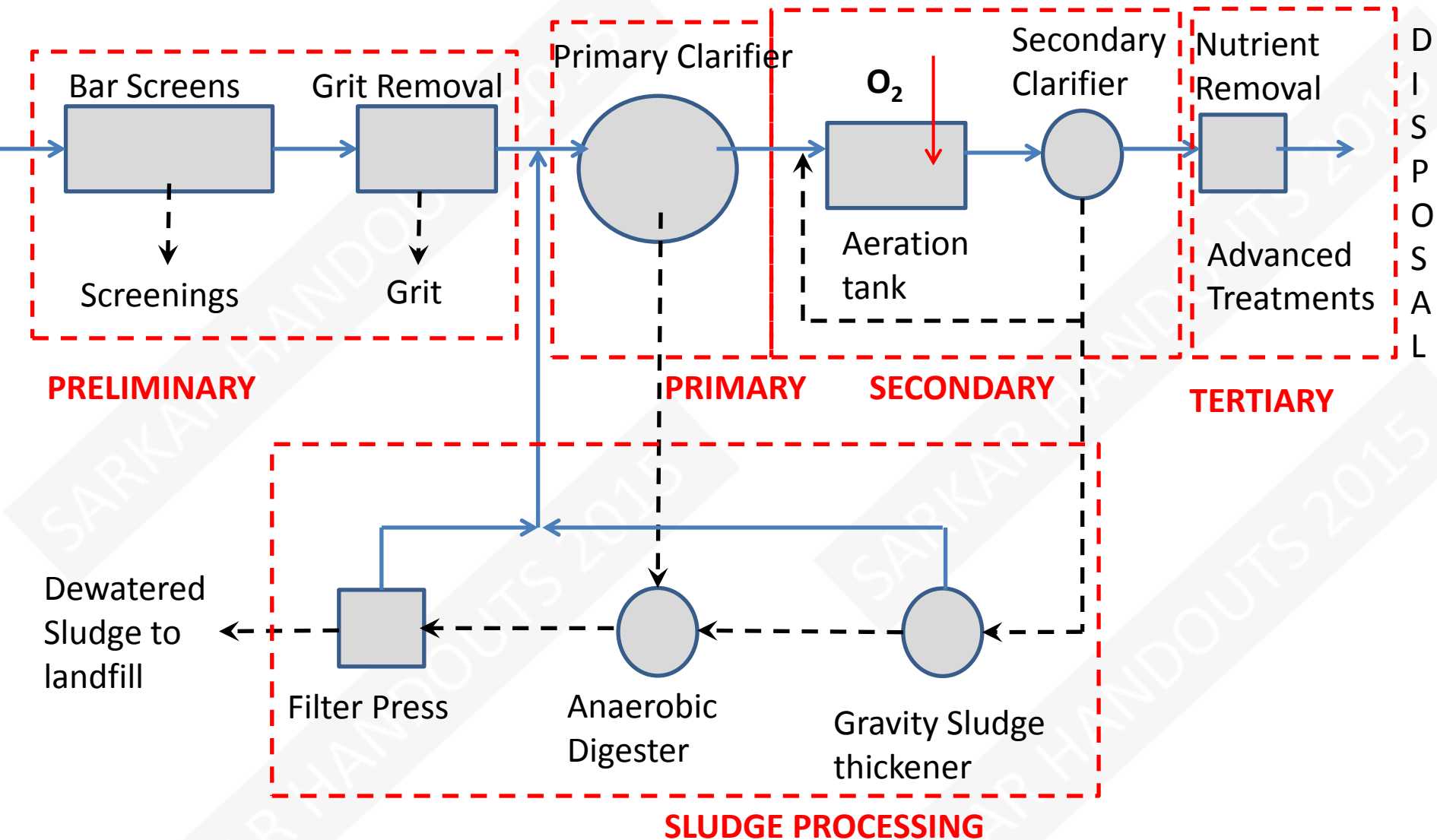


Biological Treatment of Wastewater – Secondary Treatment Process – Activated Sludge Process

Sudipta Sarkar



Typical Process flow Diagram– Different Treatment Blocks

BIOLOGICAL TREATMENT PROCESSES - OVERVIEW

Domestic sewage and some industrial or agricultural wastewater contains high concentrations of biodegradable organic matter. The organic material if discharged untreated, act as a food source for microorganisms. If the discharge is large, problems occur leading to large scale pollution.

The preliminary and primary treatment of wastewater together remove almost 60 percent of solids loading and 40 percent of BOD load that is influent to the wastewater treatment plant. The solids removed mostly are inorganic in nature, as the specific gravity and size of the commonly occurring inorganic solids are higher than their organic counterparts.

The removal of the BOD, coagulation of non-settleable colloidal solids, and the stabilization of organics are accomplished biologically using a variety of microorganisms.

Importance and Objectives of Biological Treatment

- Biological treatment is used to remove the most of the contaminants remaining in regular sewage or industrial wastewater that contains biodegradable materials. The biodegradable part may be in either particulate (solid) or dissolved form.
- Biological treatment is targeted to remove the contaminants by: a) coagulation and sedimentation and b) stabilization of organic matter so that organic content is reduced.
- Use organic matter as a food supply to support the growth of biomass
- Also use organic material to provide energy for growth resulting in production of CO_2 and other metabolic byproducts thereby reducing total BOD

Types of Microbial Communities

- Aerobic
 - utilize oxygen
- Anaerobic
 - grow in absence of oxygen
- Facultative
 - can grow either with or without oxygen
 - metabolism changes as environment changes from aerobic to anaerobic

Aerobic Organisms

- require oxygen to perform their metabolic activities
- Require high rates of oxygen supply for wastewater treatment processes

Aerobic Processes

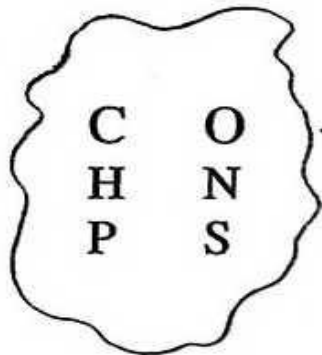
1. presence of oxygen
2. rapid conversion of BOD
3. release lots of energy

Organic nutrients (growth factor)

Amino acids

Purines and pyrimidines

vitamins



+ aerobic bacteria + O₂

Inorganic

Essential nutrients: N, S, P, K, Mg, Ca, Fe, Na, Cl

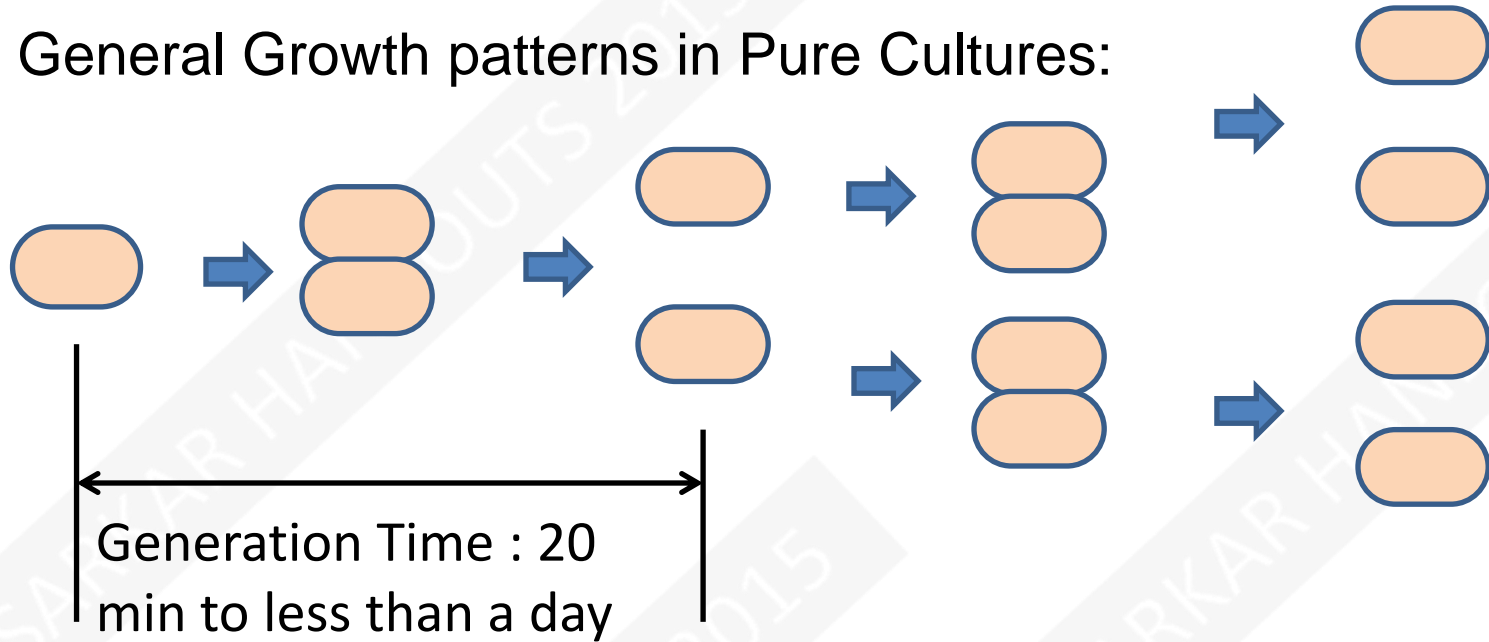
Micro-nutrients: Zn, Mn, Mo, Se, Co, Cu, Ni, V and W

⇒

bacterial biomass + CO₂ + more energy
C₅H₇O₂N NO₃
SO₄
PO₄
H₂O

Microbial Growth

General Growth patterns in Pure Cultures:



