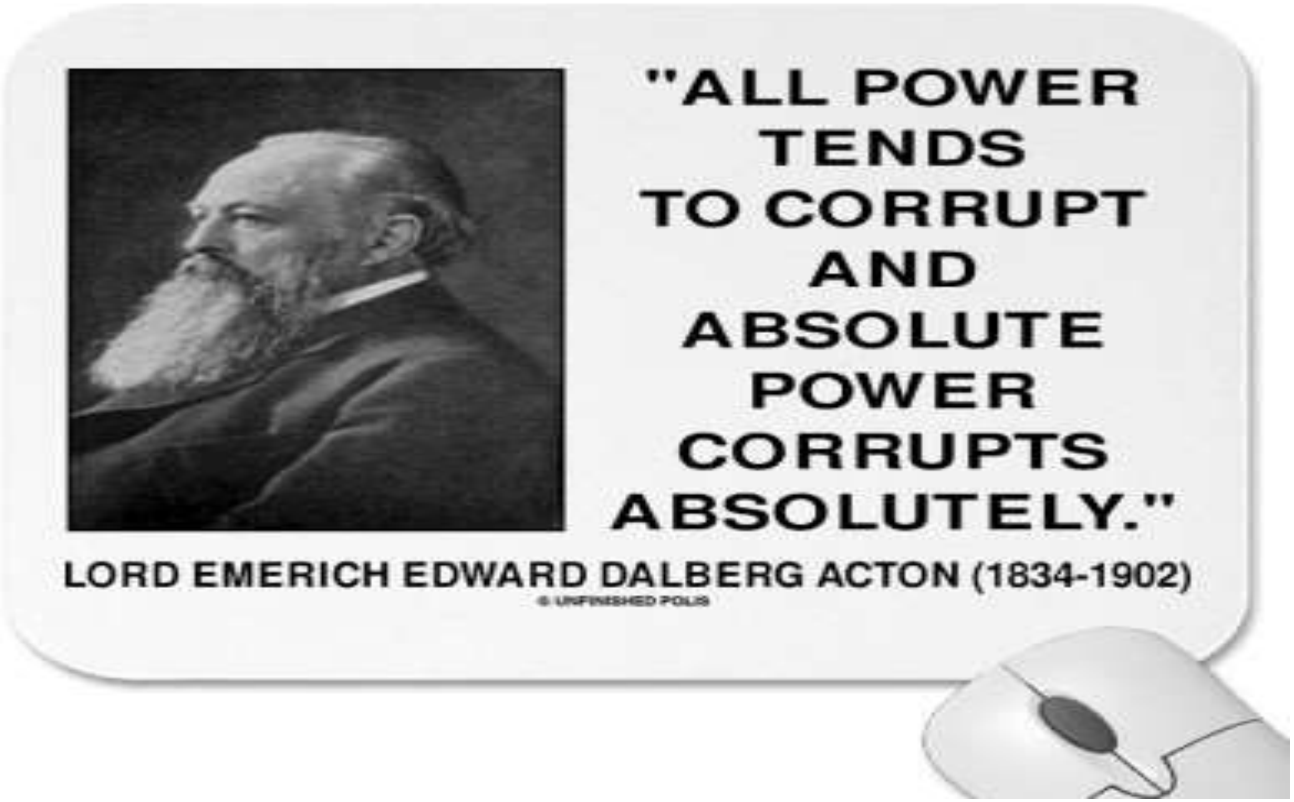
Activated Sludge Process

Thought of the Day

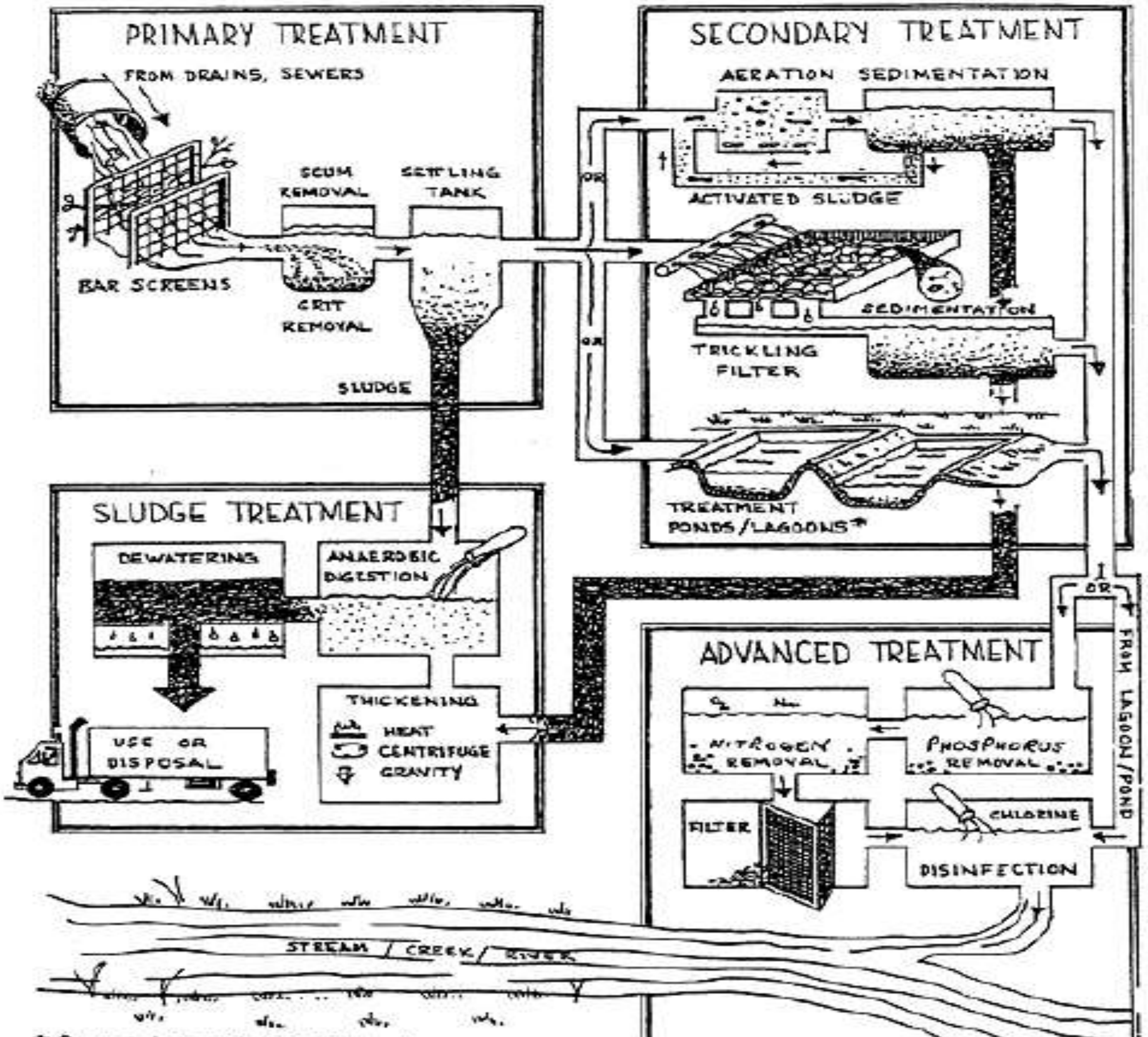


"ALL POWER TENDS TO CORRUPT AND ABSOLUTE POWER CORRUPTS ABSOLUTELY."

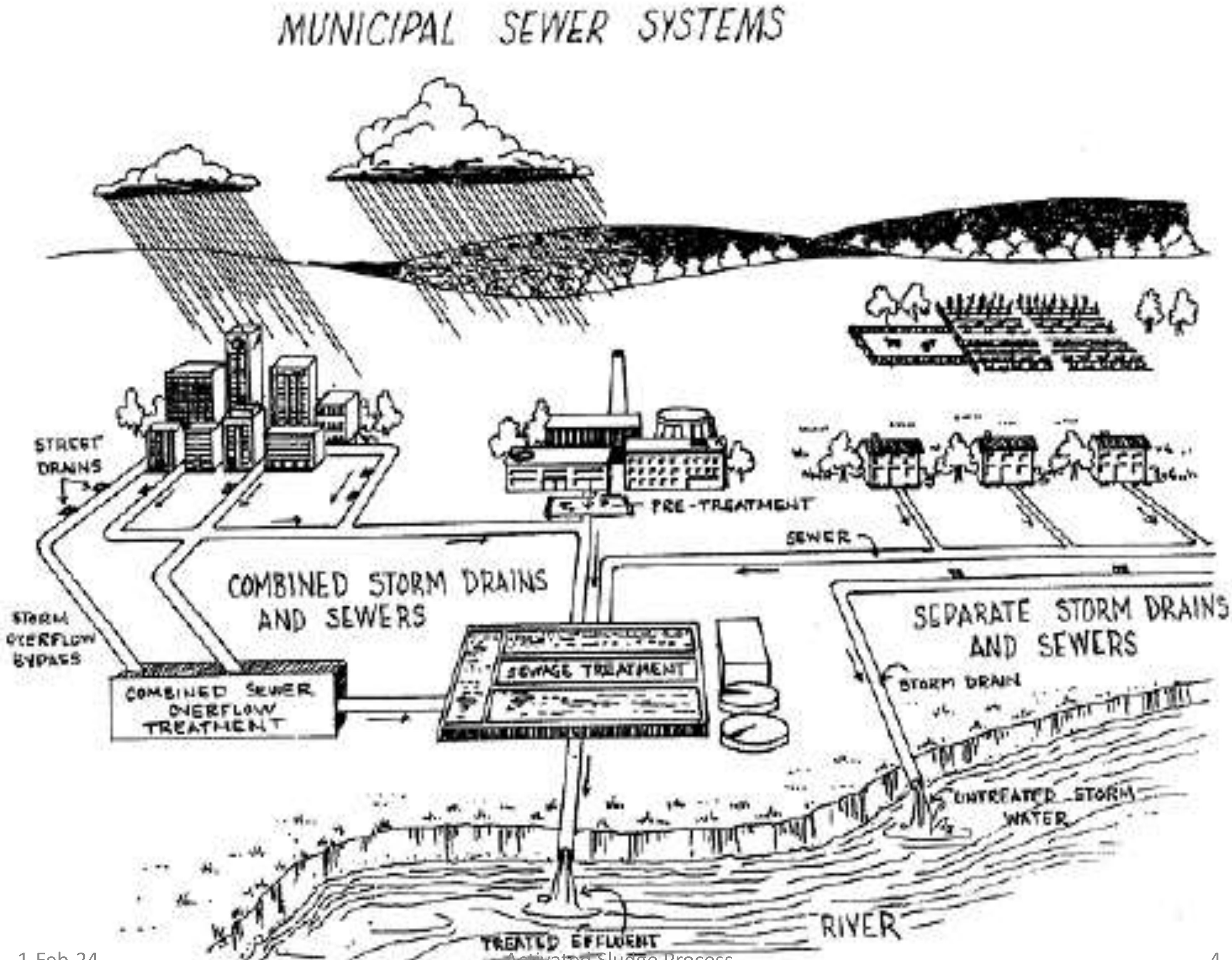
LORD EMERICH EDWARD DALBERG ACTON (1834-1902)

© UNFINISHED POLIS

TYPICAL WASTEWATER TREATMENT FACILITY



* PONDS/LAGOONS ARE DREDGED OUT ONLY WHEN SYSTEMS FAIL.


