

CE412A:
2022-23 II

Design of Water Treatment & Waste Disposal Systems

Instructor : Dr Vinod Tare,
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Preliminary and Primary Wastewater Treatment

Sewage: After Primary Sedimentation

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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. $\text{SOR} = 32 \text{ m}^3/\text{m}^2/\text{d}$, organic particles: $60 \mu\text{m}$, inorganic particles: $20 \mu\text{m}$
3. $\text{SOR} = 48 \text{ m}^3/\text{m}^2/\text{d}$, organic particles: $75 \mu\text{m}$, inorganic particles: $25 \mu\text{m}$
4. Type II settling, hence smaller particles are also removed
5. SS removal: $50 - 70 \%$; BOD_5 removal: $25 - 40 \%$

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Preliminary and Primary Wastewater Treatment

Primary Sedimentation Tank

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

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Biological Wastewater Treatment

Secondary Treatment: Aerobic Biological Treatment

Sewage: After Primary Sedimentation

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Biological Wastewater Treatment

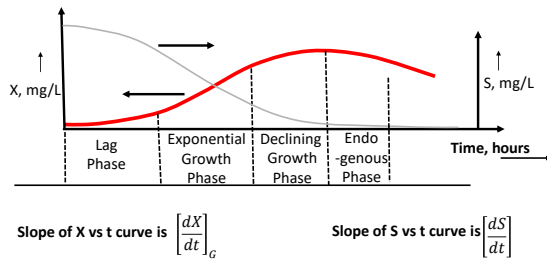
Microbial Consumption of Biodegradable Organic Carbon

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Microbial Growth Curve



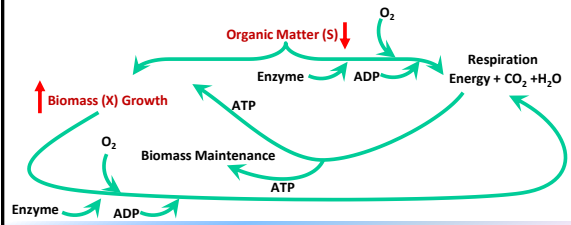
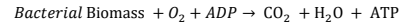
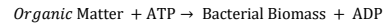
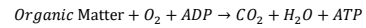
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Biological Wastewater Treatment

Microbial Consumption of Biodegradable Organic Carbon



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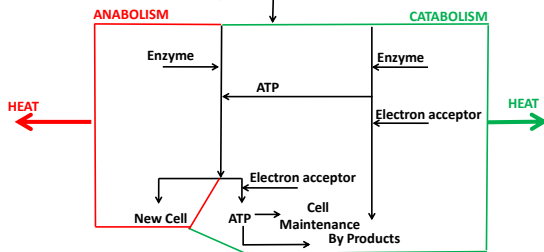
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Biological Wastewater Treatment

Heterotrophic

The Biodegradation Mechanism.....

Substrate: Organic Carbon (Electron donor)



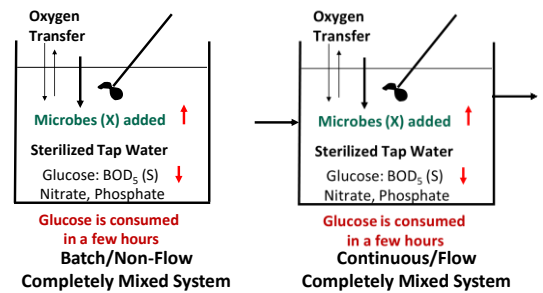
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Biological Wastewater Treatment

Microbial Consumption of Biodegradable Organic Carbon



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Microbial Growth: Definitions and Relations

X = Biomass Concentration, mg/L

S = Substrate Concentration, mg/L

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

$\left[\frac{dS}{dt}\right]_T / X = q$ = 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)

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Microbial Growth: Definitions and Relations

S = Substrate Concentration, mg/L

X = Biomass Concentration, mg/L

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

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

Y_T = Yield Coefficient

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

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

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

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Microbial Growth: Definitions and Relations

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

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

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

Y_{obs} = Observed Yield Coefficient

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

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

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

$$\mu = Y_{obs} \cdot q$$

$$Y_{obs} = Y_T - \frac{K_d}{q}$$

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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;