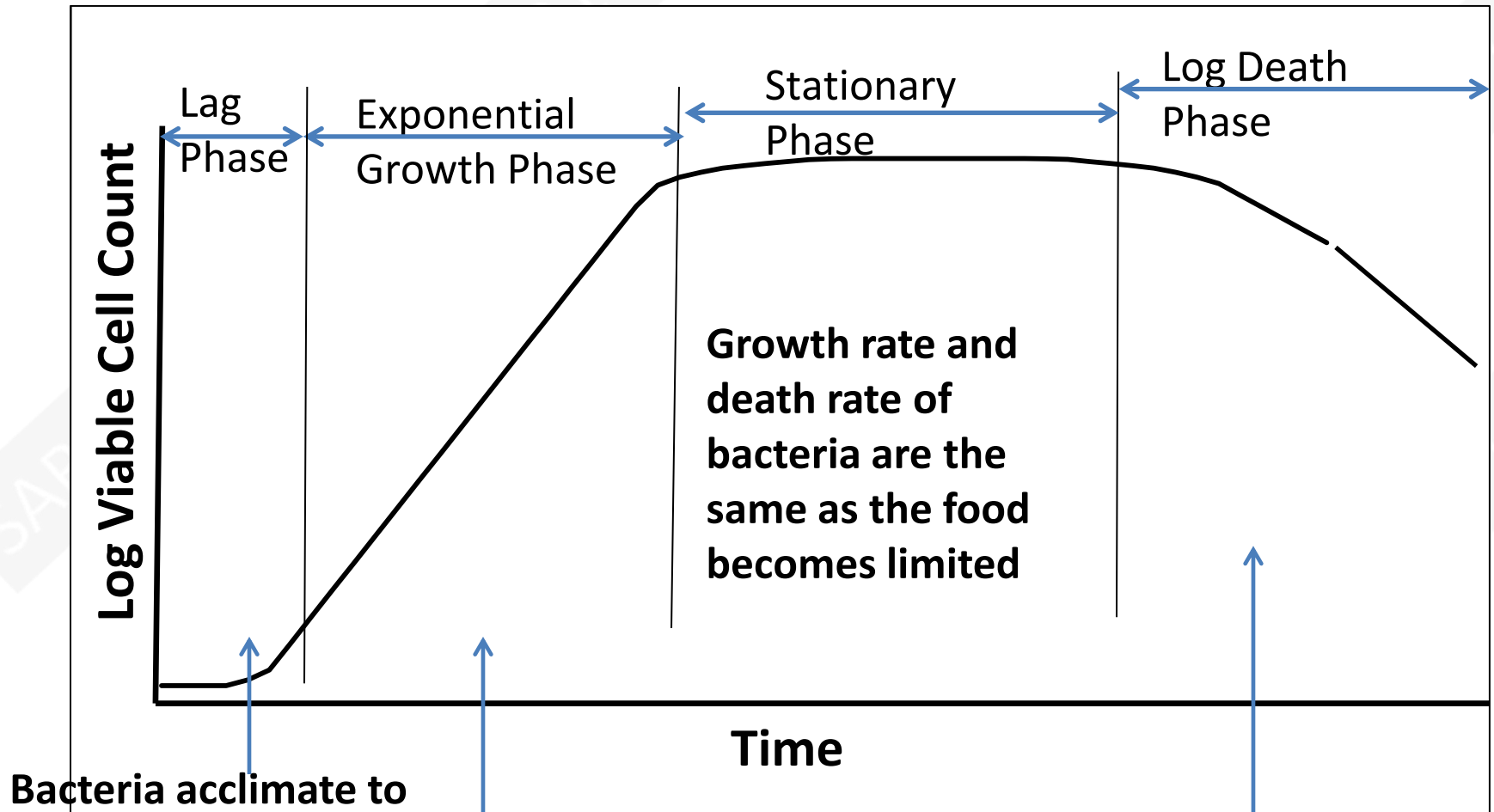
Binary Fission

Exponential Growth

Condition: unlimited supply of food, unlimited supply of nutrients and abundance of dissolved oxygen in water

Microbial growth pattern in a batch reactor

Condition: **Finite amount of food and nutrient supply**



Bacteria acclimate to the new environment

Excess food surrounding the bacteria; rate of metabolism and growth is a function of the ability of microorganism to process the substrate

Food is limited; bacteria metabolize own protoplasm, death rate far exceeds the production of new cells

Exponential Growth Phase

- Cells have abundant food and grow without limit during this phase

$$X = X_0 e^{\mu t}$$

- X is cell concentration (mass dry wt/vol)
- X_0 is cell concentration at start of exponential phase
- μ is the specific growth rate (time⁻¹)
- t is time

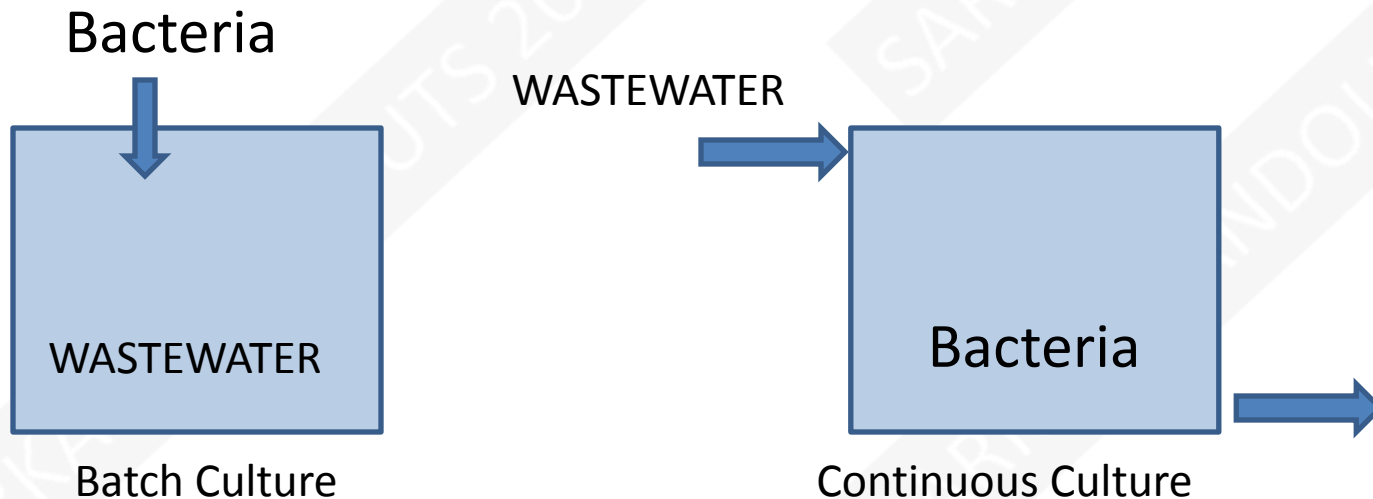
In other words, in both batch and continuous culture system, the rate of the growth of bacteria can be represented by,

$$r_g = \frac{dX}{dt} = \mu X$$

Is it a constant?

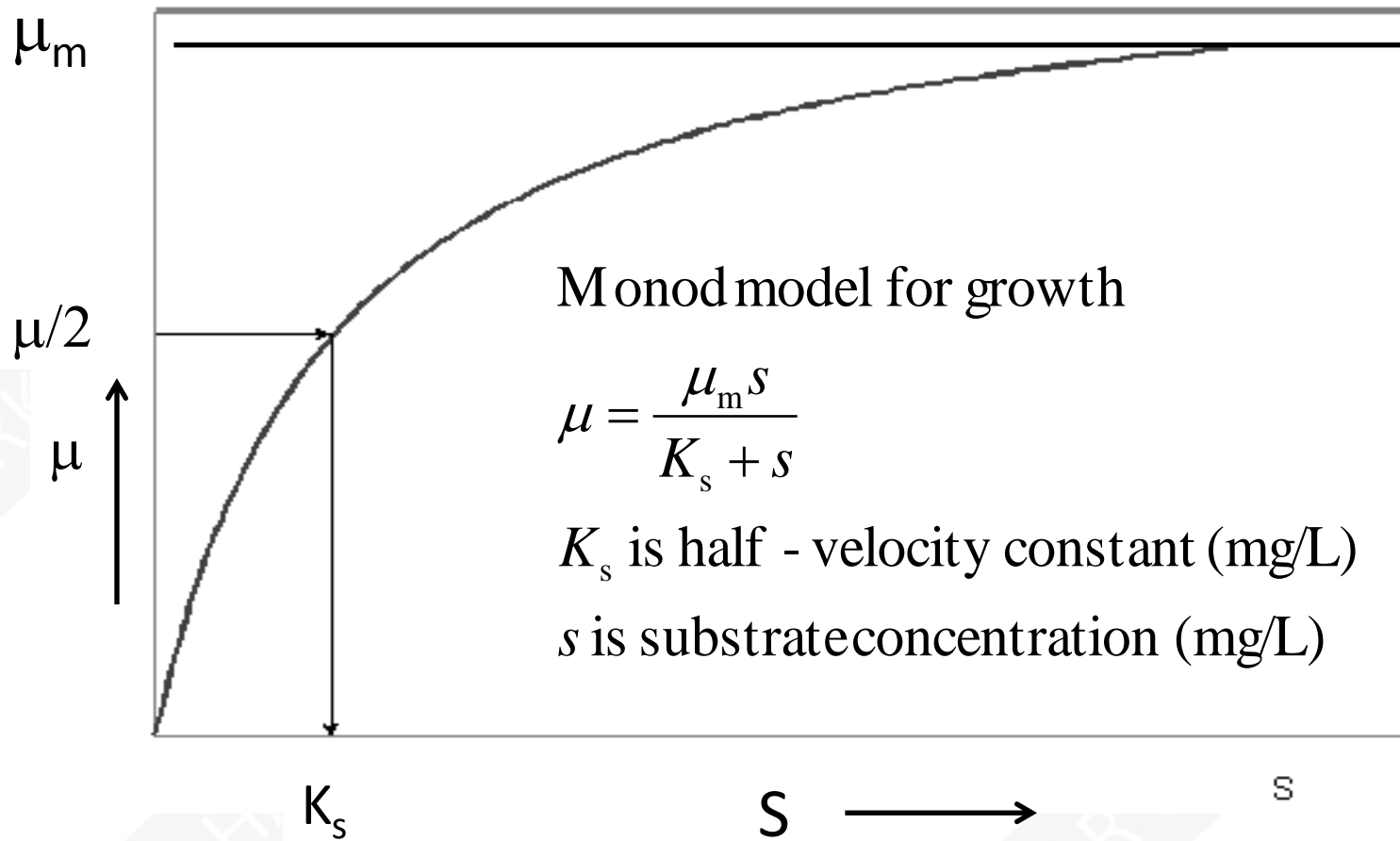
Substrate (Food) Limited Growth

- Specific growth rate is a function of environmental conditions for the organism, including substrate (food) concentration
- there is a maximum rate at which organisms can grow even with plenty of nutrients available (μ_{\max})
- as substrate becomes limited, growth slows down
- a simple equation describing this behavior is called the Monod model



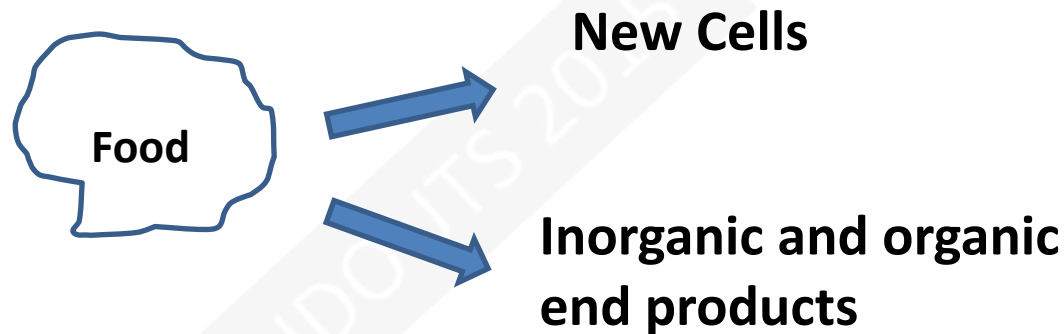
Specific Growth Rate

Substrate (food)- limited Condition



$$r_g = \frac{dX}{dt} = \mu X = \frac{\mu_m X S}{K_s + S}$$

Cell Growth and Substrate Utilization



For a given substrate (food) the quantity of new cells produced can be defined with a mathematical relationship

$$r_g = -Yr_{su}$$

r_g = rate of bacterial growth, mg/(L. sec)

Y = maximum yield coefficient, mass of cells formed per unit mass of BOD consumed, mg/mg

r_{su} = Substrate utilization rate, mg/(L. sec)

The yield of microorganism depends on (1) oxidation state of the carbon source, (2) Degree of polymerization of the substrate, (3) pathways of metabolism and (4) various environmental parameters such as temperature, pH, pressure, etc.

$$r_g = -Yr_{su}$$

$$r_g = \frac{\mu_m XS}{K_s + S}$$

$$r_{su} = -\frac{\mu_m XS}{Y(K_s + S)}$$

$$k = \frac{\mu_m}{Y}$$

k is defined to be the maximum rate of substrate utilization per unit mass of microorganism

$$r_{su} = -\frac{kXS}{(K_s + S)}$$

In a mixed system not all the cells are in log growth phase. Also, some energy derived from the food is used for cell metabolism used for maintenance. Death and predation rates were not considered in the above expression.

