EFCN

Wastewater Operator Certification Webinar Series

Date: September 27, 2023

Topic: Activated Sludge – Part 1

www.efcnetwork.org

This program is made possible under a cooperative agreement with US EPA.

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Let's start with a definition & some history

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Activated Sludge Process

Using microorganisms to convert dissolved and suspended organics into settleable solids

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Why do we use activated sludge?

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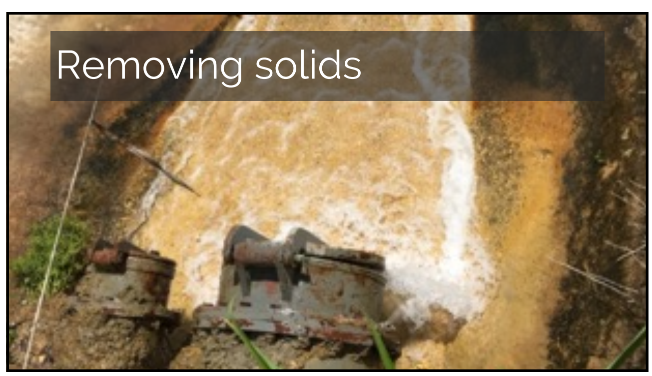

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What is the activated sludge process?

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How long has activated sludge been in use?

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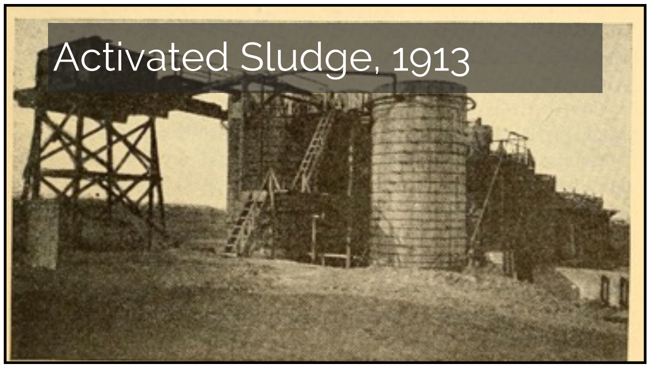

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Activated Sludge

Process Components

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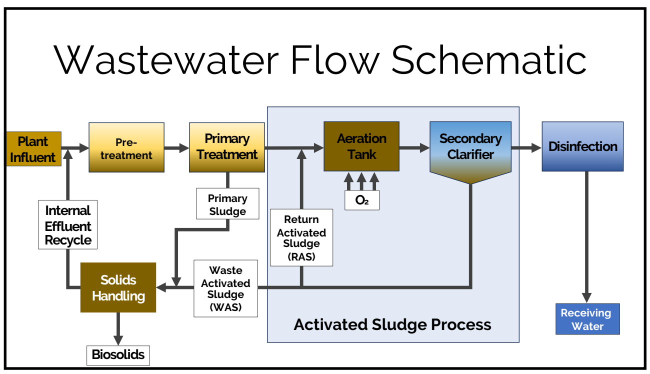

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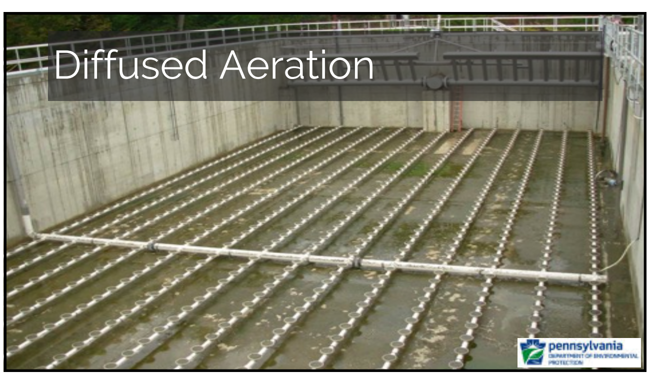

