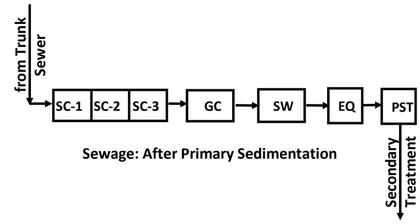
Preliminary and Primary Wastewater Treatment



Preliminary and Primary Wastewater Treatment

Primary Sedimentation for Wastewater/Sewage Treatment

Exactly same as secondary sedimentation for water treatment in most respects

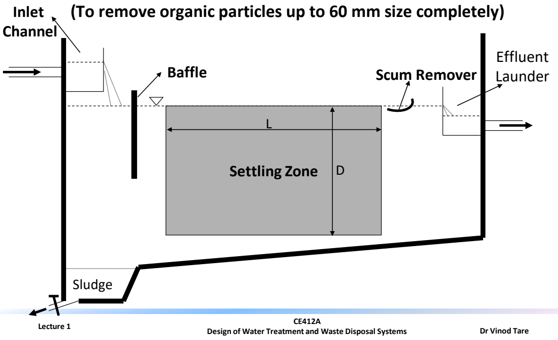
However,

1. Particles removed in this case are mostly organic particles of density 1200 kg/m^3
2. SOR = 32 m^3/m^2/d, organic particles: 60 µm, inorganic particles: 20 µm
3. SOR = 48 m^3/m^2/d, organic particles: 75 µm, inorganic particles: 25 µm
4. Type II settling, hence smaller particles are also removed
5. SS removal: 50 – 70 %; BOD$_5$ removal: 25 – 40 %

Preliminary and Primary Wastewater Treatment

Primary Sedimentation Tank

(To remove organic particles up to 60 mm size completely)



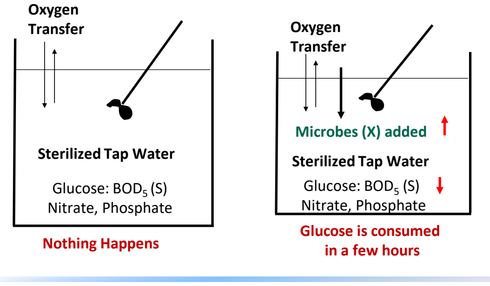
Biological Wastewater Treatment

Secondary Treatment: Aerobic Biological Treatment

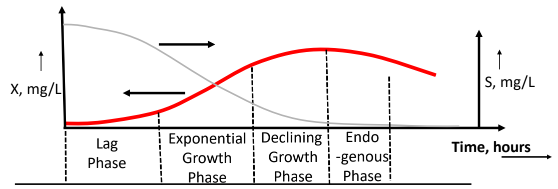
Sewage: After Primary Sedimentation

Biological Wastewater Treatment

Microbial Consumption of Biodegradable Organic Carbon



Microbial Growth Curve



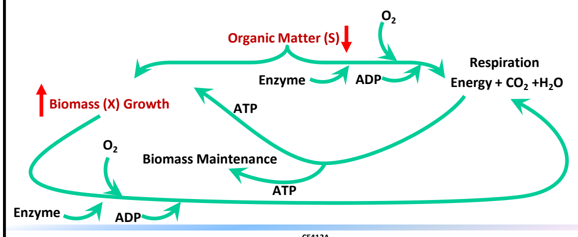
Slope of X vs t curve is $\left[\frac{dX}{dt}\right]_G$

Slope of S vs t curve is $\left[\frac{dS}{dt}\right]$

Biological Wastewater Treatment

Microbial Consumption of Biodegradable Organic Carbon

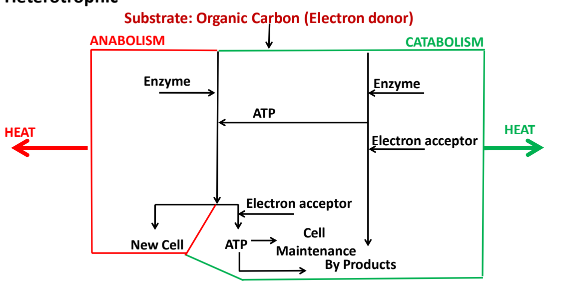
$$Organic\ Matter + O_2 + ADP \rightarrow CO_2 + H_2O + ATP$$
$$Organic\ \text{Matter} + \text{ATP} \rightarrow \text{Bacterial Biomass} + \text{ADP}$$
$$Bacterial\ \text{Biomass} + O_2 + ADP \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{ATP}$$



Biological Wastewater Treatment

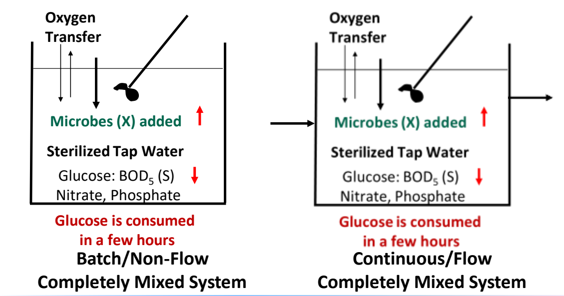
The Biodegradation Mechanism…….