Growth in Mixed Cultures

Growth curves for different species of microorganisms are different from each other.

Most biological treatment processes are comprised of complex, interrelated, mixed biological populations.

For a mixed population, the position and shape of a particular growth pattern shall depend on the relative abundance of the different species, food and nutrients available and also, on environmental factors such as temperature, pH, availability of oxygen, etc.

Death and predation factors are often lumped together for ease of design and calculation, without losing the accuracy.

Assumption: The decrease in cell mass caused by death and predation is proportional to the concentration of the microorganism present. The decrease in the number of microorganism is considered to be endogenous decay.

$$r_d = -k_d X$$

k_d = endogenous decay coefficient, time⁻¹

X = concentration of cells (microorganisms), mg/L

$$r_g' = r_g - r_d$$

r_g' = net rate of bacterial growth

$$r_g' = \frac{\mu_m X S}{(K_s + S)} - k_d X$$

net specific bacterial growth rate = $\mu_g' = \frac{r_g'}{X} = \frac{\mu_m S}{(K_s + S)} - k_d$

Observed Yield $Y_{Obs} = -\frac{r_g'}{r_{su}}$

Bioreactors

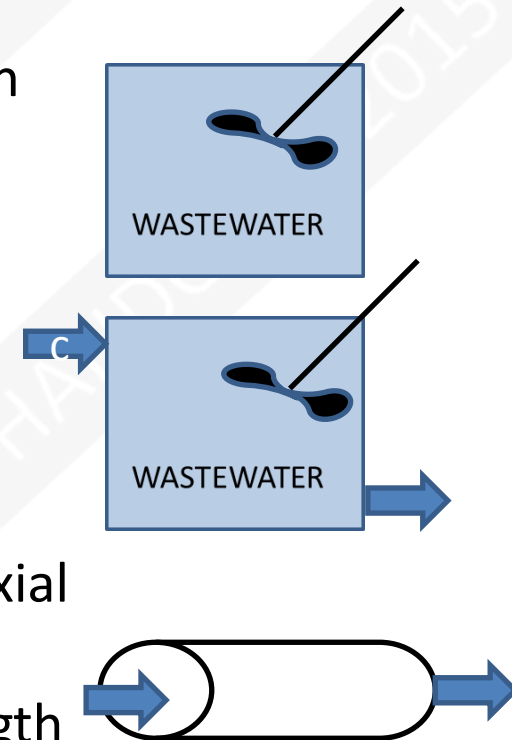
The system in which a biochemical reaction take place is known as a bioreactor. Bioreactors may contain live and dead microorganisms, organic material, essential nutrients, and may be fed with external gases such as oxygen, natural or compressed air, or carbon dioxide depending on the applications

Types of Reactors: a) Batch reactor, b) Completely mixed flow reactor (CMFR) and c) Plug Flow Reactor (PFR)

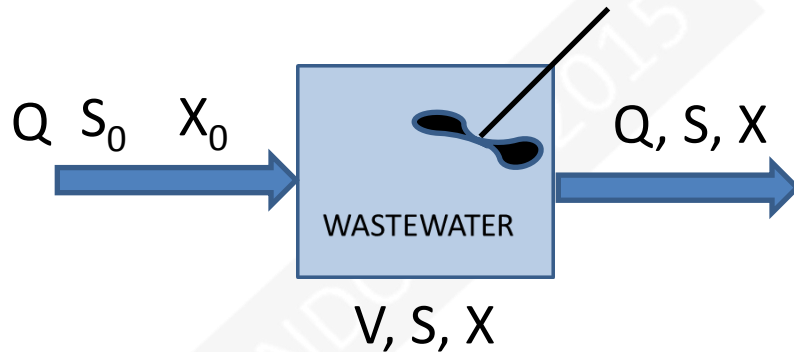
Batch reactor: A vessel loaded with reactants and then sealed, may or may not be mixed

CMFR: A fluid container with flow in and out. Contents are instantly and completely mixed. Concentration of species going out is assumed to be equal to the concentration inside the container

PFR: Uniform velocity of fluid across the reactor, no axial mixing, may or may not be any radial mixing, concentration is not uniform, may vary along the length



Reactor Mass Balances: Food and Microorganism



Suspended Growth Process:

microorganisms responsible for the conversion of organic matter to gases and cell tissue are maintained in suspension in the wastewater

Completely Mixed Flow Reactor (CMFR)

Mass balance:

Rate of accumulation of material = Rate of flow of material into the reactor - Rate of flow of material out of the reactor + Rate of formation or destruction of material within the reactor

Microorganism balance:

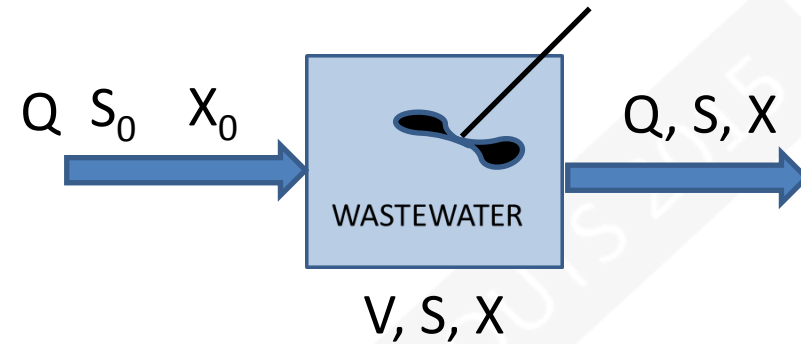
$$V \frac{dX}{dt} = Q \cdot X_0 - Q \cdot X + r'_g \cdot V$$

Food (substrate) balance:

$$V \frac{dS}{dt} = Q \cdot S_0 - Q \cdot S + r_{su} \cdot V$$

Reactor Mass Balances: Food and Microorganism

At Steady State, there is no net accumulation food or microorganism with respect to time. The reactor keeps a constant load of microorganism or food, no change over time.



$$\frac{dX}{dt} = 0 \text{ and } \frac{dS}{dt} = 0$$

$$Q \cdot X_0 = Q \cdot X - r'_g \cdot V \Rightarrow r'_g \cdot V = Q \cdot X - Q \cdot X_0 \Rightarrow \frac{Q}{V} = \frac{r'_g}{X}$$

$$\frac{V}{Q} = \theta = \text{Hydraulic detention time}$$

$$\frac{1}{\theta} = \frac{\frac{\mu_m X S}{(K_s + S)} - k_d X}{X} = \frac{\mu_m S}{(K_s + S)} - k_d$$

$$\frac{1}{\theta} = \frac{\mu_m S}{(K_s + S)} - k_d$$

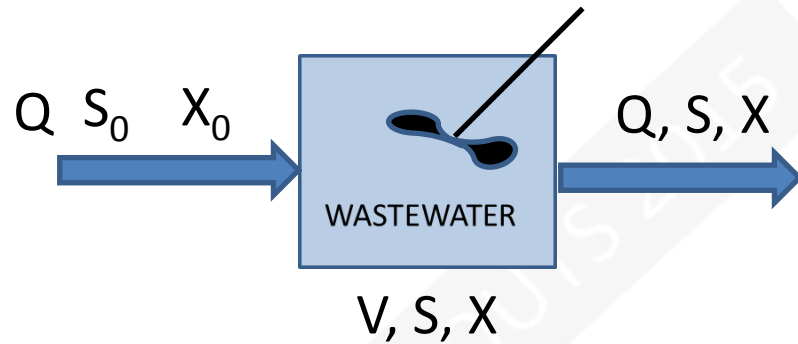
At steady state, $\frac{dS}{dt} = 0$

$$Q \cdot S_0 - Q \cdot S = -r_{su} \cdot V$$

$$(S_0 - S) = -r_{su} \cdot \frac{V}{Q}$$

$$(S_0 - S) = \frac{kXS}{(K_s + S)} \cdot \theta$$

$$r_{su} = -\frac{kXS}{(K_s + S)}$$



$$\frac{(S_0 - S)}{k\theta X} = \frac{S}{(K_s + S)}$$

$$\frac{1}{\theta} = \frac{\mu_m S}{(K_s + S)} - k_d \quad \rightarrow \quad \left(\frac{1}{\theta} + k_d\right) \frac{1}{\mu_m} = \frac{S}{(K_s + S)}$$

$$\left(\frac{1}{\theta} + k_d\right) \frac{1}{\mu_m} = \frac{S_0 - S}{k\theta X}$$