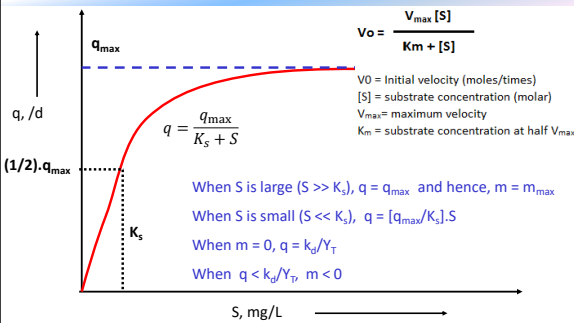
Endogenous Phase: X is declining, S is zero, μ is negative; $\left[\frac{dX}{dt}\right]_D$ is negative; $\left[\frac{dS}{dt}\right]$ is zero;

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Monod's Kinetics Michaelis-Menten Equation

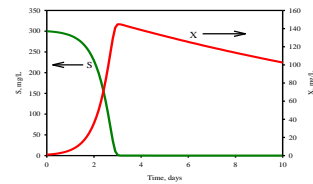


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Microbial Growth Simulation: Solution of the Differential Equations



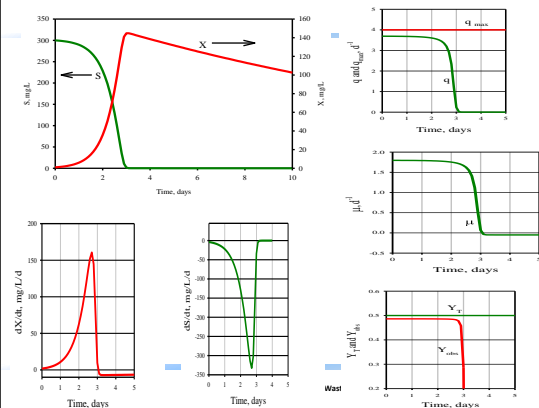
Sewage with BOD_5 of 300 mg/L (S) and 1 mg/L biomass (X) are put in a container and aerated. Assume oxygen and nutrients are not limiting. The BOD_5 is fully consumed in ~3 days and the biomass concentration increases to ~150 mg/L. Beyond that the biomass concentration decreases.

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Microbial Growth Simulation:



Microbial Growth Simulation:

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

Initial Conditions:

At, $t = 0$, $S = S_0 = 300 \text{ mg/L}$
 $X = X_0 = 1 \text{ mg/L}$

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

$$q_{max} = 4 \text{ d}^{-1}$$

$$K_s = 25 \text{ mg L}^{-1}$$

$$Y_T = 0.5 \text{ mg mg}^{-1}$$

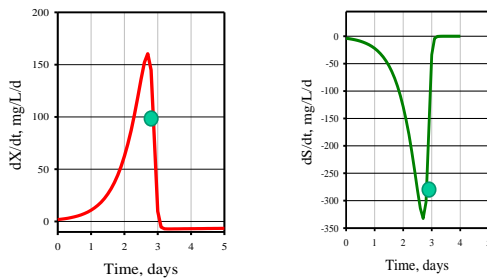
$$K_d = 0.05 \text{ d}^{-1}$$

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Process dynamics of a continuous flow bioreactor.....

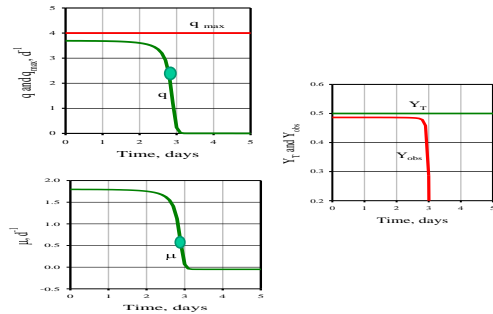


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Process dynamics of a continuous flow bioreactor.....