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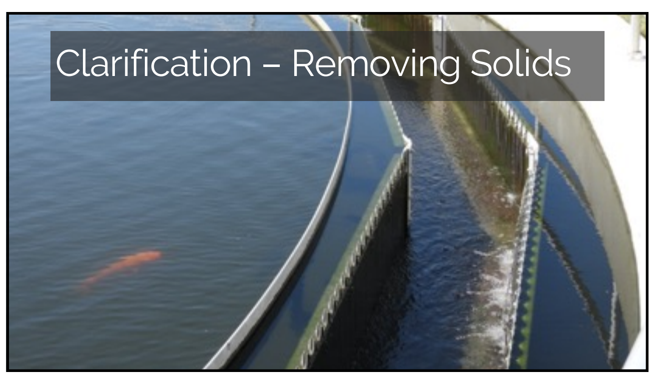

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Sludge Waste & Return

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Activated Sludge

Biological Components

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Aerobic Bacteria

- Need oxygen
- Grow relatively fast
- Produce little to no odor
- Are efficient waste oxidizers

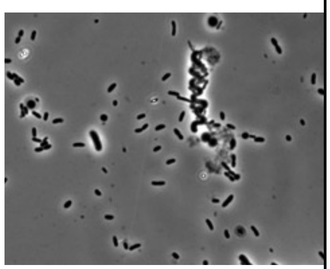

Image Source: http://ofbacteriaandmen.blogspot.com/2013/02/bacteria-in-wastewater-treatment-plant.html

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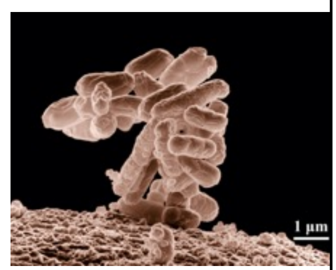
Facultative Bacteria

- Don't need oxygen (but typically prefer it)
- Grow slower than aerobic microbes
- Produce unpleasant odors when oxygen is scarce
- Are less efficient waste oxidizers than aerobic microbes



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Filamentous Organisms

Nocardia

Thiothrix

Actinomycetes

- These **don't settle well** in secondary clarifiers, resulting in **poor effluent quality**
- Are often **minimized using chemicals** like bleach, polymer and flocculants

Image Source: https://www.maine.gov/dep/water/wwtreatment/ten.pdf

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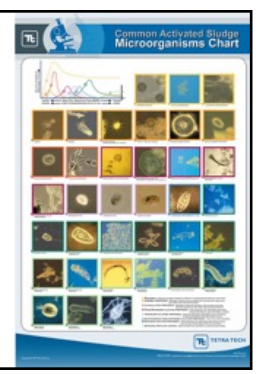
Other Organisms

- Microscopic analysis of your system should be part of daily monitoring and process control
- Usually correlate to plant performance
- Indicator species will help you determine the health of the system and help predict where it's headed
- Can be used as an early warning and to help prevent critical upsets
- Can indicate sludge age and reflect recent high BOD loading



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Bacterial Digestion

$$\frac{\textbf{organic matter (wastewater)} + O_2 + \textbf{nutrients} + \textbf{microbes}}{= \textbf{new microbes} + CO_2 + H_2O}$$

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Aerobic Oxidation: 3 perspectives

Bacterial standpoint: Food + Bacteria + O_2

Or

Operator standpoint: Waste + Activated Sludge + Aeration

Or

Chemical Reaction: Electron Donor + Energy + Reproduction + Electron Acceptor

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End Products: = Oxidized Wastewater + More Bacteria + CO_2 + H_2O

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BNR - Nutrient Removal

Nitrogen removal is a 2-step process:

- Nitrification (aerobic process) converts ammonia into nitrite and subsequently nitrate
- Denitrification (anoxic progress) converts nitrate into nitrogen gas