$$X = \frac{\mu_m (S_0 - S)}{k(1 + k_d \theta)}$$

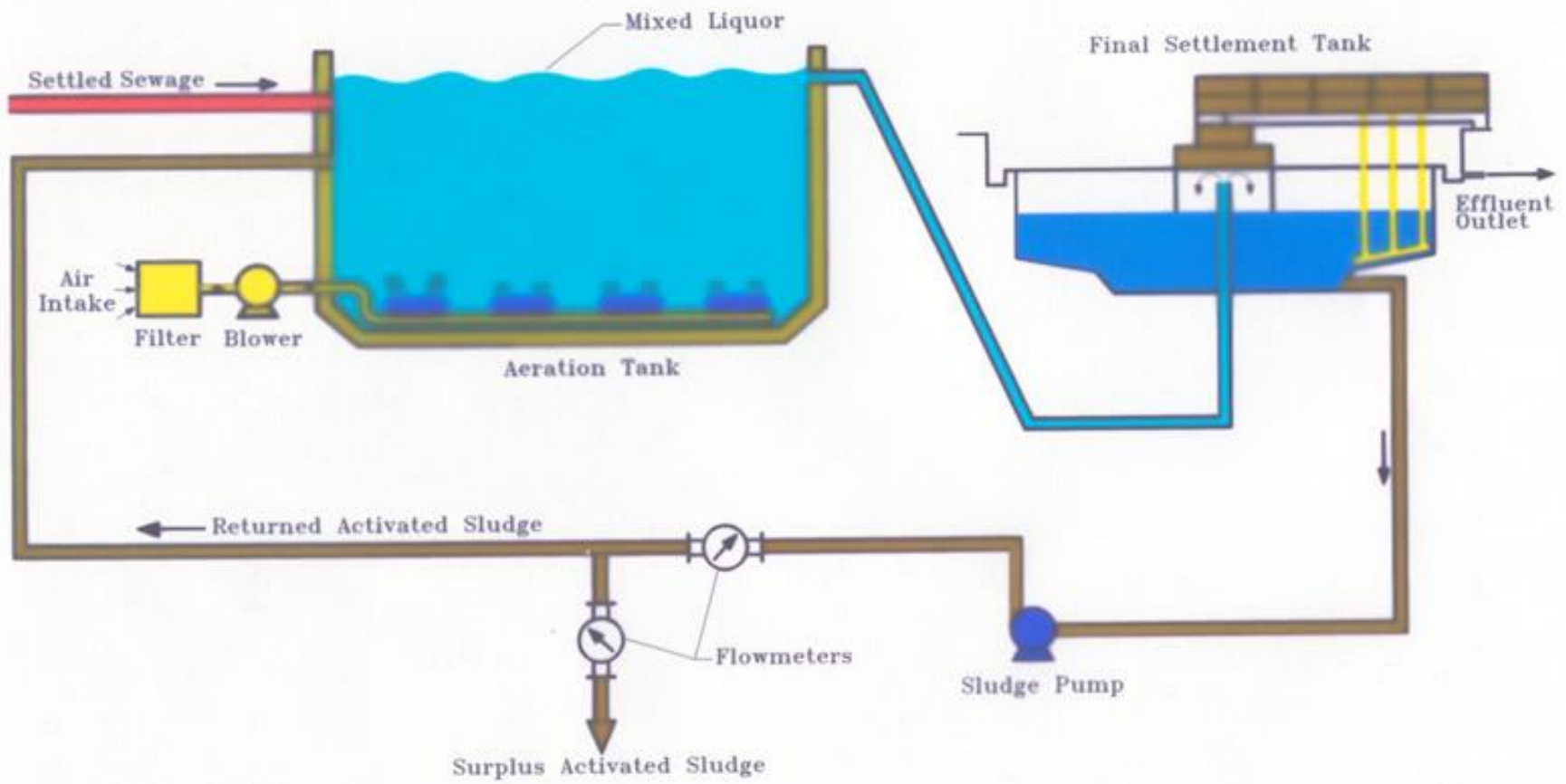
$$X = \frac{Y(S_0 - S)}{(1 + k_d \theta)}$$

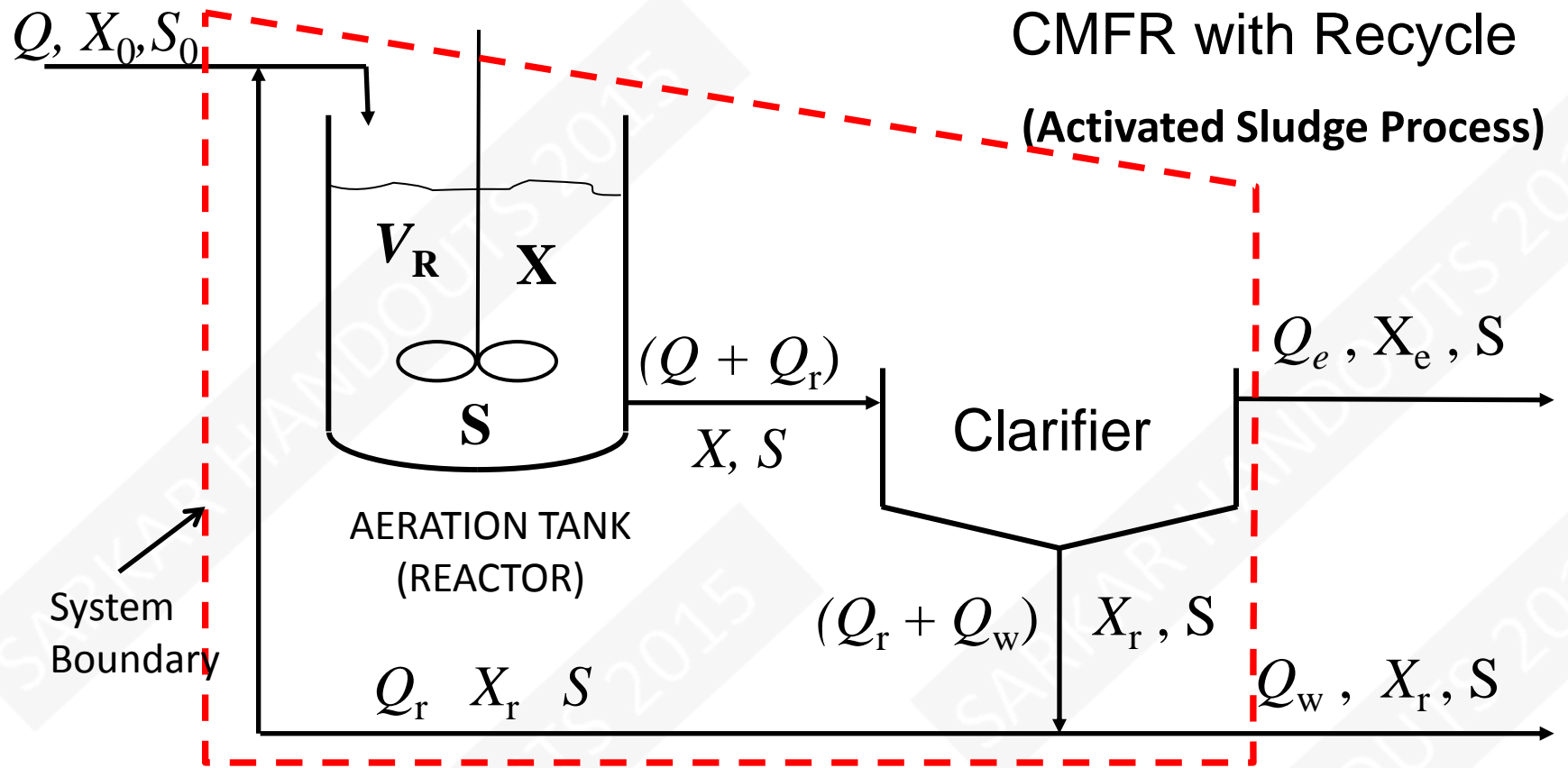
Task: Prove that

$$S = \frac{K_s (1 + \theta k_d)}{\theta(Yk - k_d) - 1}$$

WTT

ACTIVATED SLUDGE PROCESS





Accumulation = Inflow - outflow + Net growth

$$V_R \frac{dX}{dt} = QX_0 - [Q_w X_r + Q_e X_e] + V_R (r'_g)$$

At Steady State,

$$\frac{dX}{dt} = 0 \quad QX_0 + V_R \left(\frac{\mu_m X S}{(K_s + S)} - k_d X \right) = Q_w X_r + Q_e X_e$$

$$QX_0 + V_R \left(\frac{\mu_m XS}{(K_s + S)} - k_d X \right) = Q_w X_r + Q_e X_e$$

Assume, $X_0 \approx 0$

$$\left(\frac{\mu_m S}{(K_s + S)} - k_d \right) = \frac{Q_w X_r + Q_e X_e}{V_R X}$$

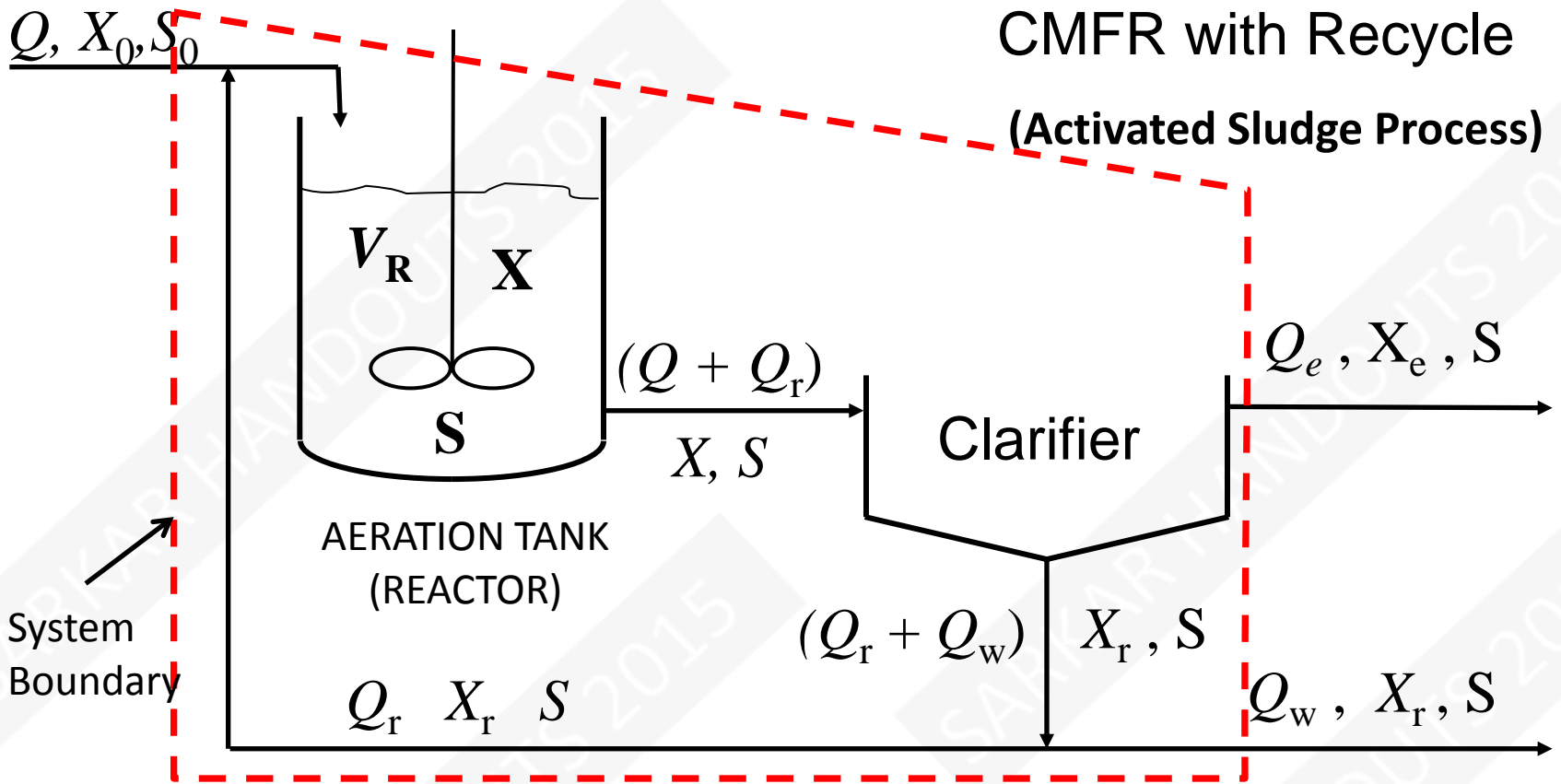
$$r_g = -Y r_{su}$$

$$\frac{Q_w X_r + Q_e X_e}{V_R X} = -Y \frac{r_{su}}{X} - k_d$$

$$r_g = \frac{\mu_m XS}{K_s + S}$$

$$\text{Mean Cell Residence Time (MCRT)} = \theta_c = \frac{V_R X}{Q_w X_r + Q_e X_e}$$

MCRT is defined as the mass of microorganisms in the reactor divided by the mass of the microorganisms wasted per unit time (day). It signifies the average time the microorganism spend inside the reactor. It is also called sludge age or solids retention time (SRT).