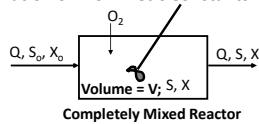


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Determination of Bio-Kinetic Constants



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)

$$= V/Q$$

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

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

Substrate Mass Balance:

$$Q \cdot S_0 = Q \cdot S + \left[\frac{dS}{dt} \right] \cdot V$$

$$Q \cdot \frac{(S_0 - S)}{V} = q \cdot X$$

Biomass Mass Balance:

$$Q \cdot X_0 + \left[\frac{dX}{dt} \right] \cdot V = Q \cdot X$$

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

Influent BOD (S_0) = 250 mg/L

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

q	μ	1/S	1/q	Y_{obs}	
/day	/day	L/mg	d		
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

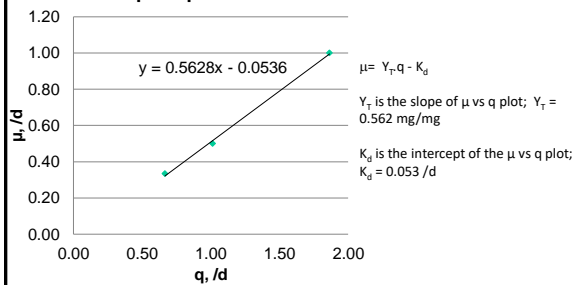
The reactor is operated under three conditions as above and the reactor performance is shown in the table to the left

$$Q \cdot \frac{(S_0 - S)}{V \cdot X} = q$$

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

Determination of Bio-Kinetic Constants....continued

μ vs q Plot



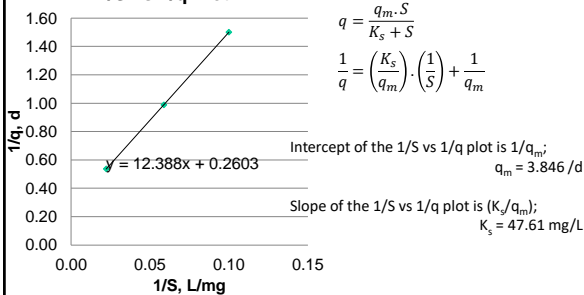
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Determination of Bio-Kinetic Constants....continued

1/S vs 1/q Plot

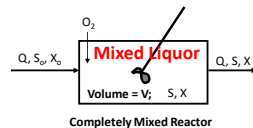


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Example Problem....Biodegradation of Domestic Sewage



Microbial Kinetic Constants:

$$q_{max} = 4$$
 /d

$$K_s = 25$$
 mg/L

$$K_d = 0.05$$
 /d

$$Y_T = 0.50$$
 g biomass / g BOD₅

$$\text{Hydraulic Retention Time } (\theta) = V/Q = \frac{M}{\Delta M} = X / \left(\frac{\Delta X}{\Delta t} \right)$$

$$\mu = Y_T \cdot q - k_d \quad q = \frac{q_{max}}{K_s + S} \quad Q \cdot \frac{(S_0 - S)}{V \cdot X} = q \quad \mu = \frac{Q}{V} = \frac{1}{\theta}$$

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Example Problem....Biodegradation of Domestic Sewage

Example Problem

$$Q = 1 \text{ MLD}; \quad V = 1000 \text{ m}^3; \quad S_0 = 300 \text{ mg/L} \quad q = V/Q = 1 \text{ day};$$

$$\mu = 1/q = 1/\text{d}$$

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

$$S = \frac{q \cdot K_s}{(q_{max} - q)} = \frac{(2.1) \cdot (25)}{(4 - 2.1)} \text{ mg/L} \quad X = \frac{(S_0 - S)}{\theta \cdot q} = \frac{(300 - 27.63)}{1 \cdot (2.1)} = 129.7 \text{ mg/L}$$

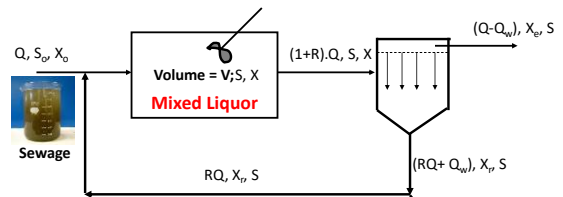
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Activated Sludge Process