Heterotrophic



Biological Wastewater Treatment

Microbial Consumption of Biodegradable Organic Carbon



Microbial Growth: Definitions and Relations

X = Biomass Concentration, mg/L

S = Substrate Concentration, mg/L

$\frac{dS}{dt}$ = Substrate Utilization Rate, mg/L/d

$\left[\frac{dS}{dt}\right]/X = q$ = Specific Substrate Utilization Rate, $(-ve)$

$\left[\frac{dX}{dt}\right]_T$ = Gross Biomass Growth Rate, mg/L/d

$\left[\frac{dX}{dt}\right]_G$ = Net Biomass Growth Rate, mg/L/d

$\left[\frac{dX}{dt}\right]_G/X = \mu$ = Specific Net Biomass Growth Rate, /d

$\left[\frac{dX}{dt}\right]_E$ = Biomass Decay Rate, mg/L/d

$\left[\frac{dX}{dt}\right]_E/X = k_d(-ve)$

Microbial Growth: Definitions and Relations

S = Substrate Concentration, mg/L

X = Biomass Concentration, mg/L

$\frac{dS}{dt}$ = Substrate Utilization Rate, mg/L/d

$\left[\frac{dS}{dt}\right]/X = q$ = Specific Substrate Utilization Rate, /d

$\left[\frac{dX}{dt}\right]_T$ = Gross Biomass Growth Rate, mg/L/d

$$\left[\frac{dX}{dt}\right]_G = \left[\frac{dX}{dt}\right]_T + \left[\frac{dX}{dt}\right]_E$$

$$\left[\frac{dX}{dt}\right]_T = Y_T.\left[\frac{dS}{dt}\right]$$

Y_T = Yield Coefficient

$$\left[\frac{dX}{dt}\right]_G/X = Y_T.\left[\frac{dS}{dt}\right]/X - \left[\frac{dX}{dt}\right]_E/X$$

$$\boxed{\mu = Y_T.q - k_d}$$

Microbial Growth: Definitions and Relations

$\left[\frac{dX}{dt}\right]_G$ = Net Biomass Growth Rate, mg/L/d

$\left[\frac{dX}{dt}\right]_G /X = \mu$ = Specific Net Biomass Growth Rate, /d

$\left[\frac{dX}{dt}\right]_E$ = Biomass Decay Rate, mg/L/d

$\left[\frac{dX}{dt}\right]_E /X = k_d$ = Specific Biomass Decay Rate, /d (- ve)

$$\left[\frac{dX}{dt}\right]_G = Y_{obs}\cdot\left[\frac{dS}{dt}\right]$$

Y_{obs} = Observed Yield Coefficient

$$\left[\frac{dX}{dt}\right]_G /X = Y_{obs}\cdot\left[\frac{dS}{dt}\right]/X$$

$$\boxed{\mu = Y_{obs}\cdot q} \qquad \boxed{Y_{obs} = Y_T - \frac{K_d}{q}}$$

Microbial Growth Curve

Slope of X vs t curve is $\left[\frac{dX}{dt}\right]_G$ **Slope of S vs t curve is** $\left[\frac{dS}{dt}\right]$

Lag Phase: X is low, S is high;

$\left[\frac{dX}{dt}\right]_G$ is low; $\left[\frac{dS}{dt}\right]$ is low;

Exponential Growth phase: X is higher, S is sufficient, μ is high;

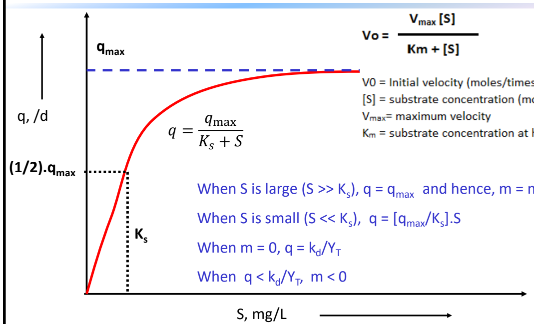
$\left[\frac{dX}{dt}\right]_G$ is high; $\left[\frac{dS}{dt}\right]$ is high;

Declining Growth phase: X is high, S is low, μ is decreasing;

$\left[\frac{dX}{dt}\right]_G$ is lower; $\left[\frac{dS}{dt}\right]$ is lower;

Endogenous Phase: X is declining, S is zero, μ is negative; $\left[\frac{dX}{dt}\right]_G$ is negative; $\left[\frac{dS}{dt}\right]$ is zero;

Monod's Kinetics Michaelis-Menten Equation



Vo = $\frac{\mathbf{V_{max}\,[S]}}{\mathbf{Km + [S]}}$

V0 = Initial velocity (moles/times)
[S] = substrate concentration (molar)
V_{max}= maximum velocity
K_m = substrate concentration at half V_{max}