Conventional BOD systems that run with longer aeration times often result in nitrification as well, but the denitrification process has to be separated from the aerobic step

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Operational Variables

Influent BOD, DO, WAS

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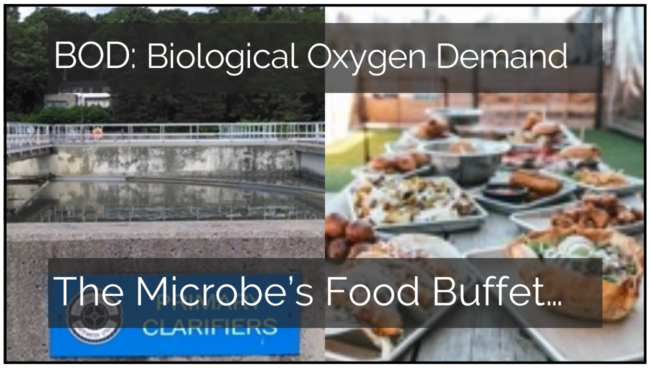

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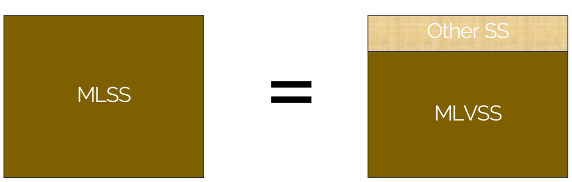
MLVSS: Mixed Liquor Volatile Suspended Solids

- The amount of organic or volatile suspended solids in the mixed liquor in an aeration tank.
- The volatile portion is used as an indicator of the microorganisms present.
- This is approximately equal to the biomass in the the MLS.



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F/M Ratio: Food/Microorganisms

$$\frac{F}{M} = \frac{total\ rate\ of\ applied\ food}{total\ microbe\ biomass} = \frac{Q \times BOD}{V_{ab} \times MLVSS} = \left[\frac{lb\ BOD}{lb\ VSS\ \cdot day}\right]$$

Q = Flow Rate into aeration Tank
BOD = concentration of BOD in the flow into Aeration Tank
V_{ab} = volume of Aeration Tank
MLSS = concentration of suspended solids in the Aeration Tank
MLVSS (or VSS) = concentration of MLVSS in the Aeration Tank

Expressed as $\frac{mass}{mass \cdot day}$

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F/M Ratio: Example

$$\frac{F}{M} = \frac{total\ rate\ of\ applied\ food}{total\ microbe\ biomass} = \frac{Q \times BOD}{V_{ab} \times MLVSS} = \left[\frac{lb\ BOD}{lb\ VSS\ \cdot day}\right]$$

Q = Flow Rate into aeration Tank
BOD = concentration of BOD in the flow into Aeration Tank
V_{ab} = volume of Aeration Tank
MLVSS = concentration of MLVSS in the Aeration Tank

$$\frac{F}{M} = \frac{Q\left[\frac{Mgal}{day}\right] \times BOD\left[\frac{mg}{L}\right] \times \frac{8.34lb \quad L}{mg \cdot Mgal}}{V_{ab}\,[Mgal] \times MLVSS\left[\frac{mg}{L}\right] \times \frac{8.34lb \cdot L}{mg \cdot Mgal}} = \left[\frac{lb\ BOD}{lb\ VSS\ \cdot day}\right]$$

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F/M Ratio: Calculate MLVSS

$$\frac{F}{M} = \frac{total\ rate\ of\ applied\ food}{total\ microbe\ biomass} = \frac{Q \times BOD}{V_{ab} \times MLVSS} = \left[\frac{lb\ BOD}{lb\ VSS\ \cdot day}\right]$$

Q = Flow Rate into aeration Tank
BOD = concentration of BOD in the flow into Aeration Tank
V_{ab} = volume of Aeration Tank
MLSS = concentration of suspended solids in the Aeration Tank
MLVSS (or VSS) = concentration of MLVSS (biomass) in the Aeration Tank

