadvantages of aeration tanks:

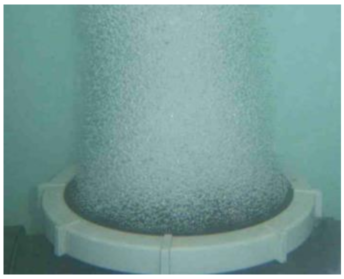
1- It can not take shock loads and sudden increase in discharge.

2- Needs a supervisor since it is the most complicated systems.
3- High cost of construction , operation and maintenance.



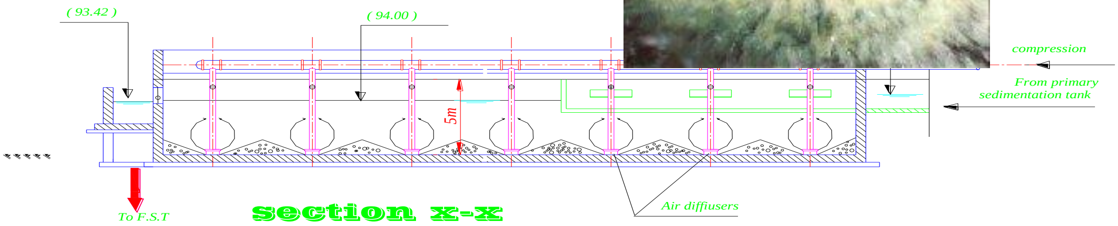
Flow line diagram of activated sludge process

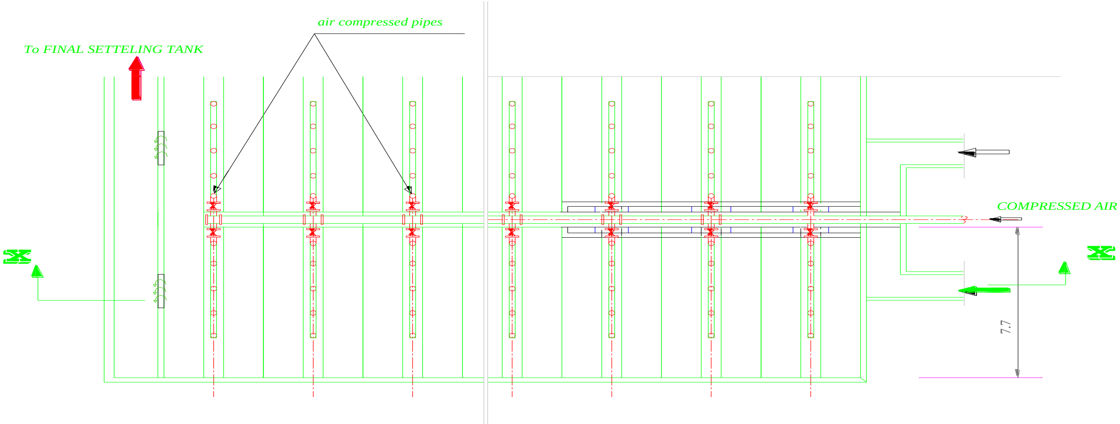




Diffused air system of aeration tank

Surface aerators of aeration tank





Aeration tank

<u>Factors affecting design of aeration tank:</u>

1- Temperature: the biological reaction increase with the increase of temperature.

2- MLSS: (mixed liqueur suspended solids) 2000 - 4000 mg/L

MLVSS: (mixed liqueur volatile suspended solids)

MLVSS = 0.8 MLSS

3- Sludge retention time = T = 4 - 8 hrs

4- Sludge return rate (R) = 0.2 – 0.3

R = QR / Qd

Return sludge QR.s = 0.2 - 0.3 Qd

Types of aeration :
1- Diffused air system
2- Surface aerators

Design criteria :

$$V = \frac{y \times \theta_c \times Q \times (S_0 - S_e)}{X(1 + K_d \theta_c)}$$

Q = discharge influent to the aeration tank (A.T).
= 1.5 x $Q_{ave\ sewage}$ (Q = 0.8 x 1.5 x pop x q_{ave})

- S_o = dissolved BOD_5 influent to the A.T.
- S_e = dissolved effluent BOD_5
- Set = effluent total BOD_5 → suspended / dissolved
- Xe = suspended solids concentration (S.S) → inorganic 30% / organic 70%
- BOD_5 suspended = S.S x 0.7
- BOD_5 dissolved = total BOD_5 - BOD_5 suspended
- S_e = Set – Xe x 0.7

X: total number of microorganisms responsible for the stabilization of organic matter.