MUNICIPAL SEWER SYSTEMS
STREET DRAINS
PRE-TREATMENT
SEWER
COMBINED STORM DRAINS AND SEWERS
SEPARATE STORM DRAINS AND SEWERS
STORM OVERFLOW BYPASS
COMBINED SEWER OVERFLOW TREATMENT
SEWAGE TREATMENT
STORM DRAIN
UNTREATED STORM WATER
RIVER
TREATED EFFLUENT

Water/Wastewater Terms

activated sludge: sludge particles produced by the growth of microorganisms in aerated tanks as a part of the activated sludge process to treat wastewater

aeration: exposing to circulating air; adds oxygen to the wastewater and allows other gases trapped in the wastewater to escape (the first step in secondary treatment via activated sludge process)

biochemical oxygen demand (BOD): a laboratory measurement of wastewater that is one of the main indicators of the quantity of pollutants present; a parameter used to measure the amount of oxygen that will be consumed by microorganisms during the biological reaction of oxygen with organic material

biosolids: sludge that is intended for beneficial use. Biosolids must meet certain government specified criteria depending on its use (e.g., fertilizer or soil amendment)

Water/Wastewater Terms

decomposition: the process of breaking down into constituent parts or elements

domestic wastewater: wastewater that comes primarily from individuals, and does not generally include industrial or agricultural wastewater

effluent: treated wastewater, flowing from a lagoon, tank, treatment process, or treatment plant

grit chamber: a chamber or tank used in primary treatment where wastewater slows down and heavy, large solids (grit) settle out and are removed

influent: wastewater flowing into a treatment plant

Water/Wastewater Terms

lagoons (oxidation ponds or stabilization ponds): a wastewater treatment method that uses ponds to treat wastewater. Algae grow within the lagoons and utilize sunlight to produce oxygen, which is in turn used by microorganisms in the lagoon to break down organic material in the wastewater. Wastewater solids settle in the lagoon, resulting in effluent that is relatively well treated, although it does contain algae

municipal: of or relating to a municipality (city, town, etc.). Municipal wastewater is primarily domestic wastewater.

primary treatment: the first stage of wastewater treatment that removes settleable or floating solids only; generally removes 40% of the suspended solids and 30-40% of the BOD in the wastewater

secondary treatment: a type of wastewater treatment used to convert dissolved and suspended pollutants into a form that can be removed, producing a relatively highly treated effluent. Secondary treatment normally utilizes biological treatment processes (activated sludge, trickling filters, etc.) followed by settling tanks and will remove approximately 85% of the BOD and TSS in wastewater. Secondary treatment for municipal wastewater is the minimum level of treatment required by the EPA.

Water/Wastewater Terms

sedimentation: the process used in both primary and secondary wastewater treatment, that takes place when gravity pulls particles to the bottom of a tank (also called settling).

settling tank (sedimentation tank or clarifier): a vessel in which solids settle out of water by gravity during wastewater or drinking water treatment processes.

sludge: any solid, semisolid, or liquid waste that settles to the bottom of sedimentation tanks (in wastewater treatment plants or drinking water treatment plants) or septic tanks

tertiary treatment: any level of treatment beyond secondary treatment, which could include filtration, nutrient removal (removal of nitrogen and phosphorus) and removal of toxic chemicals or metals; also called "advanced treatment" when nutrient removal is included

Water/Wastewater Terms

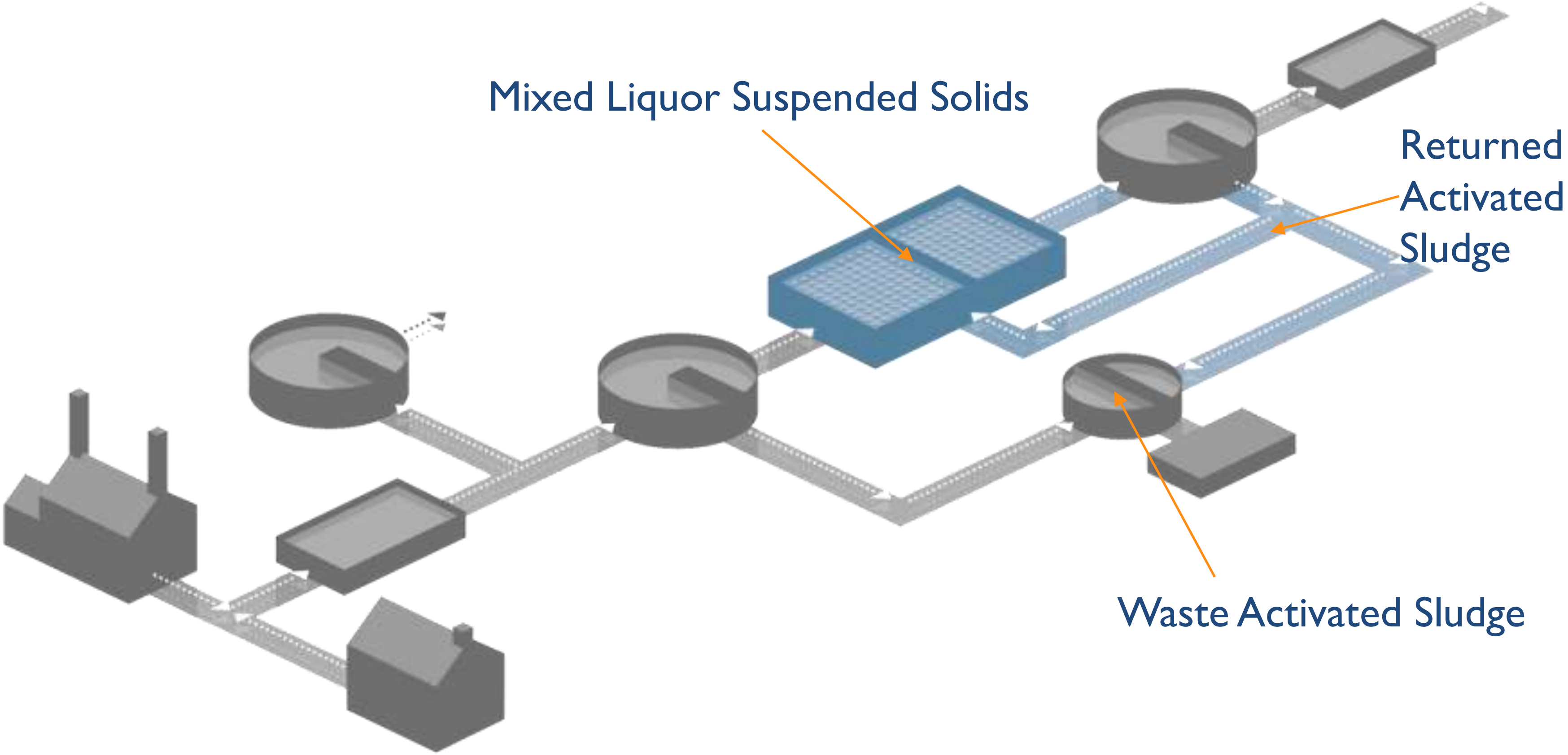
total suspended solids (TSS): a laboratory measurement of the quantity of suspended solids present in wastewater that is one of the main indicators of the quantity of pollutants present

trickling filter process: a biological treatment process that uses coarse media (usually rock or plastic) contained in a tank that serves as a surface on which microbiological growth occurs. Wastewater trickles over the media and microorganisms remove the pollutants (BOD and TSS). Trickling filters are followed by settling tanks to remove microorganisms that wash off or pass through the trickling filter media.

turbidity: the cloudy or muddy appearance of a naturally clear liquid caused by the suspension of particulate matter