→ 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 = $\frac{M}{\frac{\Delta M}{\Delta t}} = X / \left(\frac{\Delta X}{\Delta t} \right)$

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

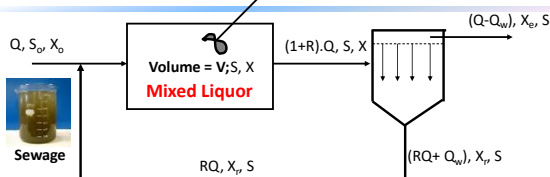
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Activated Sludge Process

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



Information Required: Q ; S_0 ; S_e ; Y_T ; k_d ; k or q_m & K_s ; O_2 Transfer Capacity & Mixing Power

Choices to make: θ ; θ_c ; X ; X_r ; R

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

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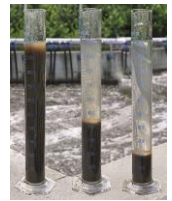
Activated Sludge Process



Aeration Tank



Secondary Sedimentation Tank



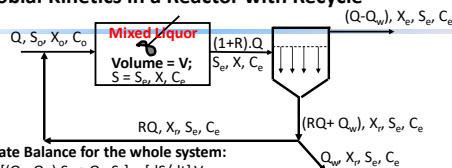
Secondary Sedimentation

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Microbial Kinetics in a Reactor with Recycle



Substrate Balance for the whole system:

$$Q \cdot S_0 - [(Q - Q_w) \cdot S_e + Q_w \cdot S_e] = [dS/dt] \cdot V$$

$$Q \cdot (S_0 - S_e) / V = q \cdot X \quad (A)$$

Biomass Balance for the whole system:

$$[dX/dt]_v \cdot V = Q_w \cdot X_r$$

$$\mu \cdot X \cdot V = Q_w \cdot X_r \quad (B)$$

Biomass Balance for Aeration Tank:

$$R \cdot Q \cdot X_r + [dX/dt]_v \cdot V = (1 + R) \cdot Q \cdot X$$

$$R \cdot Q \cdot X_r + \mu \cdot X \cdot V = (1 + R) \cdot Q \cdot X$$

$$\mu \cdot V = Q \cdot [1 + R - R(X_r/X)] \quad (C)$$

Important Relations:

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

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

$$\frac{1}{\theta_c} = Y_T K_s S_e - K_d$$

$$(X_r)_{max} = \frac{10^6}{SVI}$$

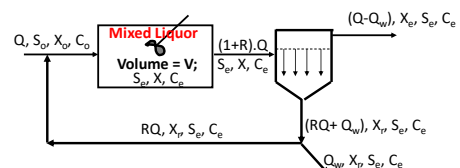
$$S_e = \frac{1/\theta_c + K_d}{Y_T K} \quad \frac{1}{\theta_c} = \frac{Q}{V_a} \left(1 + R - R \frac{X_r}{X} \right)$$

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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.

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Oxygen Requirement

Amount of Oxygen Required:

Biomass formula (dry basis): $C_5H_7O_2N$; Formula weight = 113

Respiration Equation:



This, if 1 g of biomass is produced, $\{(32 \cdot 5)/113\}$ 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.BOD₅; So, O₂ Req_d, kg/d = 1.5.Q (S₀ - S_e) - 1.42.[ΔX]

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Theory of Aeration:

$P_{O_2} \xrightarrow[k_2]{k_1} [O_2]_l$ $[O_2]_l$ in moles/L P_{O_2} in atm.

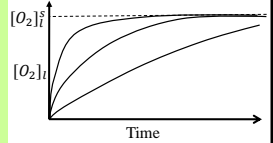
Henry's Law: $P_{O_2} = H \cdot [O_2]_g^s$
H is the Henry's Constant in atm-L/mole



Rate of oxygen input to liquid phase = $V \cdot \frac{d[O_2]_l}{dt}$
= Rate of Oxygen Absorption - Rate of Oxygen Stripping =
At equilibrium: $[O_2]_g = [O_2]_l^s$; $k_1 \cdot P_{O_2} = k_2 \cdot [O_2]_l^s$; $k_1 \cdot P_{O_2} - k_2 \cdot [O_2]_l$
 $P_{O_2} = \left(\frac{k_2}{k_1}\right) \cdot [O_2]_l^s$; $k_2 = k_1 \cdot H$ k_1 in moles/atm.-s
 k_2 in L/s