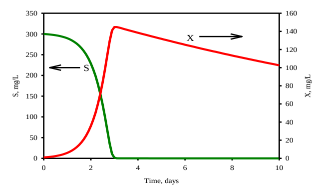
When S is large (S >> K_s), q = q_{max} and hence, m = m_{max}

When S is small (S << K_s), q = [q_{max}/K_s].S

When m = 0, q = k_d/Y_T

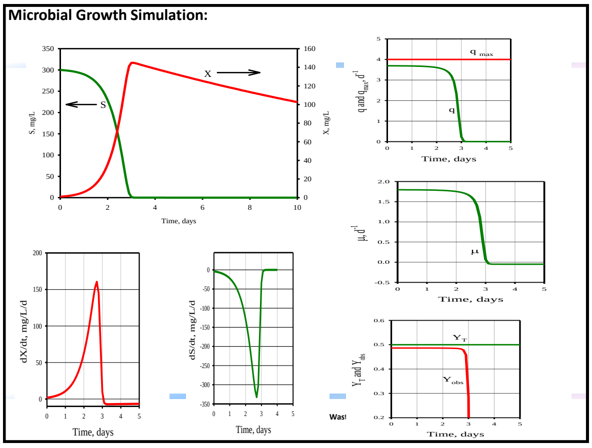
When q < k_d/Y_T, m < 0

Microbial Growth Simulation: Solution of the Differential Equations



Sewage with BOD_5 of 300 mg/L (S) and 1 mg/L biomass (X) are put in a container and aerated. Assume oxygen and nutrients are not limiting. The BOD_5 is fully consumed in ~3 days and the biomass concentration increases to ~150 mg/L. Beyond that the biomass concentration decreases.

Microbial Growth Simulation:



Microbial Growth Simulation:

$$q = \frac{q_{max}\, S}{K_s + S}$$

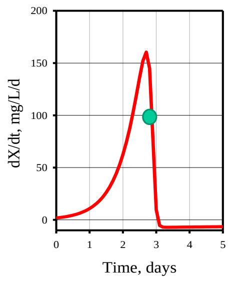
$$\mu = Y_T.q - k_d; \quad \frac{dX}{dt} = Y_T.\left[-\frac{dS}{dt}\right] - K_d.X$$

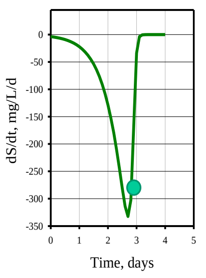
Initial Conditions:

At, t = 0, S = S_o = 300 mg/L
X = X_o = 1 mg/L

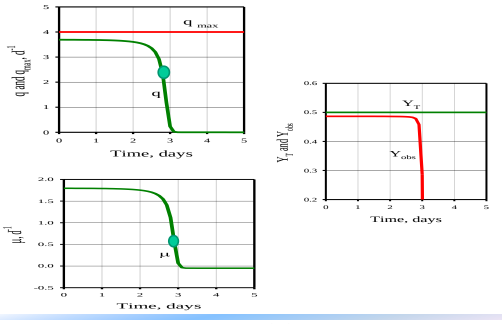
q_{max} = 4 d^{-1}
K_s = 25 mg L^{-1}
Y_T = 0.5 mg mg^{-1}
K_d = 0.05 d^{-1}

Process dynamics of a continuous flow bioreactor……..





Process dynamics of a continuous flow bioreactor…….



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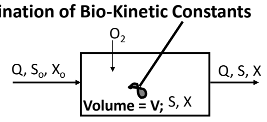
Design of Water Treatment and Waste Disposal Systems
Dr Vinod Tare

Determination of Bio-Kinetic Constants



Completely Mixed Reactor

Q	Q	V	θ	
mL/min	Liters/day	Liters	day	
2.31	3.33	10	3	**R1**
3.47	5.00	10	2	**R2**
6.94	10.00	10	1	**R3**

Hydraulic Retention Time (q) = V/Q

$$\mu = Y_T . q - k_d$$

$$q = \frac{q_{\max}}{K_s + S}$$

Substrate Mass Balance:

$$Q.S_o = Q.S + \left[\frac{dS}{dt}\right].V$$

$$Q.\frac{(S_o - S)}{V} = q.X$$

Biomass Mass Balance:

$$Q.X_o + \left[\frac{dX}{dt}\right]_G .V = Q.X$$

$$\mu.X.V = Q.X; \quad \mu = Q/V = 1/\theta$$

Influent BOD (S_o) = 250 mg/L

	θ, days	S, mg/L	X, mg/L
R1	3	10	120
R2	2	17	115
R3	1	45	110

q / day	μ / day	1/S L/mg	1/q d	Y_{obs}	
0.67	0.33	0.10	1.50	0.492	**R1**
1.01	0.50	0.06	0.99	0.495	**R2**
1.86	1.00	0.02	0.54	0.538	**R3**