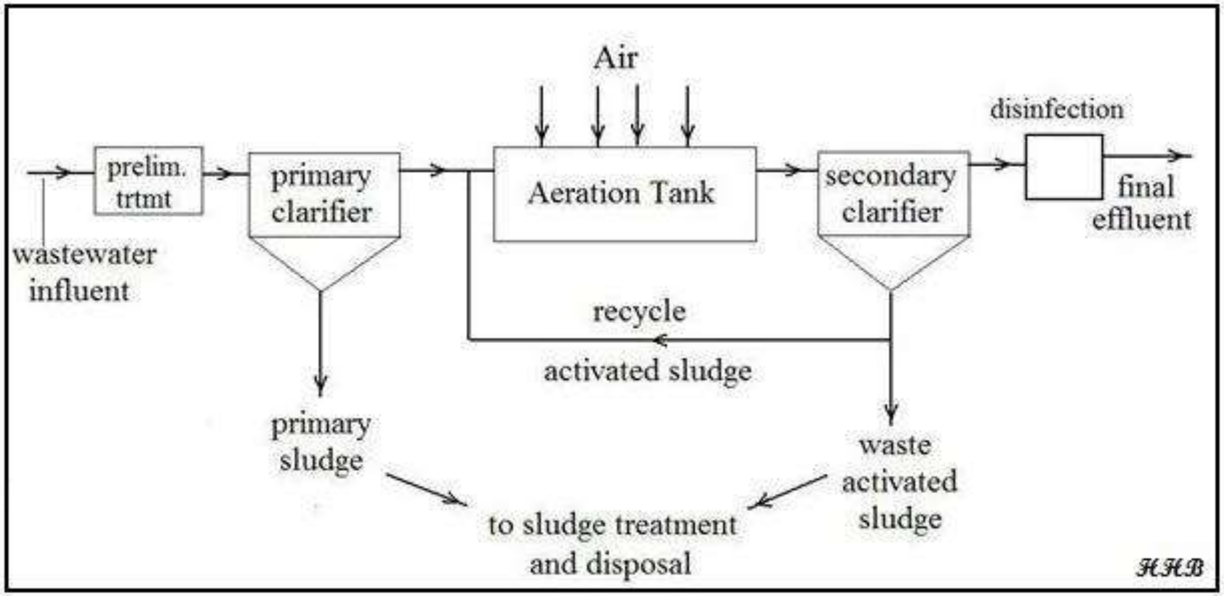
wastewater: water that has been used for domestic or industrial purposes

Activated Sludge Process



Activated Sludge Process

The most common suspended growth process used for municipal wastewater treatment is the activated sludge process



Activated Sludge Wastewater Treatment Flow Diagram

Activated Sludge Plant

Activated sludge plant involves

- wastewater aeration in the presence of a microbial suspension
- solid-liquid separation following aeration
- discharge of clarified effluent
- wasting of excess biomass
- return of remaining biomass to the aeration tank

Activated Sludge

Activated Sludge serves two purposes

1. Reducing organic matter in wastewater by using a complex biological community in the presence of oxygen and converting the organic matter to new cell mass, carbon dioxide and energy
2. Producing solids capable of bio-flocculating and settling out in the clarifier to produce and effluent low in Biochemical Oxygen Demand (BOD) and Total Suspended Solids (TSS)

The Process

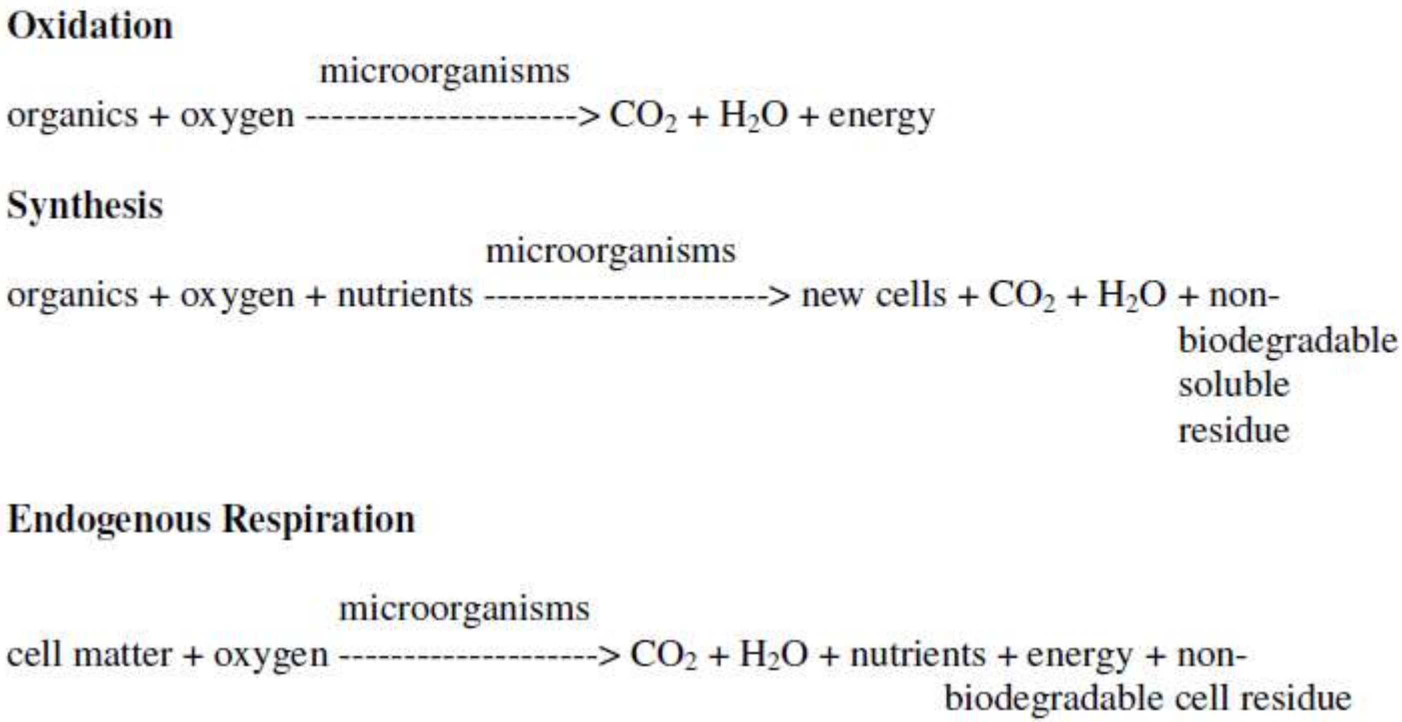
- In activated sludge process wastewater containing organic matter is aerated in an aeration basin in which micro-organisms metabolize the suspended and soluble organic matter.
- Part of organic matter is synthesized into new cells and part is oxidized to CO_2 and water to derive energy.
- In activated sludge systems the new cells formed in the reaction are removed from the liquid stream in the form of a flocculent sludge in settling tanks.
- A part of this settled biomass, described as activated sludge is returned to the aeration tank and the remaining forms waste or excess sludge

Activated Sludge Process Variables

The main variables of activated sludge process are the

- mixing regime
- loading rate
- flow scheme

Oxidation and Synthesis



Oxidation

organics + oxygen $\xrightarrow{\text{microorganisms}}$ $CO_2 + H_2O$ + energy

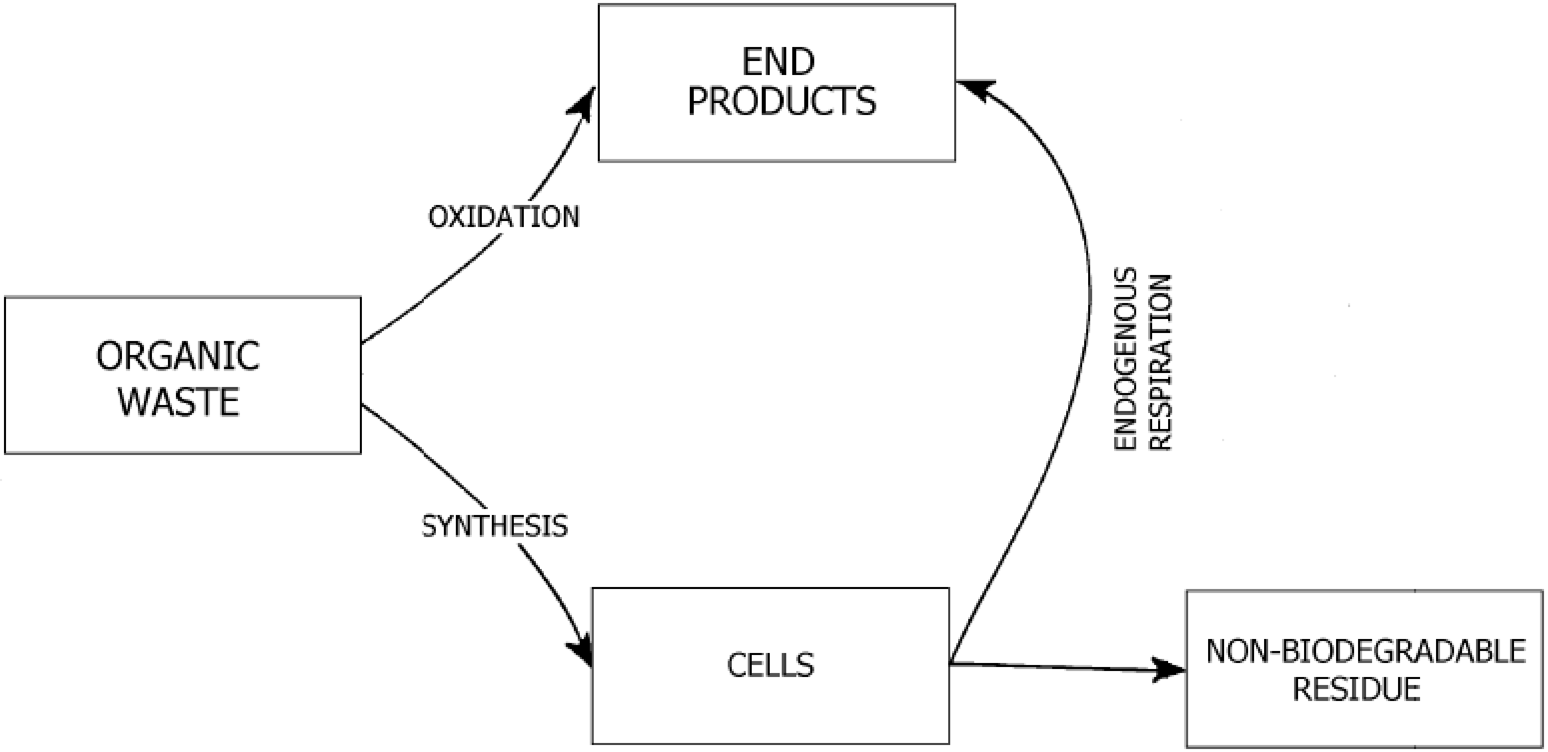
Synthesis

organics + oxygen + nutrients $\xrightarrow{\text{microorganisms}}$ new cells + $CO_2 + H_2O$ + non-biodegradable soluble residue