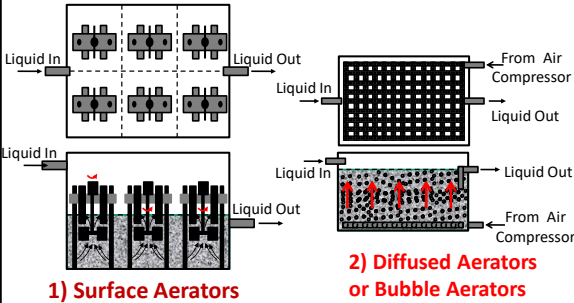
$V \cdot \frac{d[O_2]_l}{dt} = k_1 \cdot (H \cdot [O_2]_g^s - [O_2]_l)$
 $= k_1 \cdot H \cdot ([O_2]_g^s - [O_2]_l)$
 $k_1 \cdot H = (k_a \cdot H) \cdot A = k_L \cdot A$
 $V \cdot \frac{d[O_2]_l}{dt} = k_L \cdot A \cdot ([O_2]_g^s - [O_2]_l)$
 k_L = Mass transfer coefficient;
 A = contact area between liquid-gas phases

$\frac{d[O_2]_l}{dt} = k_L \cdot \left(\frac{A}{V}\right) \cdot ([O_2]_g^s - [O_2]_l)$
 $= k_L \cdot a \cdot ([O_2]_g^s - [O_2]_l)$
 a = Specific Surface Area (m²/m³)



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

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1) Surface Aerators



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1) Surface Aerators



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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 O₂ transfer efficiency (SOT) is given by the manufacturer as, kg O₂ transferred per hour per KW under standard conditions

Standard Conditions: T = 20°C; [O₂]_l = 0.0; In tap water

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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 $[O_2]_i^s$. Measure temp.
Add sodium sulfite to de-aerate water, i.e., $[O_2]_i = 0.0$
Aerate from $t = 0$ to $t = t$. Measure $[O_2]_t$ at various times during aeration.

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Surface Aerator: Design Procedure (Continued)

$$\frac{d[O_2]_t}{dt} = K_L \cdot a \{ [O_2]_i^s - [O_2]_t \}$$

Integrating,

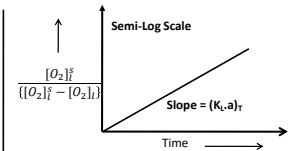
$$\int_{[O_2]_i}^0 \frac{d[O_2]_t}{\{ [O_2]_i^s - [O_2]_t \}} = \int_0^t K_L \cdot a \cdot dt$$

$$\ln \left\{ \frac{[O_2]_i^s}{[O_2]_i^s - [O_2]_t} \right\} = K_L \cdot a \cdot t$$

$$\frac{d[O_2]_t}{dt} = k_L \cdot a \cdot ([O_2]_i^s - [O_2]_t)$$

$$V \cdot \frac{d[O_2]_t}{dt} = k_L \cdot a \cdot ([O_2]_i^s - [O_2]_t) \cdot V$$

$$SOT = (K_L \cdot a)_{20} \cdot [O_2]_i^{s_{20}} \cdot (V)$$



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

T in celsius

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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 $15 - 20 \text{ W/m}^3$

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

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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 m³. No nitrification occurs in the aeration tank. Turbine Aerators are available with power rating 10, 25, 50 KW with area of influence being 36 m². 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°C. Saturation concentration of oxygen in water at 20°C is 9.1 mg/L and at 30°C is 7.5 mg/L.