BOD = 200 mg/L
Biomass = 85% of solids
Tank Volume (V_{ab}) = 1 MG
Flow (Q) = 4 MG/day
MLSS = 2,400 mg/L

1) Calculate MLVSS: $MLVSS = 85\% \times MLSS\ concentration = 85\% \times 2{,}400\frac{mg}{L} = 2{,}040\frac{mg}{L}$

2) Calculate F/M ratio:

$$\frac{F}{M} = \left[\frac{lb\ BOD}{lb\ VSS\ \cdot day}\right] = \frac{Q \times BOD}{V_{ab} \times MLVSS} = \frac{4\frac{MG}{d} \times 200\frac{mg}{L}}{1\ MG \times 2{,}040\frac{mg}{L}} = 0.4\ \frac{lb\ BOD}{lb\ VSS\ \cdot day}$$

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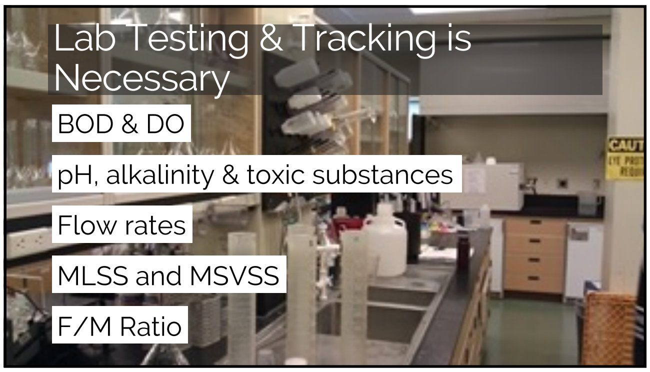

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Typical ASP Lab Results

Test	Location	Common Range
COD	Influent Primary Effluent Final Effluent (Conv. ASP)	250 – 1,000 mg/L 200 – 400 mg/L 30 – 70 mg/L
BOD	Influent Primary Effluent Final Effluent (Conv. ASP)	150 – 400 mg/L 100 – 280 mg/L 10 – 20 mg/L
Suspended Solids	Influent Primary Effluent Mixed Liquor Return Sludge Final Effluent (Conv. ASP)	150 – 400 mg/L 60 – 160 mg/L 1,000 – 4,500 mg/L 2,000 – 10,000 mg/L 1 - 20 mg/L
Dissolved Oxygen (DO)	Mixed Liquor Final Effluent (outfall)	0.5 – 4 mg/L 2 – 6 mg/L

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Typical ASP Loading Ranges

Loading Rate	Hydraulic Retention Time (hrs)	Sludge age (days)	Volumetric Loading (lb BOD/1000 ft³)	F/M (lb/lb·day)
Low Rate	18-24	20 - 30	10 - 25	0.05 – 0.15
Conventional	6-8	5 - 15	20 - 40	0.2 - 0.5
High Rate	1-3	1 - 3	100 – 1,000	0.5 – 1.5

Source: Table 5.3 Operation of Wastewater Treatment Plants, Vol. 1 8th Edition, Water Programs Sacramento State

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Operation

Three Basic ASP Variations

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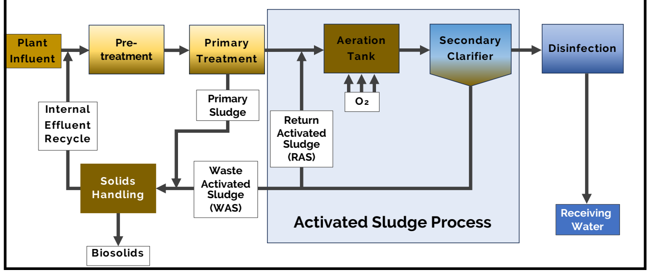
Variation 1: Conventional Plant



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Variation 1: Conventional ASP