Endogenous Respiration

cell matter + oxygen $\xrightarrow{\text{microorganisms}}$ $CO_2 + H_2O$ + nutrients + energy + non-biodegradable cell residue

Oxidation and Synthesis



The BOD Curve

The BOD determination involves the measurement of the dissolved oxygen used by microorganisms in the biochemical oxidation of organic matter. The BOD test bottle is incubated for 5 days at 20°C. A typical BOD curve is shown in Figure. The BOD_5 of secondary effluents consists of two major components – a carbonaceous demand resulting from the oxidation of carbon and a nitrogenous demand resulting from the oxidation of nitrogen. That is,

$BOD_5 = CBOD_5 + NBOD_5$

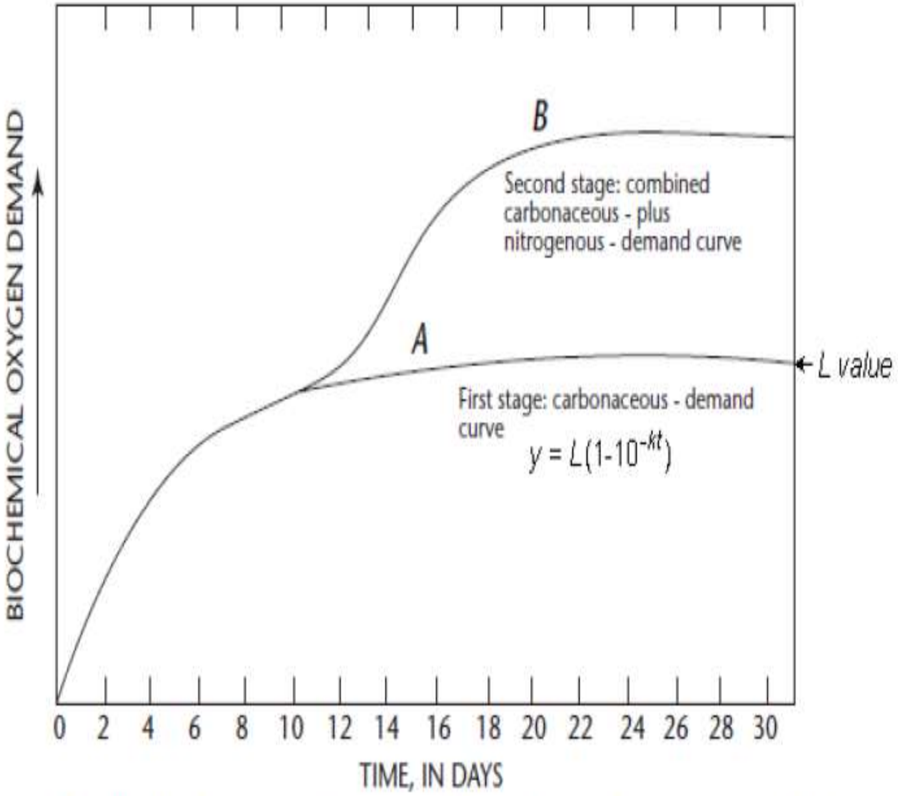


Figure P-1 The BOD curve, (a) Normal curve for oxidation of organic matter, (b) The influence of nitrification.

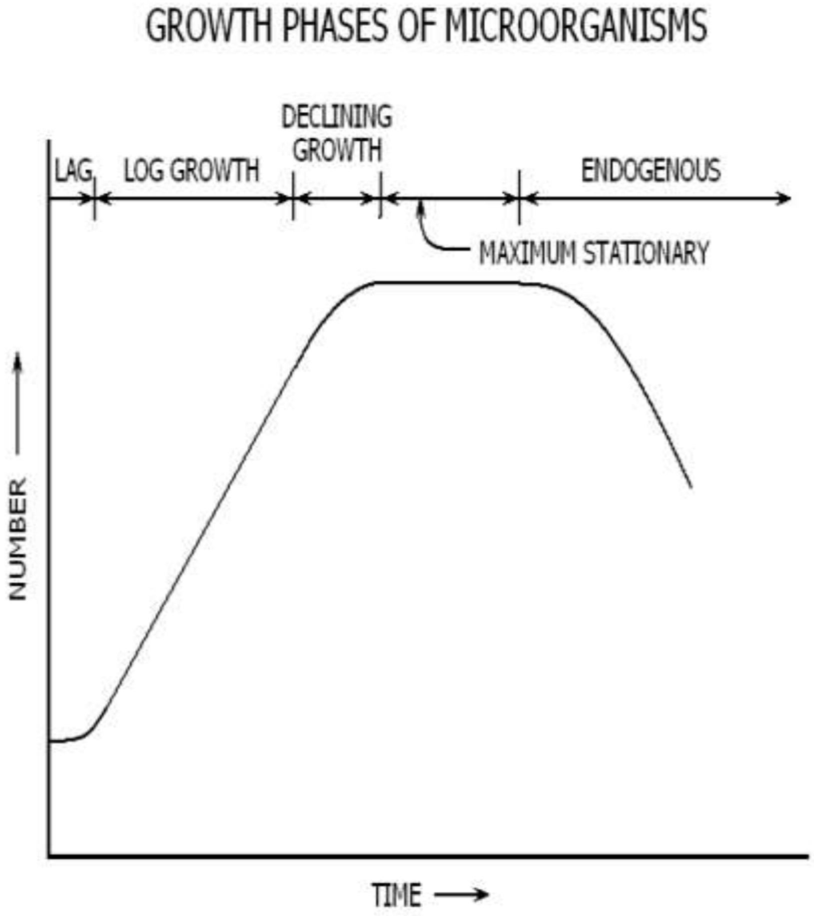
The Growth Curve

The growth curve has five distinct phases

These are:

1. Adaptation (Lag) Phase – This portion of the curve represents the time required for the organisms to acclimate themselves to the organic material present in the wastewater. The numbers of bacteria are not increasing, however, a shift in the population of the different species of bacteria in the wastewater is occurring so that the bacteria that can best utilize these organic materials become predominate.

2. Log Growth Phase – Once the bacteria have "adapted", only the number of organisms present limit the rate of growth. Because bacterial cells reproduce by binary fission (i.e., cell division – one cell divides and becomes two, these two divide and become four, then eight, sixteen …), this is known as logarithmic growth. Food is not a limiting factor for growth in this phase, that is, for each cell formed enough food is present to allow it to grow and divide.

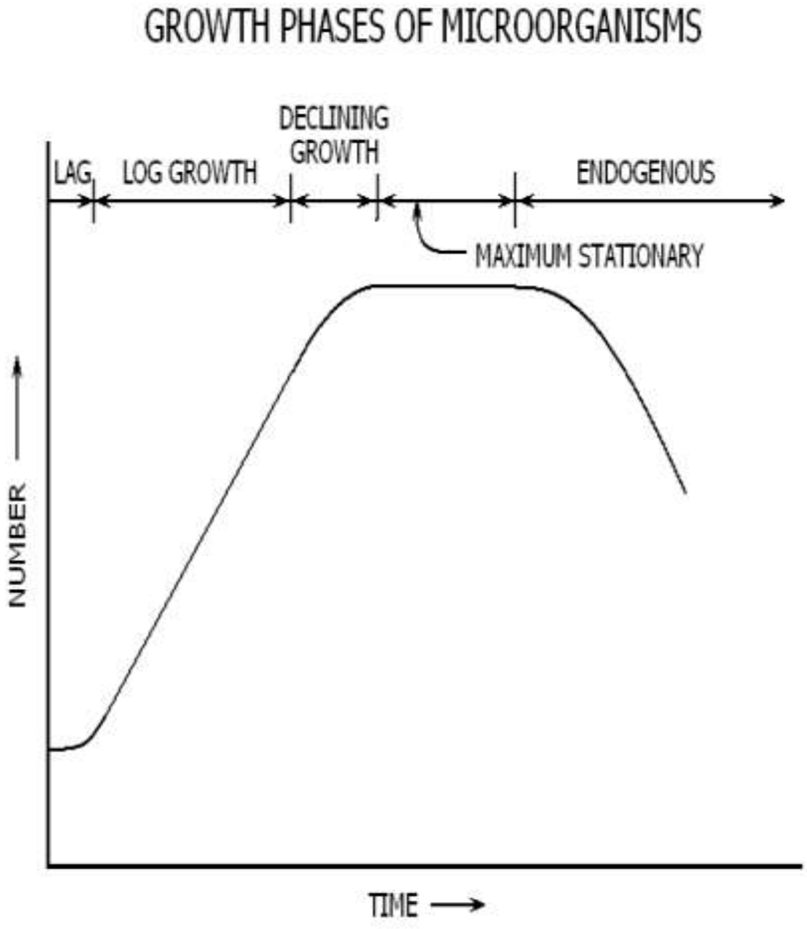


The Growth Curve

3. Declining Growth Phase – In this phase food becomes a limiting factor to the growth of the bacterial cell mass because not every bacterium that is formed has the food required to grow.