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

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

both $K_L \cdot a$ and $[O_2]_i^s$ depend on temperature

$$\alpha = \frac{(K_L \cdot a)_T^W}{(K_L \cdot a)_T^F} = 0.8; \quad \beta = \frac{[O_2]_i^s}{[O_2]_i^s} = 0.9 \quad \text{Impact of wastewater}$$

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

$[O_2]_i^s$ decreases with temperature, obtained from tables

$[O_2]_i = 1 \text{ mg/L}$ or 3 mg/L (in case of nitrification)

$$SOT = (K_L \cdot a)_{20}^F \cdot [O_2]_i^{s_{20}} \cdot (V) \quad \text{Generally } 1.5 - 2.0 \text{ kg } O_2 / \text{h/KW}$$

$$AOT = (K_L \cdot a)_T^W \cdot \{ [O_2]_i^{s_T} - [O_2]_t \} \cdot (V)$$

$$AOT = (K_L \cdot a)_{20}^F \cdot (\alpha \cdot [1.02]^{T-20}) \{ \beta \cdot [O_2]_i^{s_T} - [O_2]_t \} \cdot (V)$$

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Solution

c/s area of each tank = $4320/4/2 = 540 \text{ m}^2$

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

$SOT = 2.0 \text{ kg } O_2/\text{h/KW};$ Find AOT at 30°C

$$[O_2]_i^{s_{20}} = 9.1 \text{ mg/L} \quad [O_2]_i^{s_{30}} = 7.5 \text{ mg/L} \quad [O_2]_t = 1.0 \text{ mg/L}$$

$$SOT = (K_L \cdot a)_{20}^F \cdot [O_2]_i^{s_{20}} \cdot (V) \quad 2 = (K_L \cdot a)_{20}^F \cdot (V) \cdot 9.1$$

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

$$AOT = (K_L \cdot a)_{20}^F \cdot (V) \cdot (5.607) = \frac{2}{9.1} \cdot (5.607)$$

$$= 1.232 \text{ kg } O_2/\text{h/KW}$$

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Solution continued

$$AOT = (K_L \cdot a)_{20}^F \cdot (V) \cdot \left(\frac{2}{9.1} \right) \cdot (5.607) = 1.232 \text{ kg O}_2/\text{h/KW}$$

Oxygen transfer per aerator = $4200/15/24 = 11.67 \text{ kg/hr}$;

Hence, Power Req'd. = $11.67/1.232 = 9.56 \text{ KW}$; Provide 15 no. aerators@10KW/tank

Power Req'd. for mixing/tank = $540 \cdot (4) \cdot (20)/1000 = 43.2 \text{ KW}$

Power provided for aeration/tank = $15 \cdot (10) = 150 \text{ KW}$. Hence, completely mixed conditions will prevail.

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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 BOD₅ (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

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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): $\text{C}_{60}\text{H}_{87}\text{O}_{23}\text{N}_{12}\text{P}$; 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

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

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

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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).

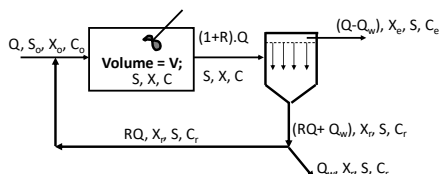
Pin-point flocs: In these flocs, filamentous bacteria are absent or occur in low numbers. This results in small flocs that do not settle well (Low BSRT).

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

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Activated Sludge: High Growth, Standard and Extended Aeration process

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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??

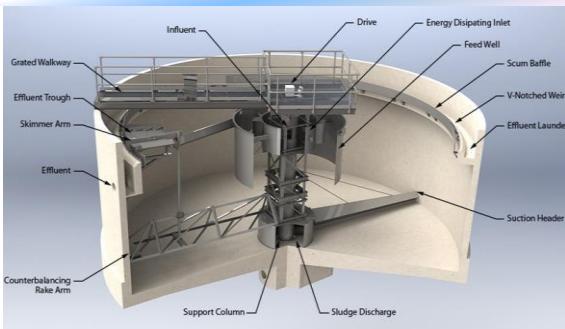
In such a system, q_c is high. Hence μ and q are low, S is relatively low. ΔX is low, hence O_2 requirement is high, but nutrient requirement is low. The inert matter concentration (C) in the aeration tank may be high. Chance of forming filamentous bulking sludge with poor settling characteristics.