Accumulation = Inflow - outflow + Net growth

$$\text{At Steady State, } V_R \frac{dS}{dt} = QS_0 - [Q_w S + Q_e S] + V_R r_{su}$$

$$\frac{dS}{dt} = 0 \quad QS_0 + V_R r_{su} = (Q_e + Q_w)S = QS$$

$$r_{su} = -\frac{S_0 - S}{V_R / Q} = -\frac{S_0 - S}{\theta}$$

$$\theta = \frac{V_R}{Q} = \text{Hydraulic retention time}$$

$$\frac{1}{\theta_c} = -Y \frac{r_{su}}{X} - k_d$$

$$r_{su} = -\frac{S_0 - S}{Q/V_R} = -\frac{S_0 - S}{\theta}$$

$$\frac{1}{\theta_c} = Y \frac{S_0 - S}{\theta X} - k_d$$



$$X = \frac{\theta_c Y (S_0 - S)}{\theta (1 + k_d \theta_c)}$$

$$r_g = -Y r_{su}$$

$$r_{su} = -\frac{S_0 - S}{\theta}$$

$$r_g = \frac{\mu_m X S}{K_s + S}$$

$$Y \frac{S_0 - S}{\theta} = \frac{\mu_m X S}{K_s + S}$$

$$X = \frac{\mu_m X S}{K_s + S} \cdot \frac{\theta_c}{\theta} \cdot \frac{1}{(1 + k_d \theta_c)}$$

$$k = \frac{\mu_m}{Y}$$

$$S = \frac{K_s (1 + k_d \theta_c)}{\theta_c (Yk - k_d) - 1}$$

= maximum rate of substrate utilization per unit mass of microorganism

Define a new term, specific utilization rate, U so that

$$\frac{1}{\theta_c} = -Y \frac{r_{su}}{X} - k_d \quad U = -\frac{r_{su}}{X} = \frac{S_0 - S}{\theta X} = \frac{Q}{V_r} \cdot \frac{S_0 - S}{X}$$

$$\frac{1}{\theta_c} = YU - k_d$$

Another important term Food-to-microorganism ratio, F/M, is defined as,

$$F / M = \frac{\text{Total food available per unit of time}}{\text{Total microbial load in the system}} = \frac{Q \cdot S_0}{V_r X} = \frac{Q}{V_r} \cdot \frac{S_0}{X} = \frac{S_0}{\theta X}$$

X is the concentration of microorganism in reactor. Often it is termed as Mixed Liquor Suspended Solids (MLSS)

Efficiency of the Activated Sludge Process (ASP):

$$E = \frac{S_0 - S}{S_0} * 100$$

$$E = \frac{S_0 - S}{\theta X} * \frac{\theta X}{S_0} * 100 = U \cdot \frac{1}{F / M} * 100$$

Volumetric loading rate is defined to be total amount of organics loading per unit volume of the reactor.

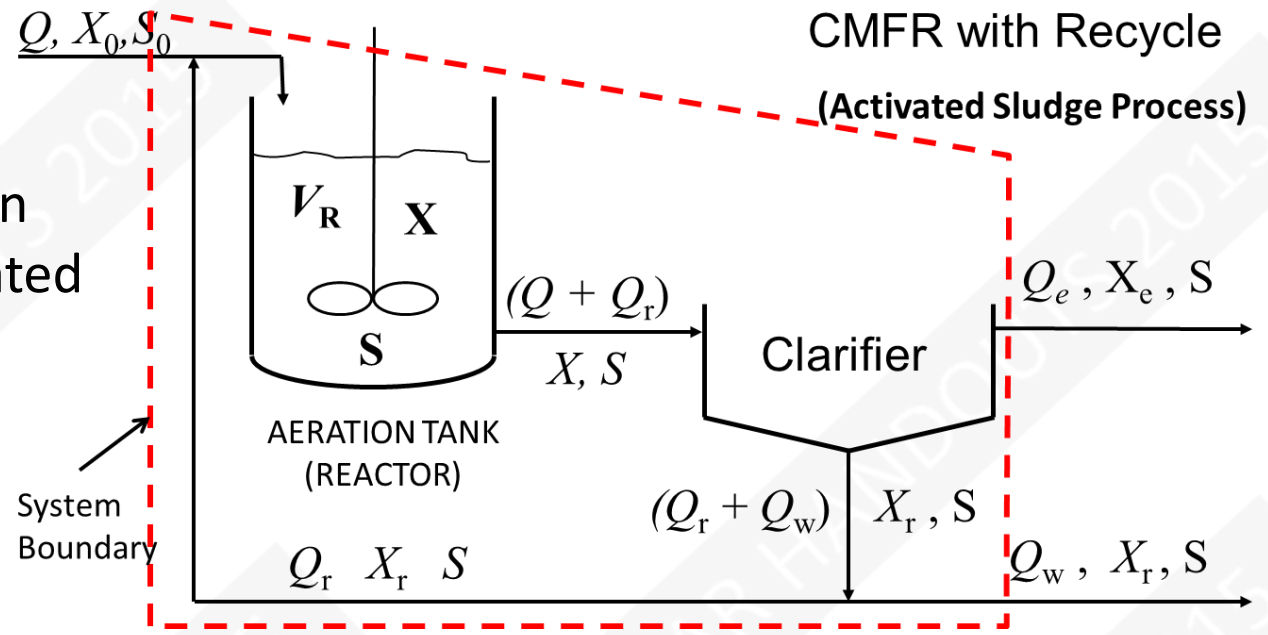
$$= \frac{QS_0}{V_r}$$

Important Variables and relationships

The relationships important for the design and control of an activated sludge process are:

$$S = \frac{K_s(1 + k_d\theta_c)}{\theta_c(Yk - k_d) - 1}$$

$$X = \frac{\theta_c Y(S_0 - S)}{\theta(1 + k_d\theta_c)}$$



$$\theta_c = \frac{V_R X}{Q_w X_r + Q_e X_e} \quad \theta = \frac{V_r}{Q} \quad U = \frac{S_0 - S}{\theta X}$$

$$\frac{1}{\theta_c} = YU - k_d \quad F/M = \frac{S_0}{\theta X} \quad E = \frac{S_0 - S}{S_0} * 100 \quad E = U \cdot \frac{1}{F/M} * 100$$

U=specific substrate utilization rate; E= efficiency; F/M = food to microorganism ratio; X=microorganism concentration in the reactor or Mixed Liquor Suspended Solids (MLSS); θ = hydraulic retention time (HRT); θ_c = mean cell residence time (MCRT); Y =yield coefficient

F/M

$$\frac{F}{M} = \frac{Q S_0}{V X}$$

$$\frac{\text{mg BOD}_5/\text{L} \times \text{L}/\text{d}}{\text{L} \times \text{mg}/\text{L} (\text{MLVSS})}$$

$$\frac{\text{mg BOD}_5/\text{d}}{\text{mg MLVSS}}$$

$$\frac{\text{mg}}{\text{mg} \cdot \text{d}}$$

F/M

↓
Controlled by wasting AS
(i.e. by reducing the MLVSS)



Rate of wasting: High (short θ_c)

↓
F/M : High

↓
Organisms : Saturated with food

↓
Treatment eff. : Poor

: Low (long θ_c)

↓
: Low

↓
Starved

↓
More complete degradation
of the waste
Better BOD₅ rem. eff.

↓
Cell yield : Less
Less sludge to handle

Means:

- Larger / more costly AT
- Higher O₂ requirement / Higher power costs
- Poor sludge settleability

F/M : Range - 0.1 - 1.0 mg/mg·d

(For various modifications)

Operation of activated sludge treatment plant is regulated by 1) quantity of air supplied in the aeration basin; 2) The rate of recirculation of activated sludge and 3) Amount of excess sludge wasted from the system.

Sludge wasting is an important step to establish the desired concentration of MLSS, F/M ratio and MCRT or mean cell residence time or sludge age.

An important measurement for operational control is the settleability of the mixed liquor as defined by sludge volume index (SVI). SVI is the volume in mL occupied by 1 g of suspended solids after 30 minutes of settling.

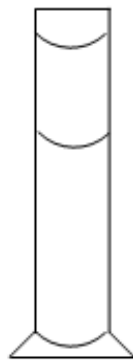
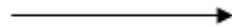
$$SVI = \frac{\text{Sludge Volume from Settling unit volume mixed liquor (mL/L)} * 1000 \text{ mg/g}}{\text{MLSS (mg/L)}} \text{ (mL/g)}$$

Start with 1L of mixed liquor

Volume of settled sludge = V_s



After 30 minutes



$$MLSS = \frac{V_s/V \text{ (mL/L)} * 1000}{SVI}$$

Sample of Mixed Liquor taken from the pond

Portion of settled sludge solid after 30 minutes

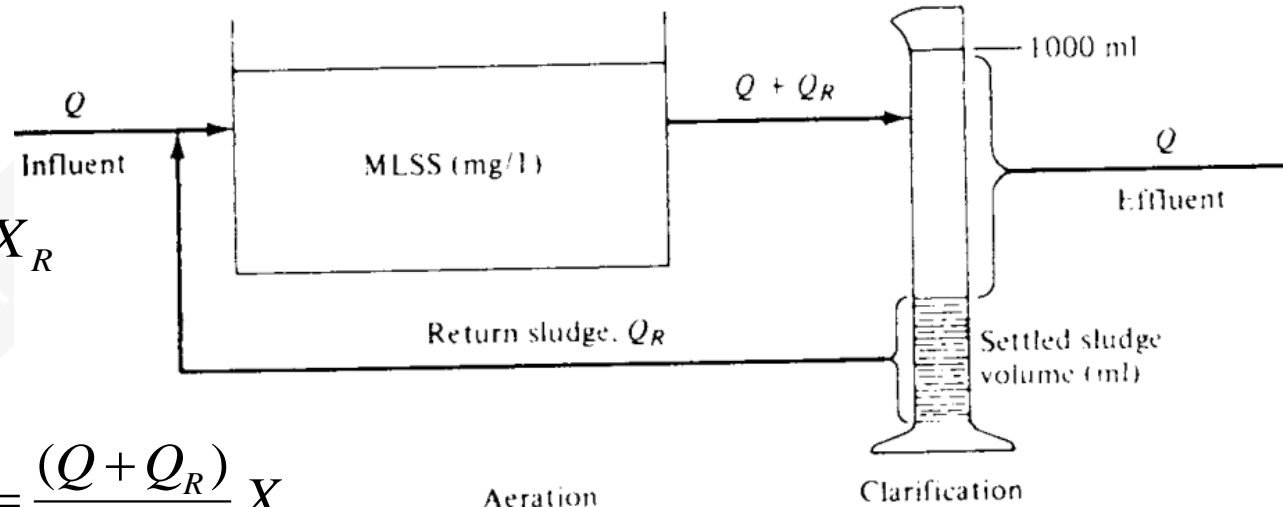
Neglecting any sludge wasting

$$(Q + Q_R)X = Q_e X_e + Q_R X_R$$

$$X_e \approx 0$$

$$(Q + Q_R)X = Q_R X_R$$

$$X_R = \frac{(Q + Q_R)}{Q_R} X$$



If the rate of sludge return is less than the rate of accumulation of settled solids, the sludge blanket in the final clarifier slowly rises until the suspended solids are carried out with overflow.