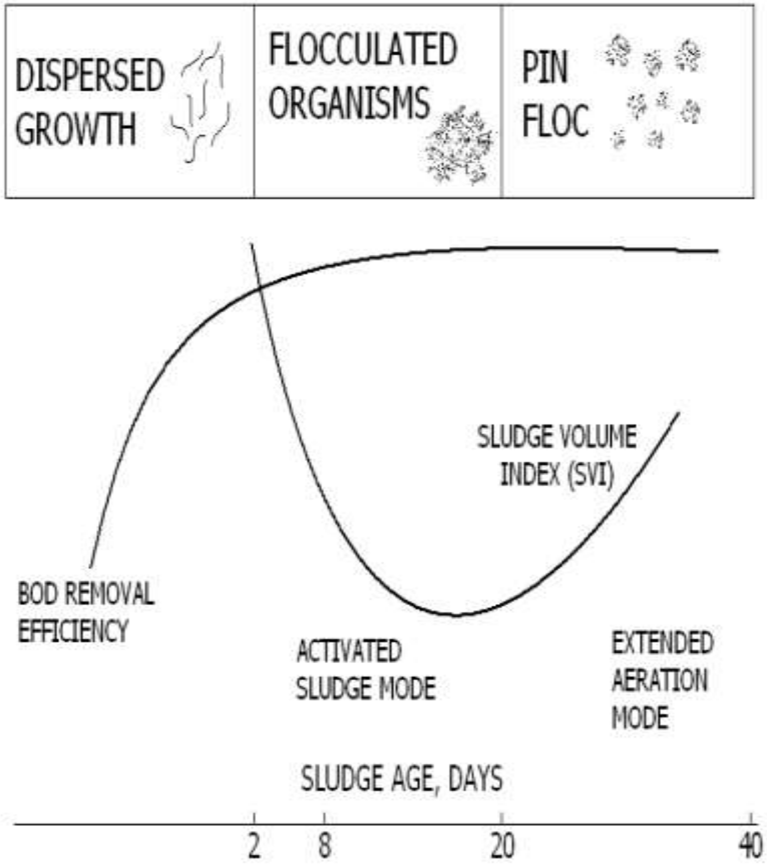
4. Maximum Stationary Phase – Here the available food is just sufficient to keep the cell mass at a constant level with a rate of growth equal to zero.

5. Endogenous (Cell Death) Phase – When the supply of food becomes insufficient to maintain the bacterial mass at a constant level, the microorganisms are forced to metabolize their own protoplasm.



Sludge Age

Therefore, an optimum "sludge age" exists which provide an adequate separation of the cell mass from the liquid. For a specific system the optimum sludge age can be determined by plotting the sludge volume index (SVI) versus the sludge age



Activated Sludge

The basic activated sludge process has several interrelated components. These components are

1. aeration tank
2. aeration source
3. clarifier
4. recycle
5. waste

Activated Sludge

Aeration tank. A single tank or multiple tanks designed generally for either complete mix or plug flow with a detention time of as little as 2 hours and up to over 24 hours. The contents of the aeration tank are referred to as mixed liquor.

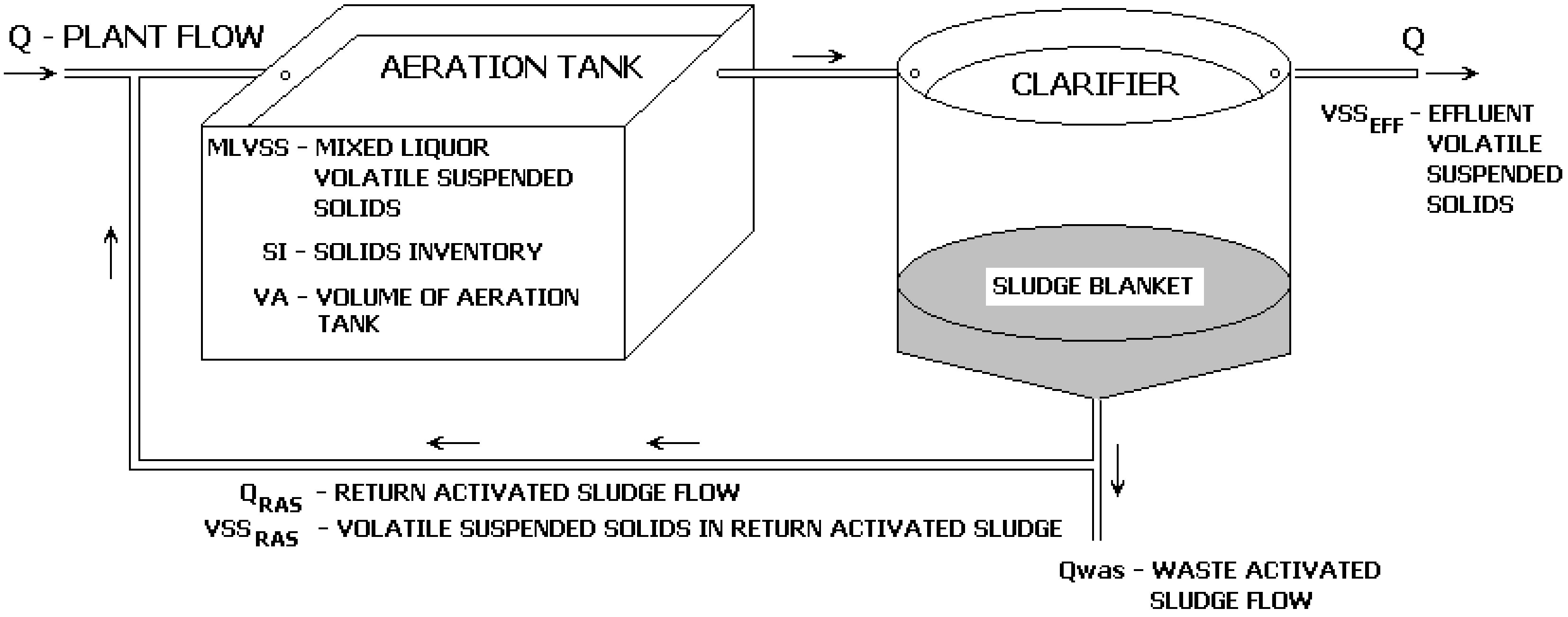
Aeration source. Generally either diffused air or surface mechanical aeration used to supply oxygen and mix the aeration tank contents.

Clarifier. A settling tank where the mixed liquor solids are separated from the treated wastewater. Most treatment plants employ several secondary clarifiers.

Recycle. Solids that settle in the clarifier and are returned to the aeration tank.

Waste. Excess solids that must be removed from the system.

Activated Sludge Flow Diagram

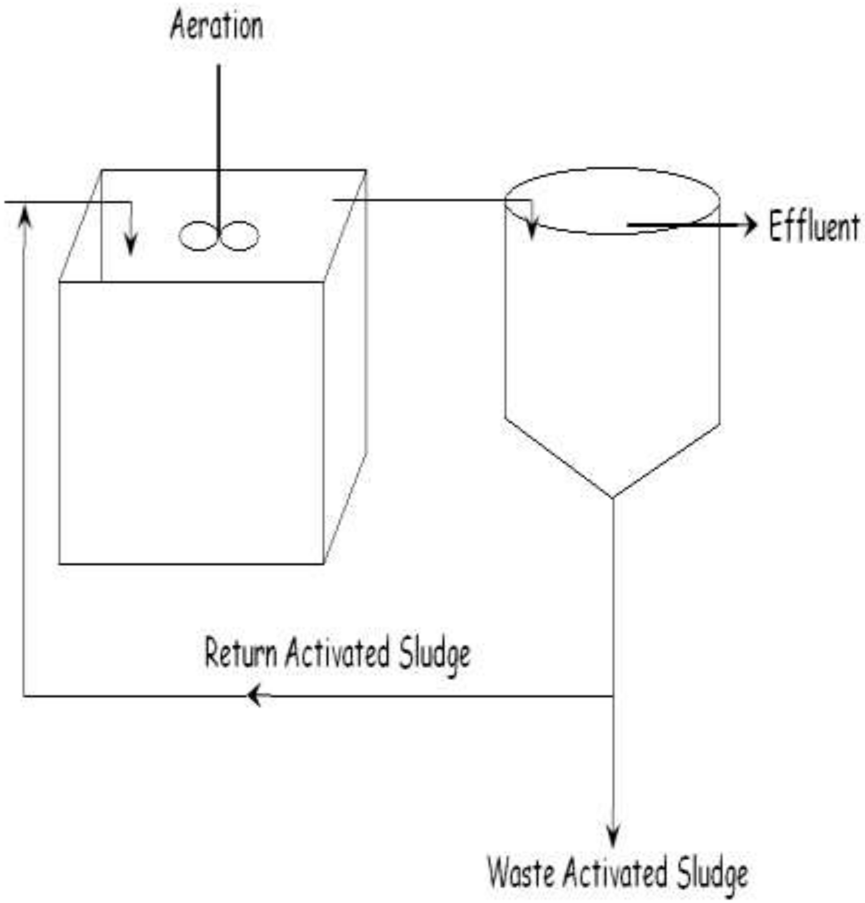


Activated Sludge

A typical activated sludge plant identifies the three major control mechanism for the activated sludge treatment process

1. aeration rate
2. return sludge rate
3. waste sludge rate

Control of three variables in addition to providing the proper environment (physical, chemical, biological and nutritional requirements) all lead to good sludge quality



Mixed Liquor Suspended Solids MLSS

- The combination of raw sewage and biological mass is commonly known as Mixed Liquor.
- In all activated sludge plants, once the sewage (or industrial wastewater) has received sufficient treatment, excess mixed liquor is discharged into settling tanks and the treated supernatant is run off to undergo further treatment before discharge.
- Part of the settled material, the sludge (RAS), is returned to the head of the aeration system to re-seed the new sewage entering the tank.
- Mixed Liquor is a mixture of raw or settled wastewater and activated sludge within an aeration tank in the activated sludge process
- Mixed Liquor Suspended Solids (MLSS) is the concentration of suspended solids in the mixed liquor, usually expressed in milligrams per litre (mg/l)

Why Measure MLSS

- If MLSS content is too high
  - The process is prone to bulking and the treatment system becomes overloaded
  - This can cause the dissolved oxygen content to drop with the effect that organic matters are not fully degraded and biological 'die off'
  - Excessive aeration required which wastes electricity
- If MLSS content is too low
  - The process is not operating efficiently and is wasting energy
- Typcial Control band
  - 2,000 to 4,000 mg/l