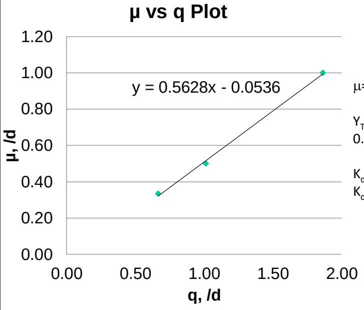
The reactor is operated under three conditions as above and the reactor performance is shown in the table to the left

$$Q.\frac{(S_o - S)}{V.X} = q$$

$$\mu = Q/V = 1/\theta$$

Determination of Bio-Kinetic Constants….continued

μ vs q Plot



μ= Y_T.q - K_d

Y_T is the slope of μ vs q plot; Y_T = 0.562 mg/mg

K_d is the intercept of the μ vs q plot; K_d = 0.053 /d

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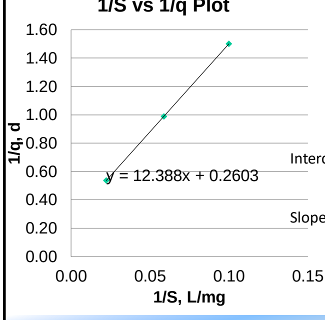
Determination of Bio-Kinetic Constants….continued

1/S vs 1/q Plot



$$q = \frac{q_m . S}{K_s + S}$$

$$\frac{1}{q} = \left(\frac{K_s}{q_m}\right).\left(\frac{1}{S}\right) + \frac{1}{q_m}$$

Intercept of the 1/S vs 1/q plot is $1/q_m$; q_m = 3.846 /d

Slope of the 1/S vs 1/q plot is (K_s/q_m); K_s = 47.61 mg/L

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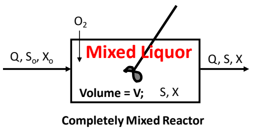
Example Problem….Biodegradation of Domestic Sewage



Completely Mixed Reactor

Microbial Kinetic Constants:

q_{max} = 4 /d

K_s = 25 mg/L

K_d = 0.05 /d

Y_T = 0.50 g biomass / g BOD_5

Hydraulic Retention Time (θ) = V/Q = $\frac{M}{\frac{\Delta M}{\Delta t}} = X/(\frac{\Delta X}{\Delta t})$

$$\mu = Y_T . q - k_d \qquad q = \frac{q_{\max}}{K_s + S} \qquad Q.\frac{(S_o - S)}{V.X} = q \qquad \mu = Q/V = 1/\theta$$

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Example Problem....Biodegradation of Domestic Sewage

Example Problem

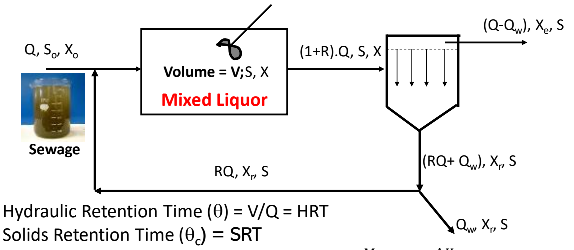
Q = 1 MLD; V = 1000 m^3; S_o = 300 mg/L q = V/Q = 1 day;

μ = 1/q = 1 / d

$$q = \frac{\mu + k_d}{Y_T} = \frac{1 + 0.05}{0.5} = 2.1\ /\text{d} \qquad Y_{obs} = \frac{\mu}{q} = \frac{1.0}{2.1} = 0.476 \text{ g biomass/g BOD}_5$$

$$S = \frac{q.K_s}{(q_{\max}\frac{(2.1).(25)}{(4-2.1)}\ \text{mg/L}} \qquad X = \frac{(S_o - S)}{\theta.q} = \frac{(300 - 27.63)}{1.(2.1)} = 129.7 \text{ mg/L}$$

Activated Sludge Process → Wastewater/Sewage Aerated in Presence of Microbes and then Separated



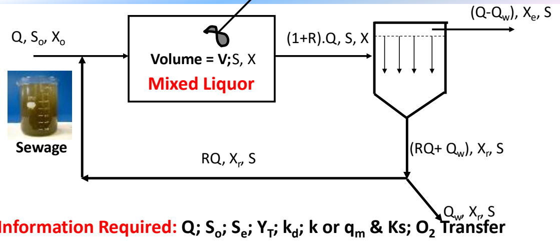
Hydraulic Retention Time (θ) = V/Q = HRT

Solids Retention Time (θ_c) = SRT

Biological Solids Retention Time = BSRT = $\frac{M}{\frac{\Delta M}{\Delta t}} = X/(\frac{\Delta X}{\Delta t})$

Suspended Solids (SS) in Mixed Liquor (ML) are referred as MLSS

Activated Sludge Process → Wastewater/Sewage Aerated in Presence of Microbes and then Separated