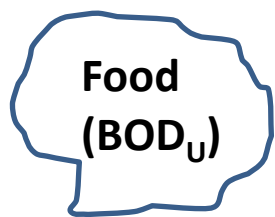
If the rate of sludge return exceeds the rate of accumulation of settled solids, clear treated water is drawn with the sludge, making it less concentrated by diluting it.

In Ideal case, the mass balance should follow the above diagram. By the time it settles down so that a flow rate of Q_R takes out all the sludge contained in it.

$$MLSS = \frac{V_s/V \text{ (mL/L)} * 1000}{SVI}$$

$$X_R = \frac{(Q + Q_R)}{Q_R} X = \frac{V}{V_s} * MLSS = \frac{V}{V_s} * \frac{V_s * 1000 \text{ (mg / g)}}{V * SVI \text{ (ml / g)}}$$

$$X_R \text{ (mg / L)} = \frac{10^6}{SVI \text{ (ml / g)}}$$



New Cells (They will also have some BOD_u)



Inorganic end products

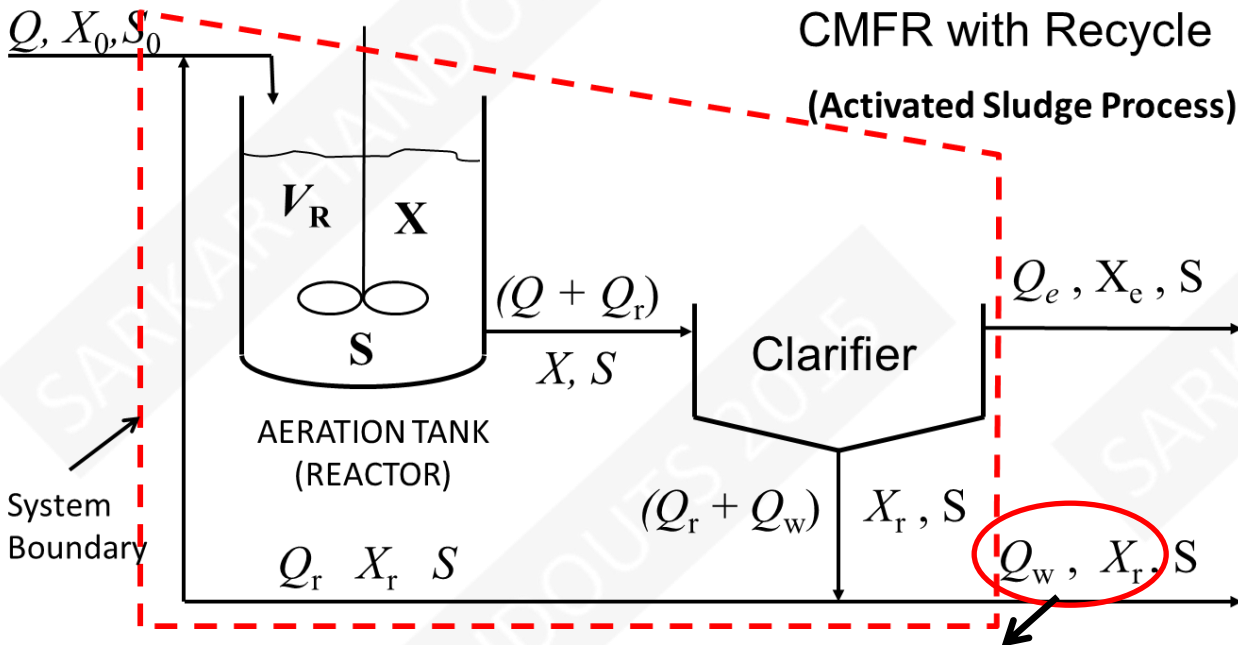


In ASP, the cells are recycled mostly in the process; however, a part of the active microorganisms are wasted

i.e. not all the BOD_u in the influent wastewater gets stabilized or degraded to inorganic end products.

CMFR with Recycle

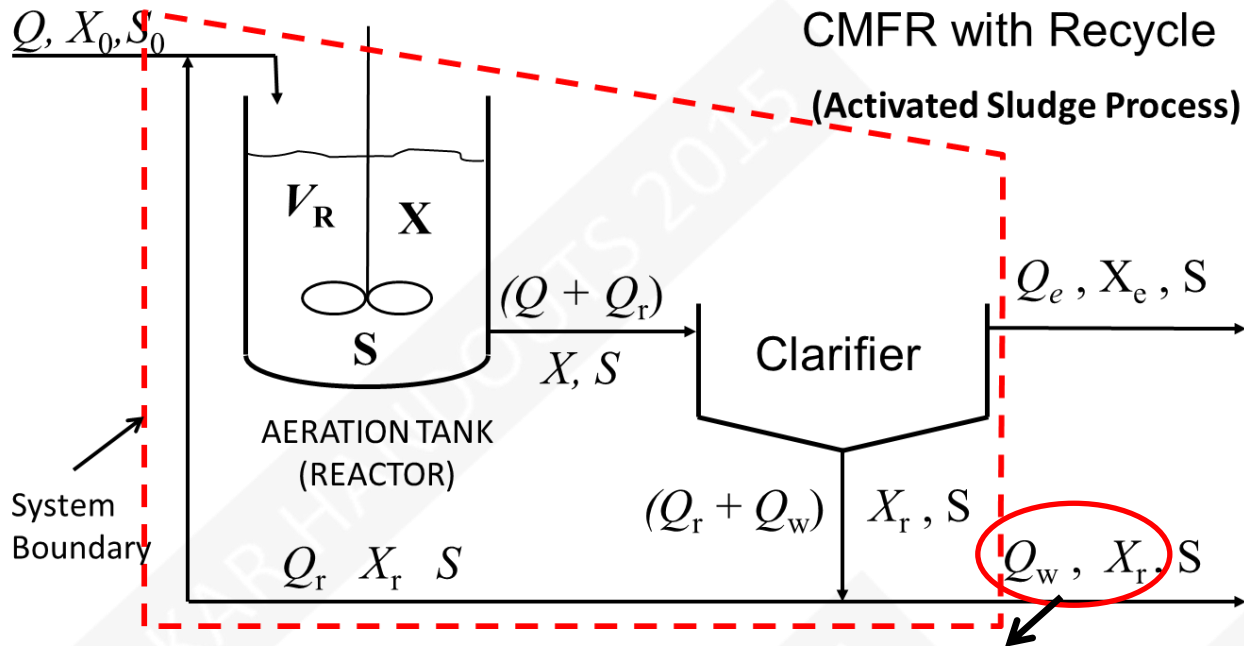
(Activated Sludge Process)



Amount of microorganism wasted

Total BOD_u destroyed = BOD_u of the influent wastewater destroyed - BOD_u of the microorganism wasted

$$= Q(S_0 - S) - \text{Biochemical } O_2 \text{ demand of } (Q_w X_r)$$



$$\theta_c = \frac{V_R X}{Q_w X_r + Q_e X_e} \leftarrow = 0$$

$$\theta_c = \frac{V_R X}{Q_w X_r}$$

$$X = \frac{\theta_c Y (S_0 - S)}{\theta (1 + k_d \theta_c)}$$

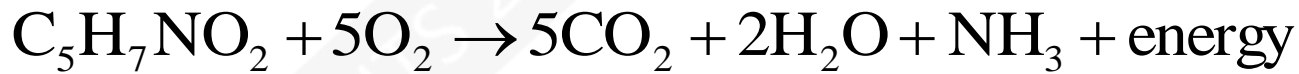
$$Q_w X_r = \frac{V_R X}{\theta_c} = \frac{V_R}{\theta_c} * \frac{\theta_c}{\theta} * \frac{Y (S_0 - S)}{(1 + k_d \theta_c)}$$

$$= \frac{V_R}{\theta} * \frac{Y (S_0 - S)}{(1 + k_d \theta_c)} = Q (S_0 - S) \frac{Y}{(1 + k_d \theta_c)}$$

$$Y_{obs} = \frac{Y}{1 + k_d \theta_c}$$

$$= Q (S_0 - S) Y_{obs}$$

Approximate chemical formula of a bacterial cell is $C_5H_7NO_2$



$$113 \qquad 5 \times 32$$

$$1 \qquad 1.42$$

Amount of sludge wasted per day $P_x = Q(S_0 - S)Y_{obs}$ Q is in cum/day

Oxygen demand of the wasted sludge is $= 1.42P_x = 1.42 * Q(S_0 - S)Y_{obs}$

$$Y_{obs} = \frac{Y}{1 + k_d \theta_c} \quad \text{Total Oxygen demand of the ASP process}$$

= Total BOD_u destroyed

$$= \frac{Q(S_0 - S)}{f} - 1.42P_x$$

S, S_0 are in BOD_5 and not BOD_u

So, it has to be divided by factor f to transform to BOD_u

so that

$$f = \frac{BOD_5}{BOD_u}$$

For BOD rate constant of value 0.23 per day (base e), $f = 0.68$

Recommended Design Parameters for Activated Sludge Process for Municipal Wastewater

Completely Mixed Type Aeration Tank

Parameter	Design Values
Mixed Liquor Suspended Solids (MLSS), X (mg/L)	3000-4000
MLVSS/MLSS	0.8
F/M (kg BOD ₅ /Kg MLSS/day)	0.3-0.5
HRT (θ), hours	4-6
MCRT or SRT or sludge age, (θ_c), days	5-8
Q _r /Q, Sludge return ratio, recirculation ratio	0.25-0.5
E, (efficiency), %	85-95
Kg O ₂ /kg of BOD ₅ removed	0.8-1.0