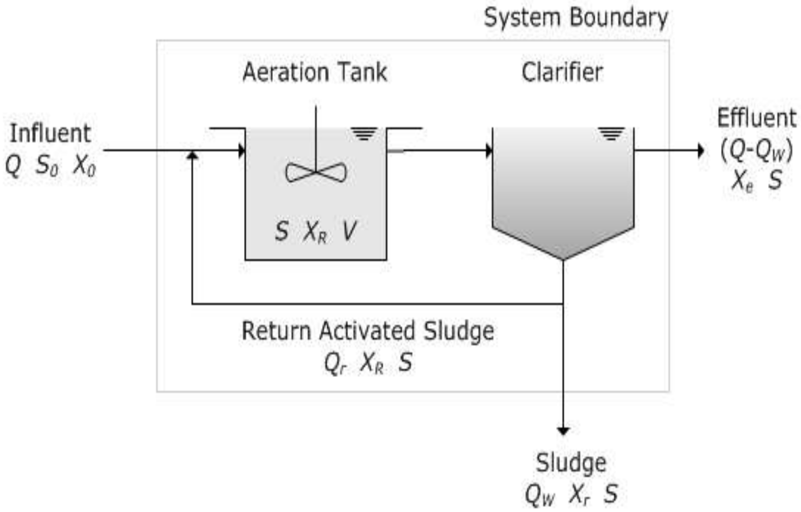
RAS and WAS

- A proportion of the floc is called Return Activated Sludge (R.A.S.) and is used to re-seed the process.
- Measuring the solids concentration of RAS allows the return volume to be adjusted to keep the solids level in the aeration basin within the control parameters
- Excess sludge which eventually accumulates beyond that returned is defined as Surplus or Waste Activated Sludge (SAS/WAS)
- This is removed from the treatment process to keep the ratio of biomass to food supplied (sewage or wastewater) in balance
- Typical Range
  - 4,000 to 6,000 mg/l

Activated Sludge Parameters

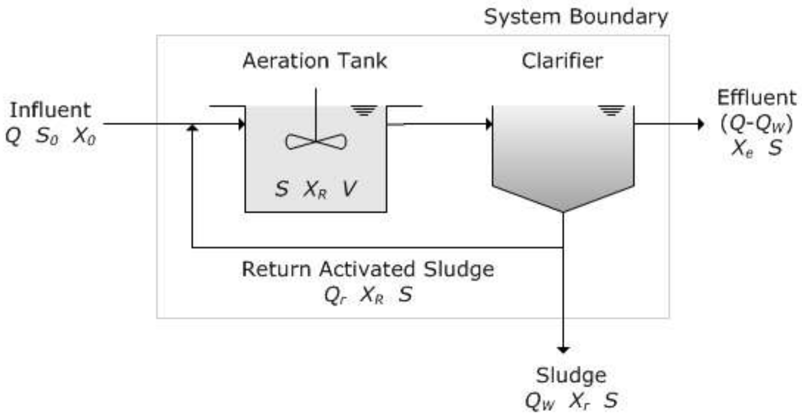
The parameters in the diagram and a few others that will be used for the activated sludge calculations are summarized in the list below.

- primary effluent flow rate, **Q_o**, MGD (m/day for S.I.)
- primary effluent biochemical oxygen demand (BOD) concentration, **S_o**, mg/L (g/m^3 for S.I.)
- primary effluent suspended solids conc., **X_o**, mg/L (g/m^3 for S.I.)
- aeration tank volume, **V**, ft^3 (m^3 for S.I.)
- aeration tank MLSS (suspended solids conc.), **X**, mg/L (g/m^3 for S.I.)
- secondary effluent flow rate, **Q_e**, MGD, (m^3/day for S.I.)
- secondary effluent susp.solids conc., **X_e**, mg/L (g/m^3 for S.I.)

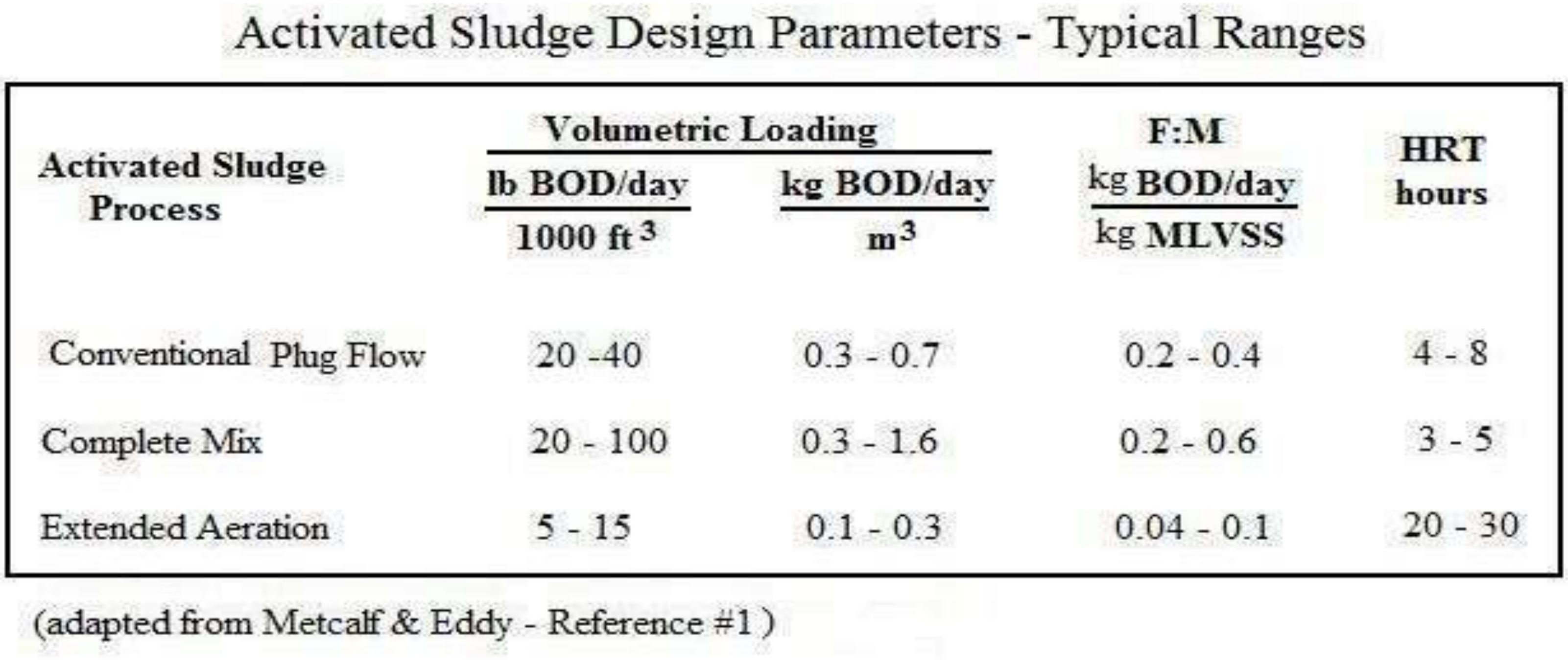


Activated Sludge Parameters

- secondary effluent biochemical oxygen demand (BOD) concentration, **S_e**, mg/L (g/m^3 for S.I.)
- waste activated sludge flow rate, **Q_w**, MGD (m^3/day for S.I.)
- waste activated sludge biochemical oxygen demand (BOD) conc., **S_w**, mg/L (g/m^3 for S.I.)
- waste activated sludge susp. solids conc., **X_w** mg/L (g/m^3 for S.I.)
- recycle activated sludge flow rate, **Q_r**, MGD (m^3/day for S.I.)
- Food to Microorganism ratio, **F:M**, lb BOD/day/lb MLVSS (kg BOD/day/kg MLVSS)
- Hydraulic retention time, **HRT**, hours (hours for S.I.)
- Sludge retention time (also called sludge age), **SRT**, days (days for S.I.)
- Volumetric loading, **VL**, lb BOD/day/1000 ft^3 (kg BOD/day/m^3 for S.I.)
- % volatile solids in the aeration tank mixed liquor suspended solids, **%Vol**.



Activated Sludge Design Parameters



Activated Sludge Design Parameters - Typical Ranges

Activated Sludge Process	Volumetric Loading		F:M	HRT hours
	$\frac{\text{lb BOD/day}}{1000\ \text{ft}^3}$	$\frac{\text{kg BOD/day}}{\text{m}^3}$	$\frac{\text{kg BOD/day}}{\text{kg MLVSS}}$	
Conventional Plug Flow	20 -40	0.3 - 0.7	0.2 - 0.4	4 - 8
Complete Mix	20 - 100	0.3 - 1.6	0.2 - 0.6	3 - 5
Extended Aeration	5 - 15	0.1 - 0.3	0.04 - 0.1	20 - 30

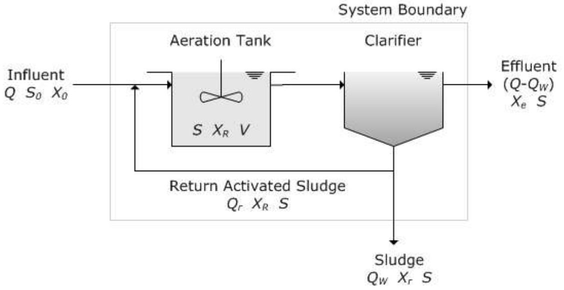
(adapted from Metcalf & Eddy - Reference #1)

Calculations

NOTE: F:M values will be the same for units of lb BOD/day/lb MLVSS. Calculations with these design parameters can be made in U.S. units using the following equations:

- $V = [\,(8.34 * S_o * Q_o)/VL\,]\,(1000)$
- $V_{MG} = V * 7.48/1{,}000{,}000$
- $HRT = 24 * V_{MG}/Q_o$
- $F{:}M = (8.34 * S_o * Q_o)/(8.34\%Vol * X * V_{MG})$

  $= (S_o * Q_o)/(\%Vol * X * V_{MG})$



V_{MG} is the tank volume in millions of gallons.

It is introduced for convenience in calculations, since the primary effluent flow rate is given in MGD.

The 8.34 factor in the equations above is used to convert mg/L to lb/MG, and the 7.48 is for conversion of ft^3 to gallons.