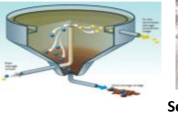
Information Required: Q; S_o; S_e; Y_T; k_d; k or q_m & Ks; O_2 Transfer Capacity & Mixing Power

Choices to make: θ; θc; X; X_r; R

Design → Specifications: Aeration Tank (AT); Secondary Clarifier (SC); Recirculation System & Sludge Wasting Line

Activated Sludge Process

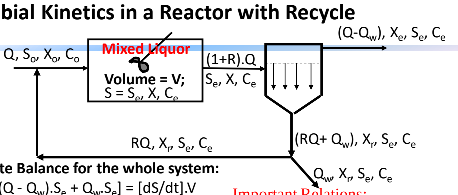
Aeration Tank



Secondary Sedimentation Tank

Secondary Sedimentation

Microbial Kinetics in a Reactor with Recycle



Substrate Balance for the whole system:

Q.S_o – [(Q - Q_w).S_e + Q_w.S_e] = [dS/dt].V

Q.(S_o – S_e)/V = q.X (A)

Biomass Balance for the whole System:

$[dX/dt]_g$.V = Q_w.X_r

μ.X.V = Q_w.X_r (B)

Biomass Balance for Aeration Tank:

R.Q.X_r + $[dX/dt]_G$.V = (1 + R).Q.X

R.Q.X_r + μ.X.V = (1 + R).Q.X

μ.V = Q.[1+ R – R(X_r/X)] (C)

Important Relations:

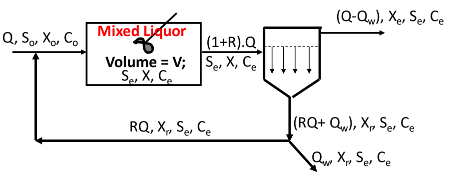
$$q = \frac{q_{\max}}{K_s + S}$$

$$\mu = Y_T.q - k_d$$

$$\frac{1}{\theta_c} = Y_T K S_e - K_d \qquad (X_r)_{max} = \frac{10^6}{SVI}$$

$$S_e = \frac{{}^1/_{\theta_e} + K_d}{Y_T K} \qquad \frac{1}{\theta_c} = \frac{Q}{V_a}\left(1 + R - R\frac{X_r}{X}\right)$$

Oxygen Requirement



Organic carbon compounds consumed by microorganisms and converted to carbon dioxide (catabolism) and biomass (anabolism). Part of this biomass is oxidized by microorganisms to carbon dioxide (endogenous respiration). Energy produced through oxidation of organic carbon to carbon dioxide is the driving force for sustenance of the microorganisms and production of new biomass. Oxygen is required as the terminal electron acceptor for this process.

Oxygen Requirement

Amount of Oxygen Required:
Biomass formula (dry basis): $C_5H_7O_2N$; Formula weight = 113

Respiration Equation:

$$C_5H_7O_2N + 5O_2 + H^+ \rightarrow 5CO_2 + 2H_2O + NH_4^+ + energy$$

This, if 1 g of biomass is produced, {(32 * 5)/113} 1.42 g of oxygen requirement is saved.

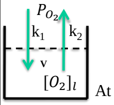
[Oxygen Required in Aeration Tank, kg/d] = [BOD_u Removed, in kg/d] – 1.42.[Sludge Wasted, kg/d]

Where, BOD_u ~ 1.5.BOD_5 ; So, O_2 Reqd, kg/d = 1.5.Q ($S_o – S_e$) – 1.42.[ΔX]

Theory of Aeration:

$$P_{O_2} \underset{k_2}{\overset{k_1}{\rightleftarrows}} [O_2]_l \quad [O_2]_l \text{ in moles/L} \quad P_{O_2} \text{ in atm.}$$

Henry's Law: $P_{O_2} = H.[O_2]_L^S$
H is the Henry's Constant in atm–L/mole



Rate of oxygen input to liquid phase = $V.\dfrac{d[O_2]_l}{dt}$

= Rate of Oxygen Absorption – Rate of Oxygen Stripping = $k_1.P_{O_2} - k_2.[O_2]_l$

k_1 in moles/atm.–s
k_2 in L/s

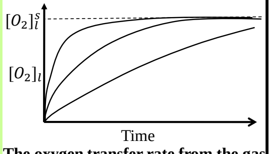
At equilibrium: $[O_2]_l = [O_2]_l^s$; $k_1.P_{O_2} = k_2.[O_2]_l^s$; $P_{O_2} = \left(k_2/k_1\right).[O_2]_l^s$; $k_2 = k_1.H$

$$V.\frac{d[O_2]_l}{dt} = k_1.(H.[O_2]_l^s) - k_1.H.[O_2]_l$$
$$= k_1.H.([O_2]_l^s - [O_2]_l);$$
$$k_1.H = (k_a.H).A = k_L.A$$
$$V.\frac{d[O_2]_l}{dt} = k_L.A.([O_2]_l^s - [O_2]_l);$$