MLVSS = mixed liquor volatile suspended solids

Design an aeration tank and suggest process control parameters of an activated sludge process for treating 20,000 cum/day wastewater with influent BOD 250 mg/L. Effluent BOD should be 20 mg/L. MLVSS to be maintained is 3000 mg/L. MCRT is 7 days. Yield Coefficient is 0.6 and endogenous death rate constant, $k_d = 0.06/\text{day}$, F/M ratio = 0.4 /day. Assume that there is negligible suspended solid (microorganism) in the effluent from the secondary clarifier. Sludge return ratio = 0.2

$$E = \frac{S_0 - S}{S_0} * 100$$

$$= \frac{250 - 20}{250} * 100 = 92\%$$

$$E = U \cdot \frac{1}{F/M} * 100$$

$$92 = U \cdot \frac{1}{0.4} * 100$$

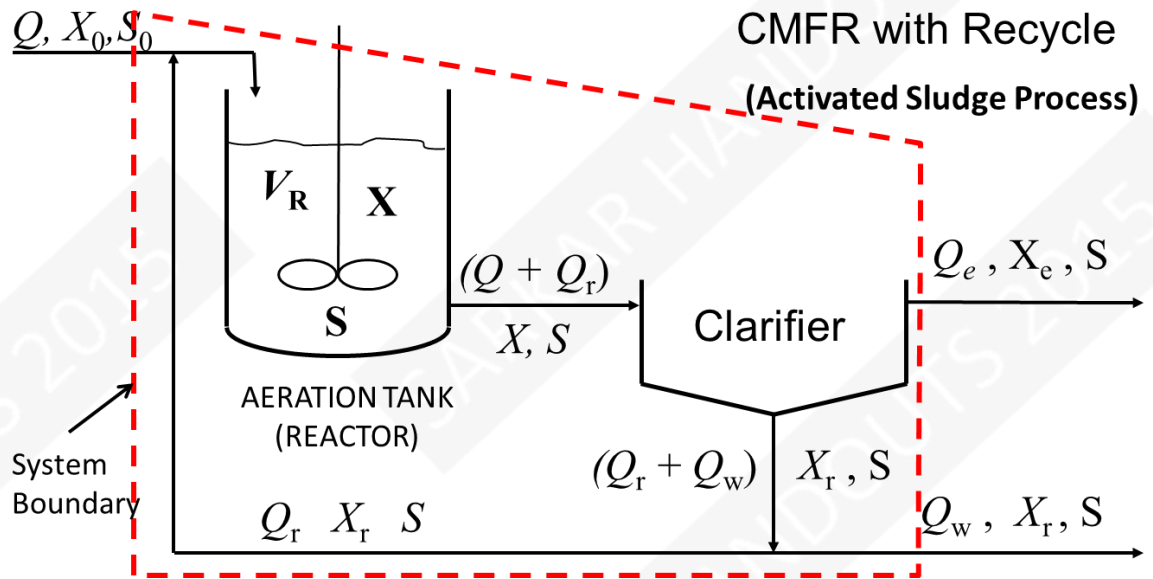
$$U = \frac{S_0 - S}{\theta X}$$

$$0.368 = \frac{250 - 20}{\theta \cdot 3000}$$

$$\theta = 0.20833 \text{ day} = 5 \text{ hours}$$

$$\theta = \frac{V_r}{Q}$$

$$V_r = Q\theta = 20,000 \text{ cum/day} * 0.20833 = 4167 \text{ cum}$$

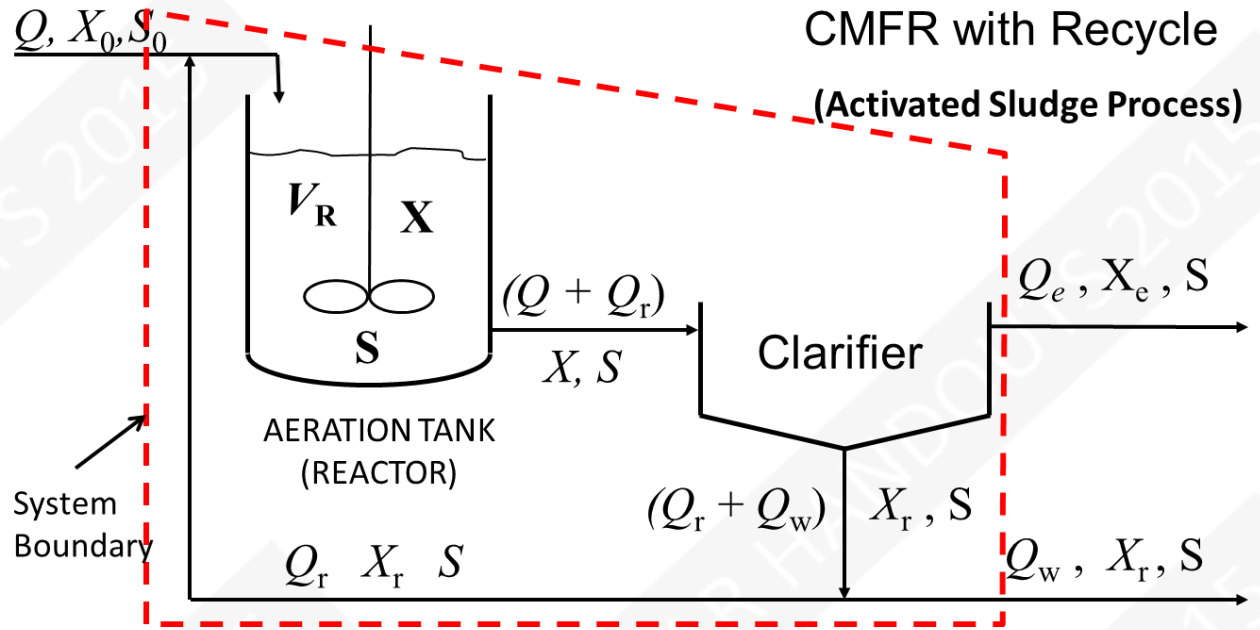


$$U = 0.368$$

$$\theta_c = \frac{V_R X}{Q_w X_r + Q_e X_e}$$

As per the problem statement the secondary clarifier have negligible SS in the effluent

System Boundary



$$\theta_c = \frac{V_R X}{Q_w X_r + Q_e X_e} \quad \begin{matrix} \nearrow \\ =0 \end{matrix}$$

$$\theta_c = \frac{V_R X}{Q_w X_r}$$

$$Q_w X_r = \frac{V_R X}{\theta_c}$$

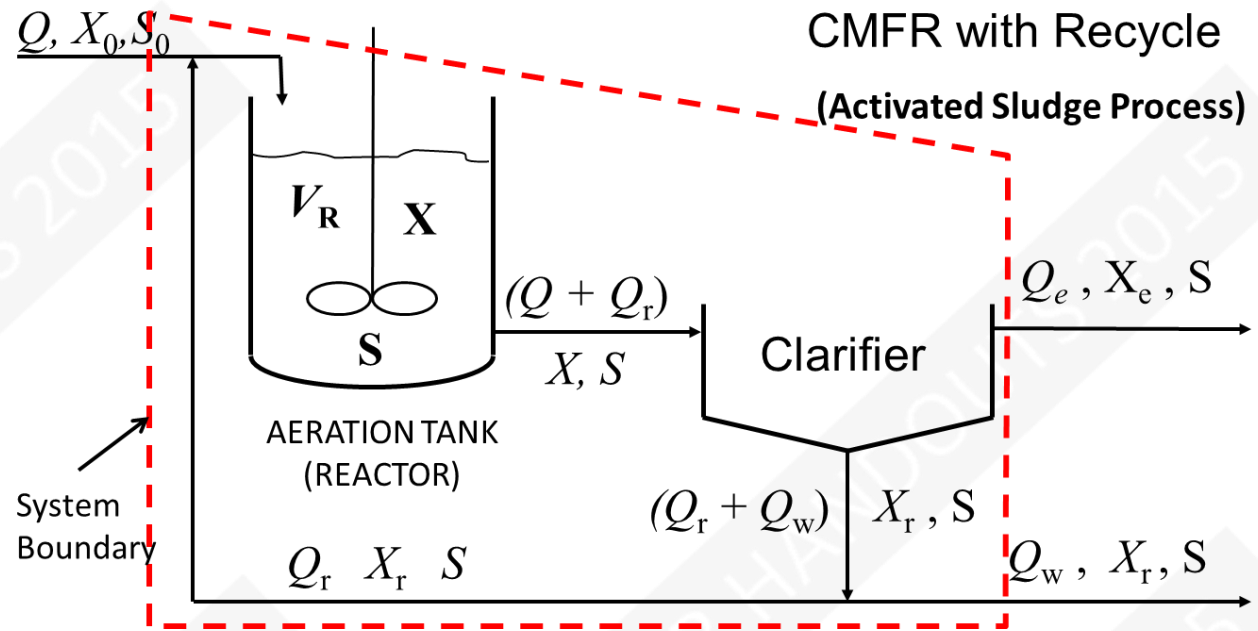
Sludge return ratio = 0.2 $\frac{Q_r}{Q} = 0.2$ $Q_r = 0.2 * Q = 0.2 * 20,000 = 4,000 \text{ cum/day}$

Microorganism balance in the clarifier

$$(Q + Q_R)X = Q_e X_e + (Q_r + Q_w)X_r \quad \begin{matrix} \nearrow \\ =0 \end{matrix}$$

$$(Q + Q_R)X = (Q_r + Q_w)X_r$$

$$(20000 + 4000) * 3000 = (4000 + Q_w)X_r$$



$$(20000 + 4000) * 3000 = (4000 + Q_w) X_r$$

$$(20000 + 4000) * 3000 = 4000 * X_r + \frac{V_R X}{\theta_c}$$

$$X_r = 17553.5 \text{ mg/L}$$

$$Q_w = \frac{V_R X}{X_r \theta_c} = 101.7 \text{ cum/day}$$

$$Q = Q_e + Q_w$$

$$Q_e = Q - Q_w = 20,000 - 100 = 19900 \text{ cum/day}$$

$$Q_r = 4000 \text{ cum/day}$$

$$Q = 20000 \text{ cum/day}$$

$$V_r = 4167 \text{ cum}$$

Find out the oxygen requirement for an activated sludge process which operates at 95% efficiency and flowrate of 30,000 cum/day. The influent BOD5 concentration is 250 mg/L. Mean cell residence time (MCRT) is kept as 7 days. The yield coefficient was found to be 0.5 kg of biomass per kg of BOD5 utilized. Endogenous growth rate constant is 0.06 per day (k_d)

$$E = \frac{S_0 - S}{S_0} * 100 \quad 95 = \frac{250 - S}{250} * 100 \quad S = 12.5 \text{ mg/L}$$

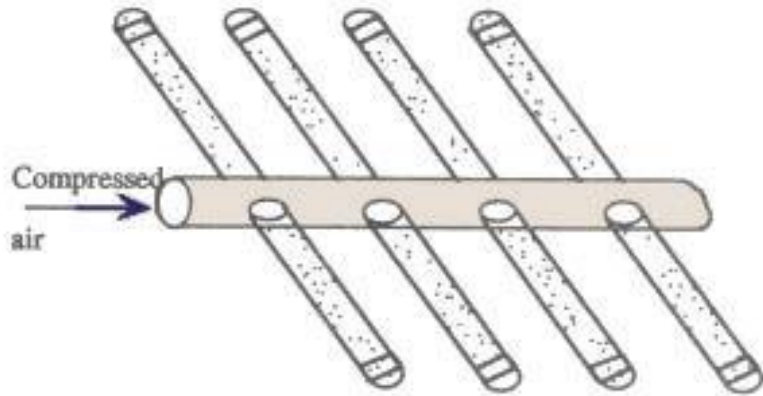
$$Y_{obs} = \frac{Y}{1 + k_d \theta_c} = \frac{0.5}{1 + 0.06 * 7} = \frac{0.5}{1 + 0.06 * 7} = 0.352$$

$$P_x = Q(S_0 - S)Y_{obs} = 30,000 * 10^3 * (250 - 12.5) * 0.352 * 10^{-6} \text{ kg/Day}$$