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Settling of Activated Sludge

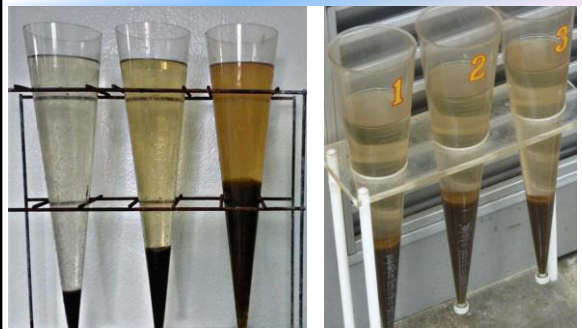


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Settling of Activated Sludge



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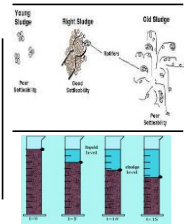
Sludge Volume Index (SVI):

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

$$SVI \text{ (mL/g)} = \frac{SV \times 1000}{MLSS} \quad (X_r)_{max} = \frac{10^6}{SVI}$$

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

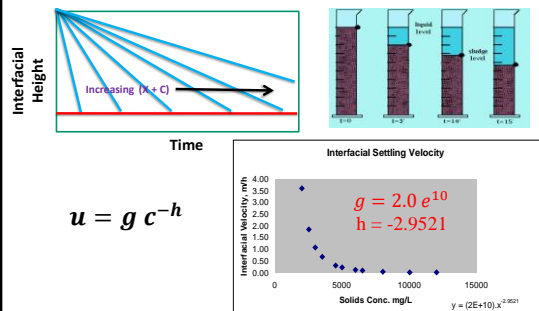


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Type III / Hindered / Zone Settling



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Interfacial Velocities of Sludge Solids

Solids (C+X) mg/L	u, 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

$$u = g c^{-h}$$

u = Interfacial settling velocity (in m/hr);
C = Mixed Liquor Suspended Solids Concentration (in mg/L)
= X + C₀ * (θ_c/θ)
X = Biomass Concentration in Aeration Tank (AT), mg/L
C₀ = Fixed Suspended Solids Concentration in inlet to AT, mg/L
g = 2x10¹⁰
h = 2.9521

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Concept of Solid Flux

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

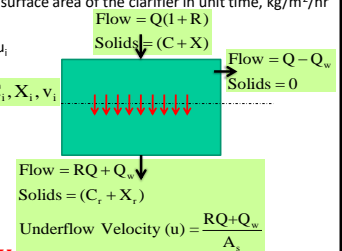
At any depth ,
Gravity/Batch Flux (SF_G) = (C_i + X_i).u_i
u_i is the interfacial velocity

Underflow Flux (SF_u) = (C_i + X_i).v
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

$$C = \frac{\theta_c}{\theta}; \quad C_0 = C + X$$



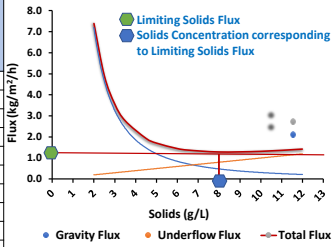
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SST or SC Design – SOR for Limiting Solid Flux

Solids Con- centration, C (g/L)	Gravity Flux (kg/m ² /h)	Underflow Flux (kg/m ² /h)	Total Flux (kg/ m ² /h)
2.0	7.196	0.200	7.396
2.5	4.655	0.250	4.905
3.0	3.261	0.300	3.561
3.5	2.414	0.350	2.764
4.5	1.478	0.450	1.928
5.0	1.203	0.500	1.703
6.0	0.843	0.600	1.443
6.5	0.721	0.650	1.371
8.0	0.481	0.800	1.281
10.0	0.311	1.000	1.311
12.0	0.218	1.200	1.418



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SST or SC Design

Area and Depth Choice:

1. Clarification Criteria $\rightarrow u = g c^{-h}$ $g = 2 \times 10^{10}$
 $h = 2.9521$
2. Solids Concentration in Under Flow
3. Retention Time < 2.5 to 3 h

SOR for Limiting Solids Flux is given by following expression:

$$\frac{Q}{A} = \frac{g(h-1)\left(\frac{h}{h-1}\right)^h (R)^{h-1}}{(C_0)^h (1+R)^h}$$

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