- X = MLVSS
- MLVSS = 0.8 MLSS
- Ɵc = sludge age =5 - 15 days
- y: cell yield coefficient
- y = gm MLVSS/gm BOD5
- Y observed = y / (1+ kd Ɵc) = 0.31
- Kd = decay coefficient = 0.05 day-1
- A = V / d
- Depth = 3 - 5 m
- n ≥ 2
- b = 1.5 – 2 d
- L ≤ 50 m

Checks :

$$T = \frac{V}{Q} \quad T = 4-8\ hrs$$

$$F/M = \frac{Q(S_o - S_e)}{MLVSS \times V} \quad F/M = 0.2-0.4$$

$$V = \frac{T.O.L}{L}$$

$$L = \frac{S_o \times Q}{V \times 1000}$$

Allowable organic load (L) = 0.3 - 2 kg BOD5 /m³/ day

$$R = \frac{Q_{R.S}}{Q} = \frac{MLSS}{TSS in R.S - MLSS}$$

$$\theta_C = \frac{X \times V}{Q_w \times X_r}$$

$$\theta_c = \frac{X \times V}{Q_w \times X_r + X_e (Q - Q_w)}$$

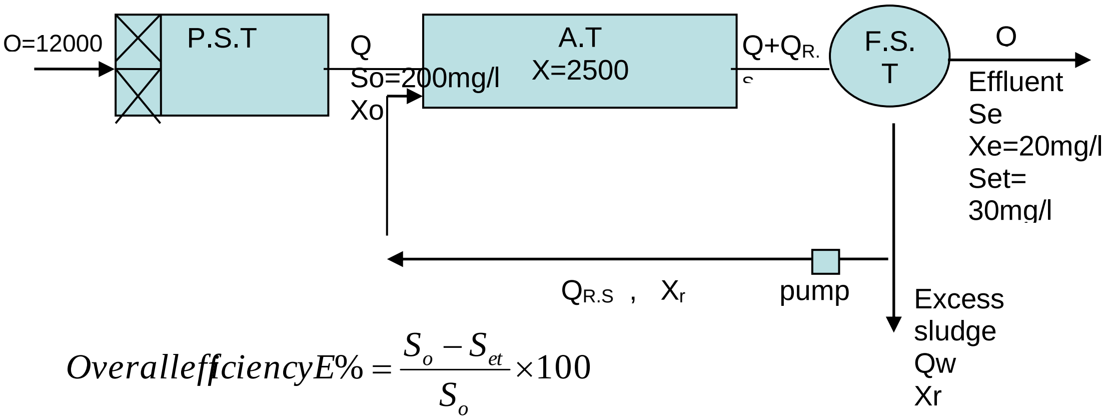
Qw = sludge withdrawal rate
Xr =MLVSS in return sludge
Xe = effluent S.S

Example:

Determine the volume and dimensions of aeration tank and the required air flow for an activated sludge process treatment plant. Which is designed to treat the flow Q = 12000 m3/d and fined overall efficiency, F/M ratio, allowable organic load and the diffused air system. Given the following data:

- BOD5 of primary effluent (So) = 200 mg/l
  - Required effluent BOD5 = 30 mg/l (Set)
- Required effluent suspended solids (Xe) = 20 mg/l
  - MLVSS in aeration tank (X) = 2500 mg/l
  - MLSS in return sludge = 10000 mg/l
  - Cell residence time (θc) = 6 days
  - Coefficient of decay (kd) = 0.06 day-1
  - Cell yield coefficient (y) = 0.65 gm MLVSS/gm BOD5
  - Efficiency of aeration = 8%

Solution:



$$Overall\,efficiency\,E\% = \frac{S_o - S_{et}}{S_o} \times 100$$

$$= \frac{200 - 30}{200} \times 100 = 85\%$$

$$V = \frac{y \times \theta_c \times Q \times (S_0 - S_e)}{X(1 + K_d \theta_c)}$$

BOD5 dissolved = BOD5 eff. – S.Seff x 0.7

Se =Set – Xe x 0.7

= 30 – 20 x 0.7 = 17.45 ~ 17.5 mg/l

Set → Dissolved, suspended

Xe → 70% organic, 30% inorganic

$$V = \frac{0.65 \times 6 \times 12000 \times (200 - 17.5)}{2500(1 + 0.06 \times 6)} = 2512m^3$$

Assume d = 4m d= 3 – 5 m

$$area = \frac{V}{d}$$

$$area = \frac{2512.5}{4} = 638.015m^2$$

Number of tanks n =2

Area of one tank = $\frac{628.015}{2} = 314m^2$

b = 1.5 – 2 d take b = 8m

$$L = \frac{A}{b} = \frac{314}{8} = 39.25m \le 50m$$

Checks :

$$F/M = \frac{Q(S_o - S_e)}{MLVSS \times V}$$

$$F/M = \frac{12000(200 - 17.5)}{2500 \times 2512.06} = 0.346 \frac{gmBOD_5}{gmMLVSS.day}$$