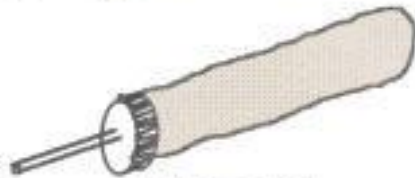
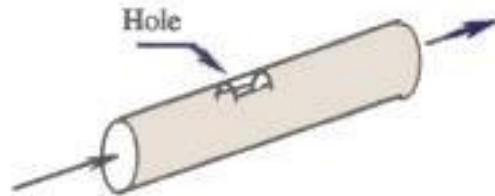
$$\begin{aligned} \text{Total Oxygen demand of the ASP process} &= \frac{Q(S_0 - S)}{f} - 1.42P_x \\ &= \frac{30,000 * 10^3 * (250 - 12.5) * 10^{-6}}{0.68} - 1.42P_x \\ &= 7969 \text{ kg/day} \end{aligned}$$

AERATION SYSTEMS FOR WASTEWATER TREATMENT

DIFFUSED AERATORS



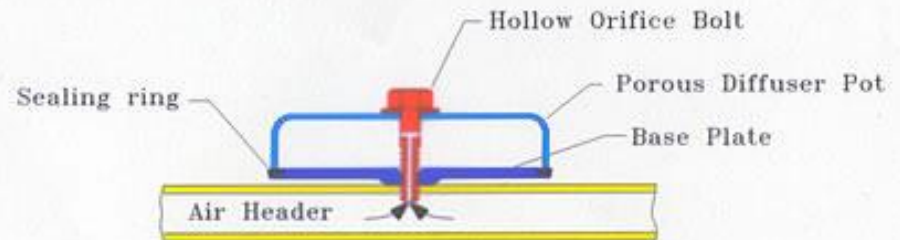
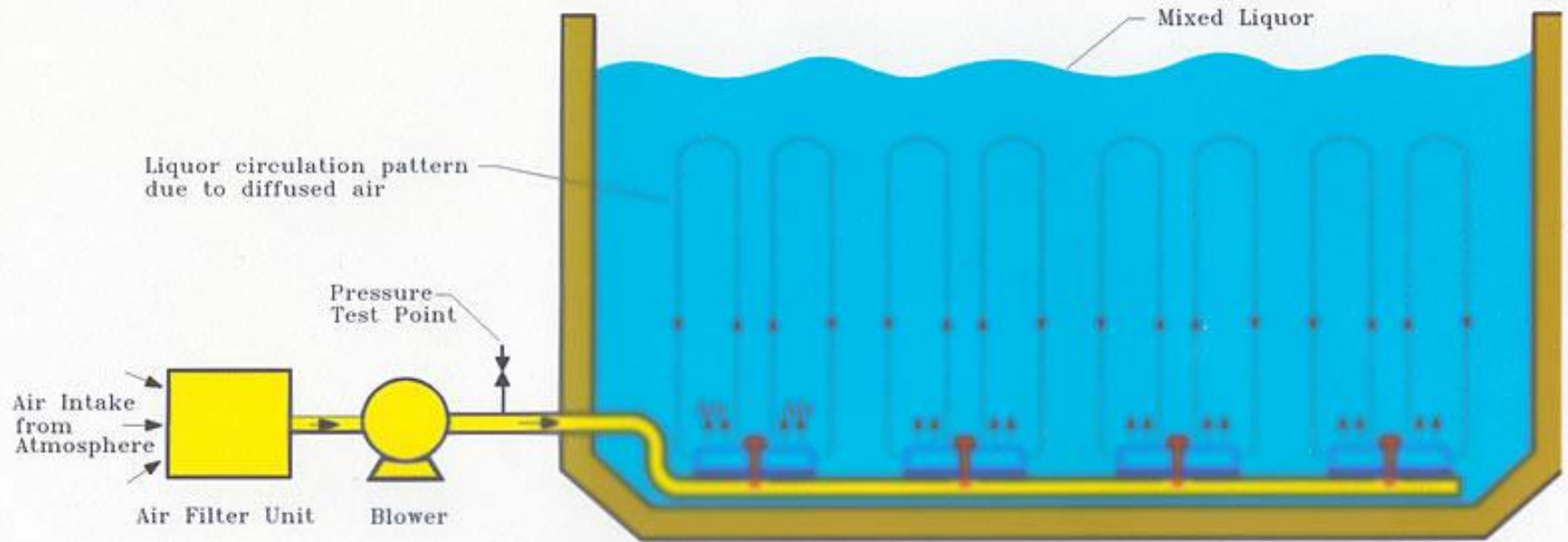
(a) Fine bubble diffuser



(b) Medium size bubble diffusers



DIFFUSED AIR SYSTEM



Enlarged Detail of Air Diffusion Assembly



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Diffused Aeration

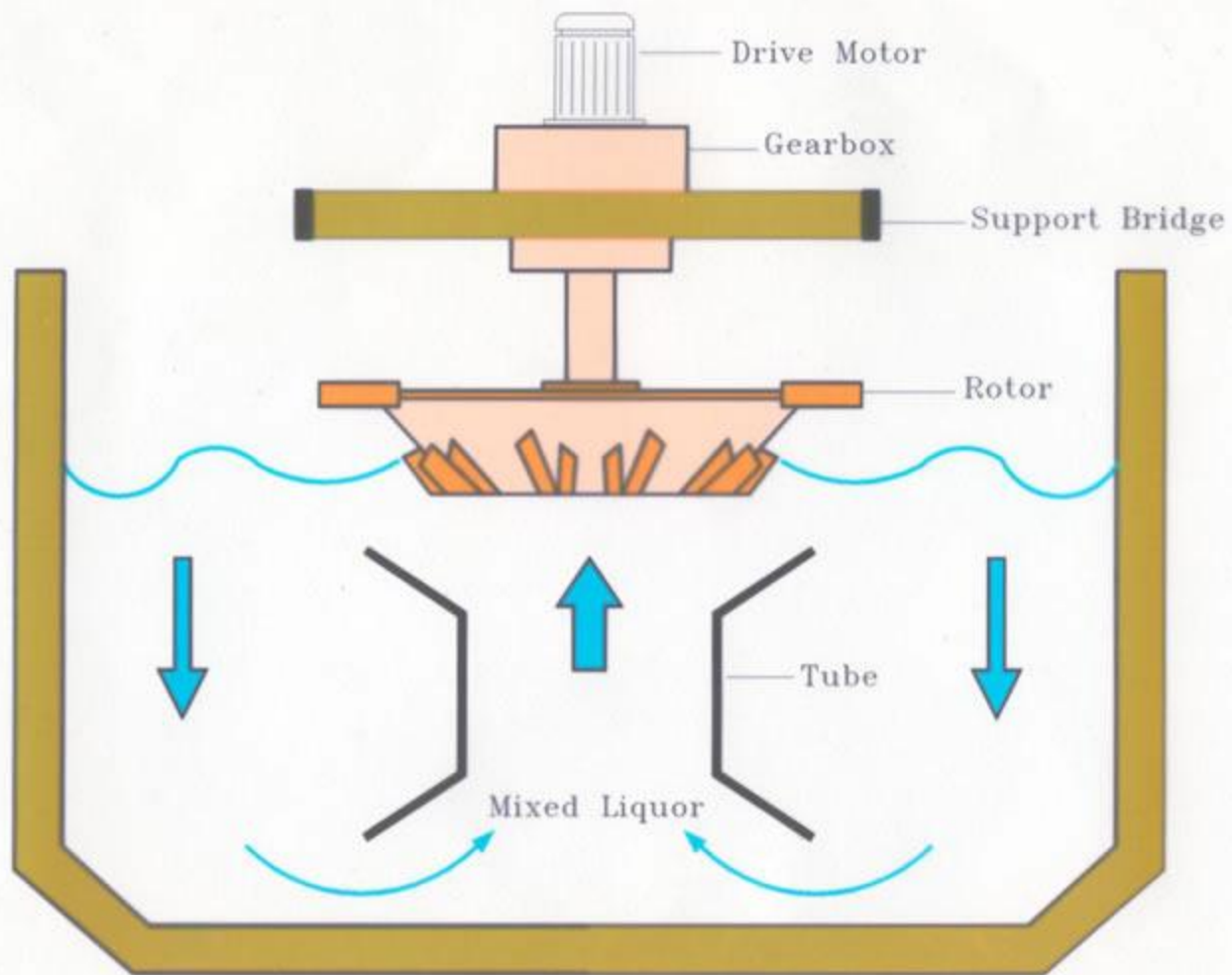




Aeration basin for activated sludge process

WTT

THE VERTICAL SHAFT ROTOR





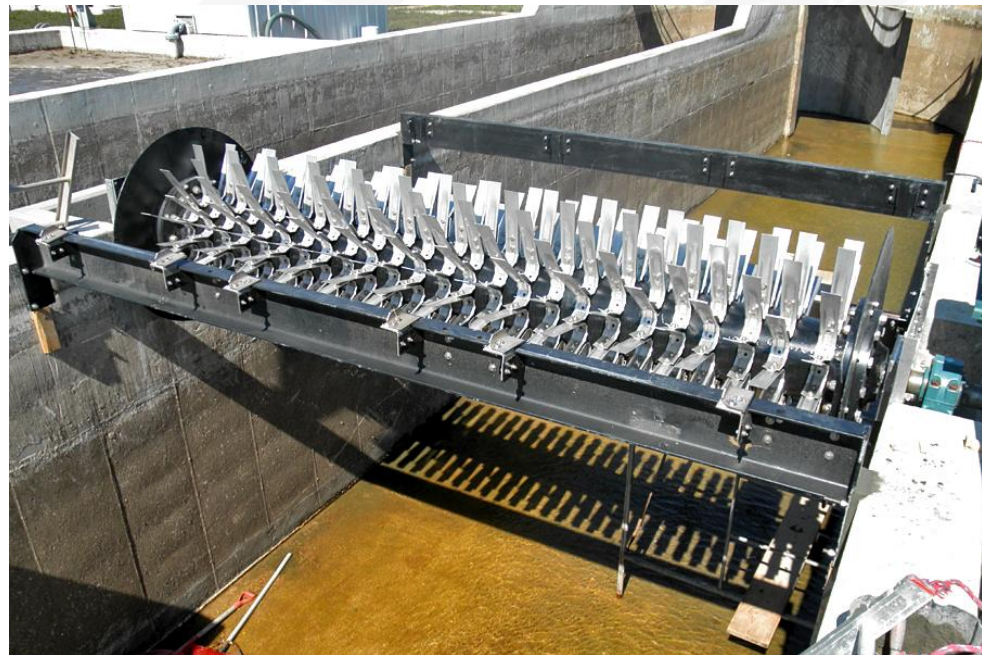




Return sludge mixing with incoming wastewater



Augurs lifting sludge coming from clarifier outlet to be returned to activated sludge treatment process.



SARKI