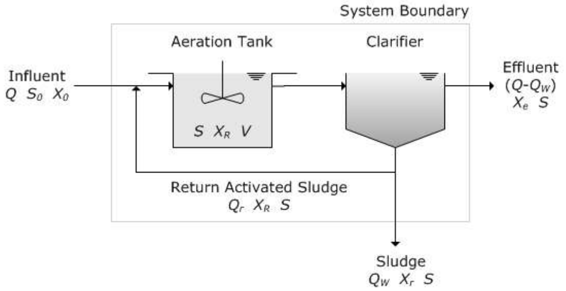
Also, note that the primary sludge flow rate is typically very small in comparison with the influent wastewater flow rate, so the primary effluent flow rate, Q_o, is typically taken to be equal to the plant influent flow rate.

Example # 1

Example #1: Calculate the aeration tank volume requirement for a conventional activated sludge plant treating a daily average flow rate of 3.5 MGD, with primary effluent BOD estimated to be 175 mg/L. The design criterion is to be a volumetric loading rate of 30 lb BOD/day/1000 ft^3.

Solution: The required volume can be calculated from the first equation in the list above:

$$\mathbf{V} = [\ (8.34^*\mathbf{S_o}^*\mathbf{Q_o})/\mathbf{VL}\ ]\ (1000) \ = \ 8.34^*175^*3.5^*1000/30 \ = \ \underline{\mathbf{170{,}275\ ft^3}}$$



Example # 2

Example #2: For an assumed aeration tank MLSS of 2100 mg/L and assumed % volatile MLSS of 75%, what would be the aeration tank F:M ratio and hydraulic residence time for the plant inflow and aeration tank volume from Example #1?

Solution: The HRT and F:M ratio can be calculated using the last three equations in the list above, as follows:

$\mathbf{V_{MG}} = \mathbf{V}*7.48/1{,}000{,}000 = 170{,}275*7.48/1{,}000{,}000 = 1.27\ \text{MG}$

$\mathbf{HRT} = 24*\mathbf{V_{MG}}/\mathbf{Q_o} = 24*1.27/3.5 =$ **<u>8.7 hours</u>**

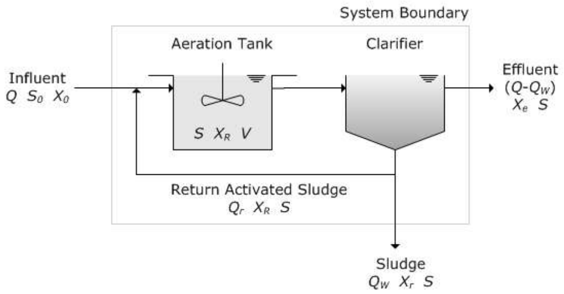
$\mathbf{F{:}M} = (8.34*\mathbf{S_o}*\mathbf{Q_o})/(8.34*\mathbf{\%Vol}*\mathbf{X}*\mathbf{V_{MG}}) = (175*3.5)/(0.75*2100*1.27)$

= **<u>0.31 lb BOD/day/lb MLVSS</u>**

Calculations in S.I. Units

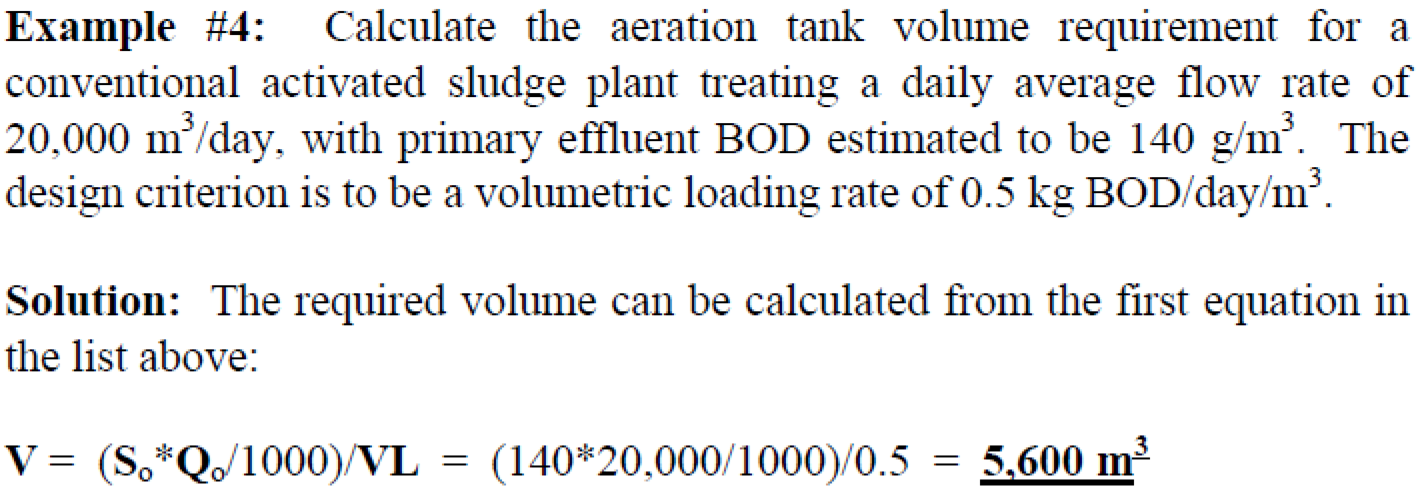
Calculations in S.I. units can be made using the following equations:

- $V = (S_o*Q_o/1000)/VL$
- $HRT = 24*V/Q_o$
- $F:M = (S_o*Q_o)/(\%Vol*X*V)$



The equations are slightly simpler, because the S.I system doesn't have a strange volume unit like the gallon! The S.I. units for all of the parameters are given in the long list above. Note that the S.I. concentration unit g/m^3 is numerically equal to mg/L.

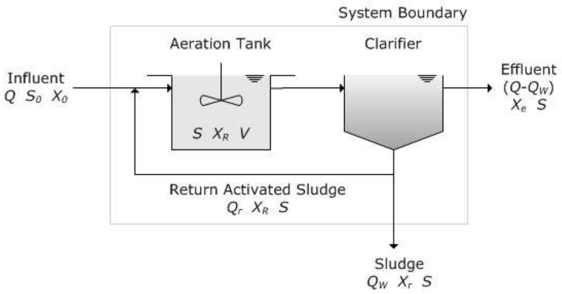
Example # 4



Example #4: Calculate the aeration tank volume requirement for a conventional activated sludge plant treating a daily average flow rate of 20,000 m^3/day, with primary effluent BOD estimated to be 140 g/m^3. The design criterion is to be a volumetric loading rate of 0.5 kg BOD/day/m^3.

Solution: The required volume can be calculated from the first equation in the list above:

$$\mathbf{V} = (S_o * Q_o/1000)/\mathbf{VL} = (140*20{,}000/1000)/0.5 = \underline{\mathbf{5{,}600\ m^3}}$$



Example # 5

Example #5: For an assumed aeration tank MLSS of 2100 mg/L and assumed % volatile MLSS of 75%, what would be the aeration tank F:M ratio and hydraulic residence time for the plant inflow and aeration tank volume from Example #3?

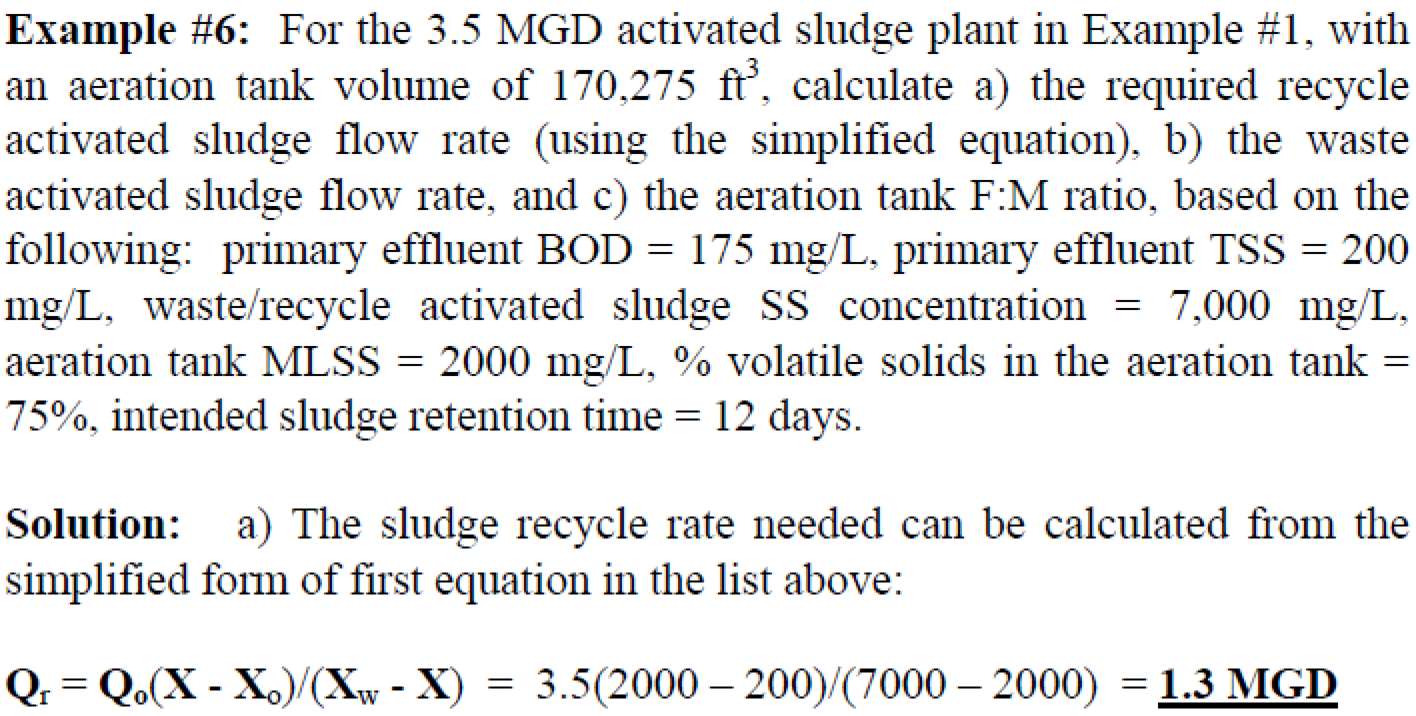
Solution: The HRT and F:M ratio can be calculated using the last two equations in the list above, as follows:

$$\mathbf{HRT} = 24{*}\mathbf{V}/\mathbf{Q_o} = 24{*}5{,}600/20{,}000 = \underline{\mathbf{6.7\ hr}}$$

$$\mathbf{F{:}M} = (S_o{*}Q_o)/(\%Vol{*}X{*}V) = (140{*}20{,}000)/(0.75{*}2100{*}5600)$$

$$= \underline{\mathbf{0.32\ kg\ BOD/day/kg\ MLVSS}}$$

Example # 6



Example #6: For the 3.5 MGD activated sludge plant in Example #1, with an aeration tank volume of 170,275 ft^3, calculate a) the required recycle activated sludge flow rate (using the simplified equation), b) the waste activated sludge flow rate, and c) the aeration tank F:M ratio, based on the following: primary effluent BOD = 175 mg/L, primary effluent TSS = 200 mg/L, waste/recycle activated sludge SS concentration = 7,000 mg/L, aeration tank MLSS = 2000 mg/L, % volatile solids in the aeration tank = 75%, intended sludge retention time = 12 days.