F/M = 0.2 - 0.4

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

$$T = \frac{2512.06}{12000} \times 24 = 5.03 hrs$$

T = 4 - 8 hrs

$$L = \frac{S_o \times Q}{V \times 1000}$$

$$L = \frac{200 \times 12000}{2512.5 \times 1000} = 0.955 \frac{kgBOD_5}{m^3.day}$$

Allowable organic load (L) = 0.3 - 2 kg BOD_5 /m^3.day

The design of the return sludge pipe:

MLVSS = 0.8 MLSS

$$R = \frac{Q_{R.S}}{Q} = \frac{MLSS}{TSS\ in\ R.S - MLSS}$$

$$\frac{Q_{R.S}}{Q} = \frac{(\frac{2500}{0.8})}{10000 - (\frac{2500}{0.8})} = 0.45$$

$$Q_{R.S} = 0.45 \times 12000 = 5454.5\ m^3/d$$

$$\frac{Q_{R.S}}{24 \times 60 \times 60} = \frac{\pi \phi^2}{4} \times v$$

$$\frac{5454.5}{24 \times 60 \times 60} = \frac{\pi \phi^2}{4} \times v$$

$$\phi = 0.28 \approx 0.3 m$$

Determination of excess sludge:

$$\theta_C = \frac{X \times V}{Q_w \times X_r}$$

$$6 = \frac{2500 \times 2512.06}{Q_w \times (10000 \times 0.8)}$$

$$Q_w = 130.83 m^3/d$$

$$\theta_c = \frac{X \times V}{Q_w \times X_r + X_e(Q - Q_w)}$$

$$6 = \frac{2500 \times 2512.06}{Q_w \times (10000 \times 0.8) + 20 \times (12000 - Q_w)}$$

$$Q_w = 126.6 m^3/d$$

Design of diffused air system:

$$P_x = \frac{y_{obs} \times Q \times (S_o - S_e)}{1000}$$

$$P_x = \frac{0.31 \times 12000 \times (200 - 17.5)}{1000} = 678.9 kg/d$$

$$Theoritical\ pure oygen(O_2) = \frac{(S_o - S_e) \times Q \times 10^{-3}}{(\frac{BOD_5}{BOD_U})} - 1.42 P_x$$

$$Theoritical\ pure oygen(O_2) = \frac{(200 - 17.5) \times 12000 \times 10^{-3}}{(0.68)} - 1.42 \times 678.9 = 2256.55 kgO_2/d$$

$$Standard\ oxygen required(SOR) = \frac{Theoritical\ pure oygen(O_2)}{0.65}$$

$$Standard\ oxygen required(SOR) = \frac{2256.55}{0.65} = 3471.61 kgO_2/d$$

$$Theoritical\ air\ demand = \frac{SOR}{1.2 \times 0.232 (O_2 ratio)}$$

$$Theoritical\ air\ demand = \frac{3471.61}{1.2 \times 0.232} = 12469.88 kg/m^3$$

$$Actual\ air\ required = \frac{theoritical\ air\ demand}{effeciency of\ oxygen}$$

$$Actual\ air\ required = \frac{12469.88}{0.08} = 155873.54 m^3/d$$

$$Blowers capacity = 1.5 \times actual\ air$$

$$Blowers capacity = 1.5 \times 155873.54 = 233810.3 m^3/d$$

$$Head\ of\ blowers = 1.3 \times depth of\ water in AT$$

$$Head\ of\ blowers = 1.3 \times 4 = 5.2m$$

$$No.\ of\ blowers = \frac{blowers capacity}{design cpacity of\ each blower}$$

Design of air pipe in aeration tank:

$$Blower\ capacity = \frac{\pi d^2}{4} \times v \qquad v = 15 m/s$$

Design of surface aerators:

$$P_x = \frac{y_{obs} \times Q \times (S_o - S_e)}{1000}$$

$$P_x = \frac{0.31 \times 12000 \times (200 - 17.5)}{1000} = 678.9\,kg/d$$

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$$Total\ aerators\ capacity = 2 \times SOR$$

$$Total\ aerators\ capacity = 2 \times 3471.61 = 6943.22\,kg\,O_2/d$$

$$NO.\ of\ aerators = \frac{2 \times SOR}{O_2/aerator}$$

$$Theoritical\ air\ demand = \frac{SOR}{1.2 \times 0.232 (O_2\ ratio)}$$

$$Theoritical\ air\ demand = \frac{3471.61}{1.2 \times 0.232} = 12469.88\,kg/m^3$$