k_L = Mass transfer coefficient;
A = contact area between liquid–gas phases

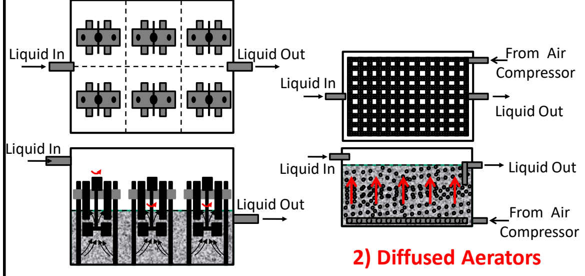
$$\frac{d[O_2]_l}{dt} = k_L.\left(\frac{A}{V}\right).([O_2]_l^s - [O_2]_l)$$
$$= k_L.a.([O_2]_l^s - [O_2]_l)$$

a = Specific Surface Area (m^2/m^3)



The oxygen transfer rate from the gas to the liquid phase can be increased by increasing the value of 'a'. The value of 'a' may be increased by using mechanical aerators

Two types of aerators are commonly used: 1) Surface Aerators & 2) Diffused Aerators



1) Surface Aerators

2) Diffused Aerators or Bubble Aerators

1) Surface Aerators

1) Surface Aerators

Surface Aerator: Design Procedure

Aerator Rating: 1, 2, 5 KW ; Area of Influence: 5m x 5m x 3m (depth)

Aerator Rating: 10, 25, 50 KW; Area of Influence: 6m x 6m x 4m (depth)

Standard O_2 transfer efficiency (SOT) is given by the manufacturer as, kg O_2 transferred per hour per KW under <u>standard conditions</u>

<u>Standard Conditions:</u> T = 20°C; $[O_2]_l$ = 0.0; In tap water

SOT calculation: (Generally specified by the manufacturer)

Fill up a 5x5x3 m or 6x6x4 m tank (depending on aerator size) with tap water

Aerate overnight. Measure DO in the morning. This is $[O_2]_l^s$. Measure temp.

Add sodium sulfite to de-aerate water, i.e., $[O_2]_l = 0.0$

Aerate from t = 0 to t = t. Measure $[O_2]_l$ at various times during aeration.

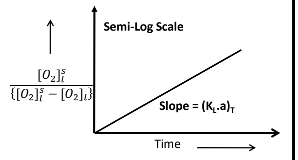
Surface Aerator: Design Procedure (Continued)

$$\frac{d[O_2]_l}{dt} = K_L.a\left\{[O_2]_l^s - [O_2]_l\right\}$$

Integrating,

$$\int_{[O_2]_l}^{0} \frac{d[O_2]_l}{\left\{[O_2]_l^s - [O_2]_l\right\}} = \int_{t}^{o} K_L.a.dt$$

$$\ln\left\{\frac{[O_2]_l^s}{[O_2]_l^s - [O_2]_l}\right\} = K_L.a.t$$



$$\frac{d[O_2]_l}{dt} = k_L.a.([O_2]_l^s - [O_2]_l)$$

$$V.\frac{d[O_2]_l}{dt} = k_L.a.([O_2]_l^s - [O_2]_l).V$$

$$SOT = (K_L.a)_{20}.[O_2]_l^{s_{20}}.(V)$$

$$(K_L.a)_{20} = \frac{(K_L.a)_T}{(1.02)^{T-20}}$$

T in celsius

Energy requirements for maintaining completely mixed conditions in the aeration tank

For an aeration tank of volume V, the P/V ratio for maintaining completely mixed conditions is 15 – 20 W/m^3

Hence in actual design power requirement in an aeration tank must be calculated both from O_2 requirement and mixing perspectives, and the larger value adopted.

In many cases, the mixing requirement becomes the controlling factor for provision of power to the aeration tank

Example Problem: Aerator Design

Given the oxygen requirement of 8400 kg/d, design the aeration system for an ASP using turbine aerators. Assume that two aeration tanks will be provided in parallel and depth of the tanks will be 4 m. Total volume of aeration tanks is 4320 m^3. No nitrification occurs in the aeration tank. Turbine Aerators are available with power rating 10, 25, 50 KW with area of influence being 36 m^2. Manufacturers specify that the oxygen transfer capacity of these aerators is 2.0 Kg O_2/kW-h under standard conditions. Based on this information, design an adequate aerator arrangement for each aeration tank. The operating temperature of the aeration tank is expected to be 30^{o}C. Saturation concentration of oxygen in water at 20^{o}C is 9.1 mg/L and at 30^{o}C is 7.5 mg/L.

$$\alpha = \frac{(K_L.a)_T^W}{(K_L.a)_T^F} = 0.8 \qquad \beta = \frac{C_s\text{ (wastewater)}}{C_s\text{ (tapwater)}} = 0.9 \qquad (K_L.a)_T^F = (K_L.a)_{20}^F.\gamma, \qquad \gamma = 1.02^{(T-20)}$$