Solution: a) The sludge recycle rate needed can be calculated from the simplified form of first equation in the list above:

$$\mathbf{Q_r = Q_o(X - X_o)/(X_w - X)} = 3.5(2000 - 200)/(7000 - 2000) = \underline{\mathbf{1.3\ MGD}}$$

Example # 6

b) The waste activated sludge flow rate needed to give SRT = 12 days can be calculated from the second and third equations in the list above:

$\mathbf{V_{MG}} = \mathbf{V}*7.48/1{,}000{,}000 = 170{,}275*7.48/1{,}000{,}000 = 1.27$ million gallons

$\mathbf{Q_w} = \mathbf{(V_{MG}*X)/(SRT*X_w)} = (1.27*2000)/(12*7000) =$ **0.030 MGD**

or **30,000 gal/day**

c) The aeration tank F:M ratio can be calculated using the last equation in the list above together with the equation for $\mathbf{V_{MG}}$:

$\mathbf{V_{MG}} = \mathbf{V}*7.48/1{,}000{,}000 = 170{,}275*7.48/1{,}000{,}000 = 1.27$ million gallons

$\mathbf{F{:}M} = \mathbf{(S_o*Q_o)/(\%Vol*X*V_{MG})} = (175*3.5)/(0.75*2000*1.27)$

= **0.32 lb BOD/day/lb MLVSS**

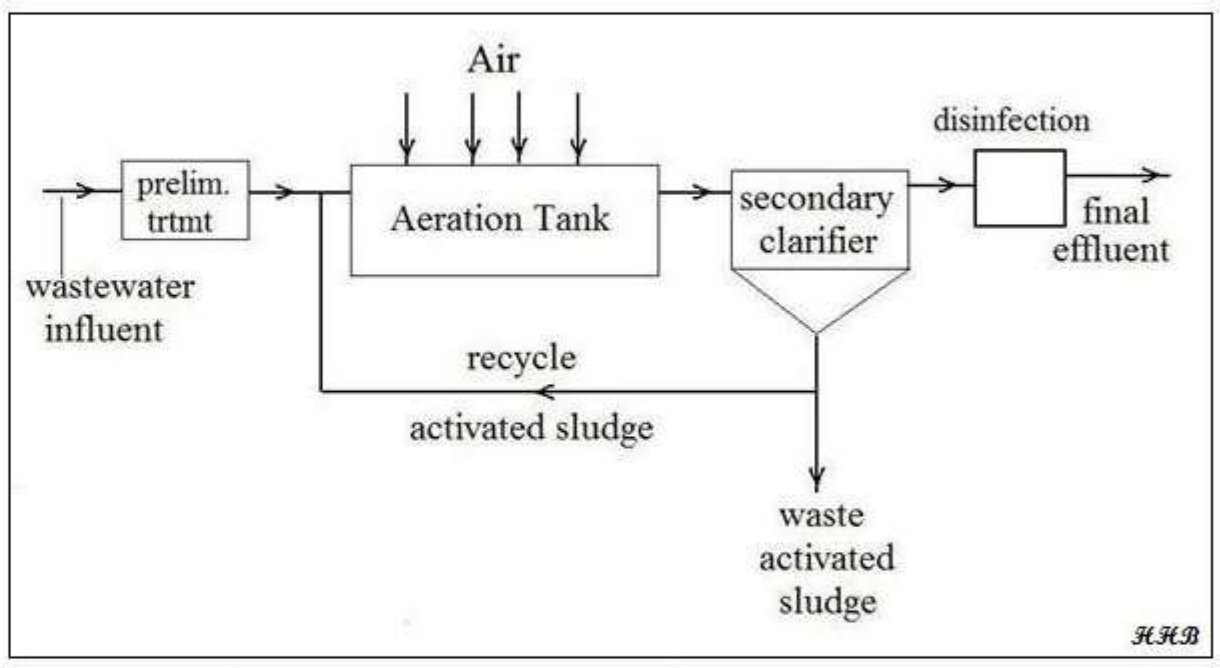
Other Aerobic Treatment Units

Stabilization ponds: The stabilization ponds are open flow through basins specifically designed and constructed to treat sewage and biodegradable industrial wastes. They provide long detention periods extending from a few to several days.

Aerated lagoons: Pond systems, in which oxygen is provided through mechanical aeration rather than algal photosynthesis are called aerated lagoons.

Oxidation ditch: The oxidation ditch is a modified form of "extended aeration" of activated sludge process. The ditch consists of a long continuous channel oval in shape with two surface rotors placed across the channel.

Extended Aeration

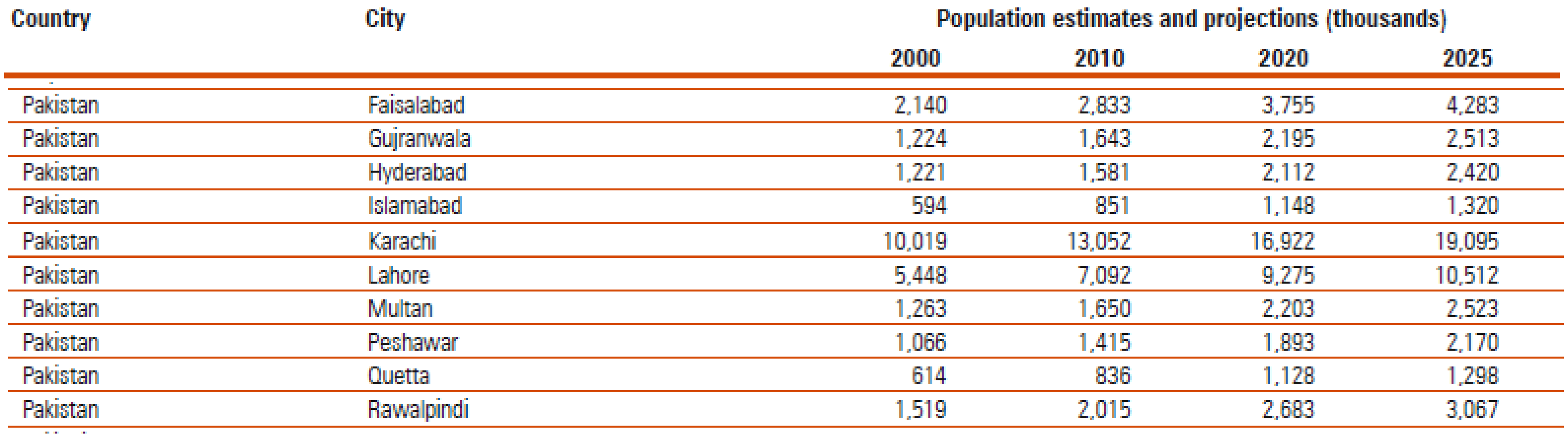


Extended Aeration Activated Sludge Wastewater Treatment Process

Assignment # 3

Due Date: Friday, 5rd April, 2013

- Each Group has to make an excel sheet in which detailed population analysis for every decade will be done for one city from 2000-2100
- Based on that population, the water demand for the same city
- Assuming 100 gallons per capita per day
- Also incorporating temp change/climate change scenario
- Assuming additional 10 gallons per capita per day per 0.2^0 C increase in temp.
- Refer to Urban Water Demand Model California



	Country	City	Population estimates and projections (thousands)			
			2000	2010	2020	2025
C	Pakistan	Faisalabad	2,140	2,833	3,755	4,283
	Pakistan	Gujranwala	1,224	1,643	2,195	2,513
	Pakistan	Hyderabad	1,221	1,581	2,112	2,420
	Pakistan	Islamabad	594	851	1,148	1,320
	Pakistan	Karachi	10,019	13,052	16,922	19,095
D	Pakistan	Lahore	5,448	7,092	9,275	10,512
	Pakistan	Multan	1,263	1,650	2,203	2,523
	Pakistan	Peshawar	1,066	1,415	1,893	2,170
	Pakistan	Quetta	614	836	1,128	1,298
	Pakistan	Rawalpindi	1,519	2,015	2,683	3,067

Dredging and Cleaning of Drains

From 17th May to 29th June 2012

Dredging

Dredging is an excavation activity or operation usually carried out at least partly underwater, in shallow seas or fresh water areas with the purpose of gathering up bottom sediments and disposing of them at a different location.

Javed Colony Drain

Before

After

Muslim Town UC 28

Before

After

Dhoke Matkal

Before

After

Javed Colony

Before

Work in progress

Javed Colony

Shamsabad

Work in progress

Work in progress

Cleared

Ganda Nullah

Work in progress

Cleaned

Work in Progress

Bohar Bazaar

Jama Masjid

Jama Masjid Road

Work in progress

Cleaned

Thandi Gali

Before

Work in Progress

Kohati Bazaar

Before

Work in Progress

Nirala Sweet Drain

Before

After

Sharjah Ground

Before

After

Dhoke Khabba

Before

After

Night Working at Bohar Bazar

Dhoke Illahi Buksh

Before

After

Sarfaraz Road

Bhatta Naik Allam

Pakistan Day

Thank You