Given SOT: To Find the Actual Oxygen Transfer Efficiency (AOT)

both $K_L.a$ and $[O_2]_l^s$ depend on temperature

$$\alpha = \frac{(K_L.a)_T^W}{(K_L.a)_T^F} = 0.8; \ \beta = \frac{[O_2^W]_l^s}{[O_2^F]_l^s} = 0.9$$

Impact of wastewater

$$(K_L.a)_{20} = \frac{(K_L.a)_T}{(1.02)^{T-20}}; \ T \text{ in celcius}$$

$[O_2]_l^s$ decreases with tempearture, obtained from tables

$[O_2]_l = 1$ mg/L or 3 mg/L (in case of nitrification)

$SOT = (K_L.a)_{20}^F.[O_2^F]_l^{S_{20}}.(V)$ Generally 1.5 – 2.0 kg O_2 / h/KW

$$AOT = (K_L.a)_T^W.\left\{[O_2^W]_l^{S_T} - [O_2]_l\right\}.(V)$$

$$AOT = (K_L.a)_{20}^F.(\alpha.[1.02]^{T-20})\left\{\beta.[O_2^F]_l^{S_T} - [O_2]_l\right\}.(V)$$

Solution

c/s area of each tank = 4320/4/2 = 540 m^2

Area of influence of each aerator = 36 m^2

Let length of each tank be 30 m and breadth be 18 m.
Hence aerators are provided in a 5x3 grid

SOT = 2.0 kg O_2/h/KW; Find AOT at 30^{o}C

$[O_2^F]_l^{S_{20}} = 9.1$ mg/L $\qquad [O_2^F]_l^{S_{30}} = 7.5$ mg/L $\qquad [O_2]_l = 1.0$ mg/L

$SOT = (K_L.a)_{20}^F.[O_2^F]_l^{S_{20}}.(V) \qquad 2 = (K_L.a)_{20}^F.(V).9.1$

$$AOT = (K_L.a)_{20}^F.([0.8].[1.02]^{30-20})\{[0.9].[7.5] - 1\}.(V)$$

$$AOT = (K_L.a)_{20}^F.(V).(5.607) = \frac{2}{9.1}.(5.607)$$
$$= 1.232 \text{ kg } O_2/h/KW$$

Solution ……… *continued*

$$AOT = (K_L.a)^F_{20}.(V).(5.607) = \frac{2}{9.1}.(5.607) = 1.232\text{ kg } O_2/h/KW$$

Oxygen transfer per aerator = 4200/15/24 = 11.67 kg/hr;

Hence, Power Reqd. = 11.67/1.232 = 9.56 KW; Provide 15 no. aerators@10KW/tank

Power Reqd. for mixing/tank = 540.(4).(20)/1000 = 43.2 KW

Power provided for aeration/tank = 15.(10) = 150 KW. Hence, completely mixed conditions will prevail.

Nutrient (N and P) Requirement:

Nitrogen in wastewater is generally expressed as TKN (mg/L as N) .
TKN (as N, mg/L) = Organic-N (as N, mg/L) + Ammonia-N (as N, mg/L)

Phosphorus in wastewater is generally expressed as total – P (mg/L as P)
Total P (as P, mg/L) = Org-P (as P, mg/L) + Condensed P (as P, mg/L) + Ortho-P (as P, mg/L)

The BOD_5 (in mg/L) : TKN (in mg/L as N) : Total-P (in mg/L as P) ratio in domestic wastewater is ~ 100 : 5 : 1

During BOD degradation: Organic –N is converted to Ammonia-N
Organic-P and Condensed-P are converted to Ortho-P

Nutrient (N and P) Requirement:

In addition to organic carbon and oxygen, all microorganisms require N and P to grow.

Wastewater generally contains sufficient nutrients (in fact excess) from microorganism growth.

Biomass formula (dry basis): $C_{60}H_{87}O_{23}N_{12}P$; Formula Weight: 1382
For the growth of 1382 g biomass, 168 g N and 31 g P is required

Nutrient Requirement: 0.121 g N and 0.022 g P per g biomass produced (or wasted).
Hence the N and P concentration will decrease by this amount in the aeration tank

$$\Delta N\text{ (kg/d)} = 0.122\ \Delta X\text{ (kg/d)} = Q\text{ (m}^3\text{/d)} * TKN\text{ (kg/m}^3\text{)}$$

$$\Delta P\text{ (kg/d)} = 0.022\ \Delta X\text{ (kg/d)} = Q\text{ (m}^3\text{/d)} * TP\text{ (kg/m}^3\text{)}$$

Settleability of Activated Sludge Solids

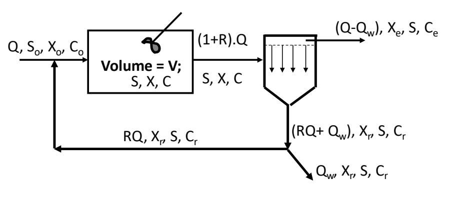
One of the factors essential to the performance of the activated sludge process is effective flocculation of the sludge, with subsequent rapid settling and compaction. Two types of bacteria are found in ASP sludge: 1) floc-forming, and 2) filamentous bacteria

Normal flocs: A balance between floc-forming and filamentous bacteria results in strong flocs that keep their integrity in the aeration basin and settle well in the sedimentation tank (High BSRT).

Pin-point flocs: In these flocs, filamentous bacteria are absent or occur in low numbers. This results insmall flocs that do not settle well (Low BSRT).

Filamentous bulking: Filamentous bulking is caused by the predominance of filamentous organisms. The filaments interfere with sludge compaction. (very high BSRT)

Activated Sludge: High Growth, Standard and Extended Aeration process

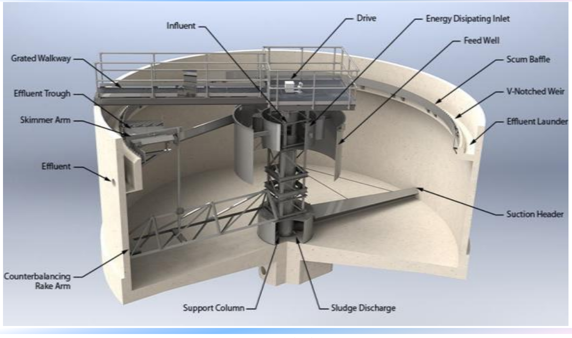


High-growth (Aerated Lagoon) versus Low-growth (Extended Aeration) System

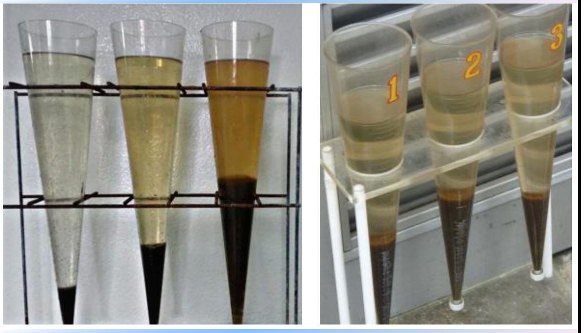
What are the characteristics of a high-growth ASP system ??
In such a system, q_c is low. Hence μ and q are high, S is relatively high. ΔX is high, hence O_2 requirement is low, but nutrient requirement is high. Chance of forming pin-point flocs with poor settling characteristics.

What are the characteristics of an extended growth ASP system??
In such a system, q_c is high. Hence μ and q are low, S is relatively low. ΔX is low, hence O_2 requirement is high, but nutrient requirement is low. The inert matter concentration (C) in the aeration tank may be high. Chance of forming filamentous bulking sludge with poor settling characteristics.

Settling of Activated Sludge



Settling of Activated Sludge

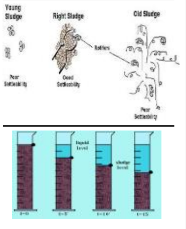


Sludge Volume Index (SVI):

Sludge settleability is determined by measuring the sludge volume index (SVI), which is given by:

$$SVI\ (mL/g) = \frac{SV \times 1000}{MLSS}$$

where SV = volume of settled sludge after 30 min (mL/L);
and MLSS = mixed liquor suspended solids (mg/L).



Low SVI (< 100) means good sludge settleability
High SVI (> 150) means bad settleability

Type III / Hindered / Zone Settling

Interfacial Velocities of Sludge Solids

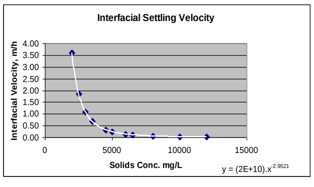
Solids (C+X) mg/L	V, m/hr
2000	3.60
2500	1.86
3000	1.09
3500	0.69
4500	0.33
5000	0.24
6000	0.14
6500	0.11
8000	0.06
10000	0.03
12000	0.02

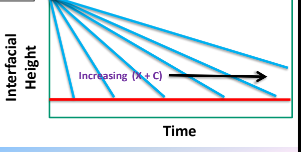
Empirical Formula:

Interfacial settling velocity V (in m/hr)

$= [2x10^{10}].[(X + C)\text{ in mg/L}]^{-2.9521}$

Type III / Hindered / Zone Settling





Concept of Solid Flux

Solid Flux (SF) =
Mass of solids passing through unit surface area of the clarifier in unit time, kg/m²/hr

At any depth ,

Gravity Flux (SF_G) = $(C_i + X_i).v_i$
v_i is the interfacial velocity

Underflow Flux (SF_u)= $(C_i + X_i).u$

Total Flux (SF_T) = $SF_G + SF_u$

Under steady state conditions,

SF_T is same at all depths

$(C_i + X_i)$ increases with depth

Concept of Solid Flux