Loading Rate	Sludge age (days)	Volumetric Loading (lb BOD/1000 ft^3)	F/M (lb/lb·day)
Medium	5 - 15	20 - 40	0.2 - 0.5

Hydraulic retention time: 6-8 hours
F/M Ratio: Moderate
Organism Growth Rate: Slow
Sludge Age: Mid-Range
Effluent Quality: Good

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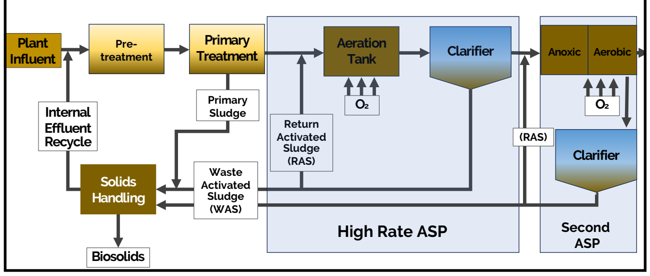
Variation 2: High Rate



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Variation 2: High Rate

Loading Rate	Sludge age (days)	Volumetric Loading (lb BOD/1000 ft^3)	F/M (lb/lb·day)
High Rate	1 - 3	100 – 1,000	0.5 – 1.5

Hydraulic Retention Time: 1-3 hours
F/M Ratio: High
Organism Growth Rate: High
Sludge Age: Short
Effluent Quality: Lower than desirable

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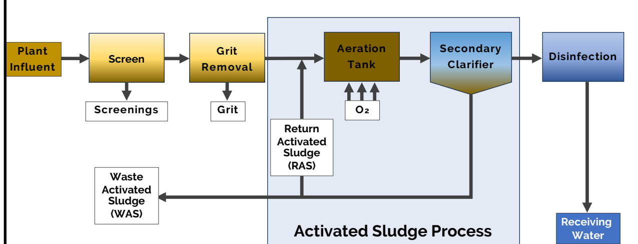
Variation 3: Extended Aeration



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Variation 3: Extended Aeration

Loading Rate	Sludge age (days)	Volumetric Loading (lb BOD/1000 ft^3)	F/M (lb/lb·day)
Low Rate	20 - 30	10 - 25	0.05 – 0.15

Hydraulic retention time: 18-24 hours
F/M Ratio: Low
Organism Growth Rate: net zero
Sludge Age: Long
Effluent Quality: Good

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Typical ASP Loading Ranges

Loading Rate	Hydraulic Retention Time (hrs)	Sludge age (days)	Volumetric Loading (lb BOD/1000 ft³)	F/M (lb/lb·day)
Low Rate	18-24	20 - 30	10 - 25	0.05 – 0.15
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Complete Mix vs Plug Flow

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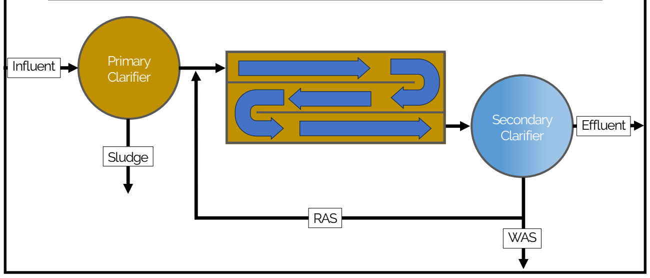
Plug Flow



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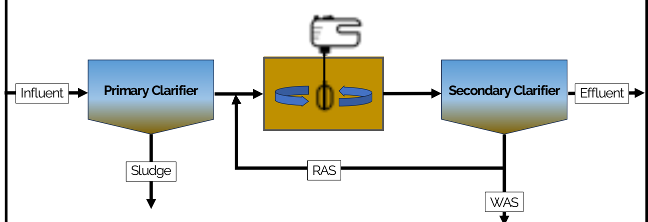
Complete Mix



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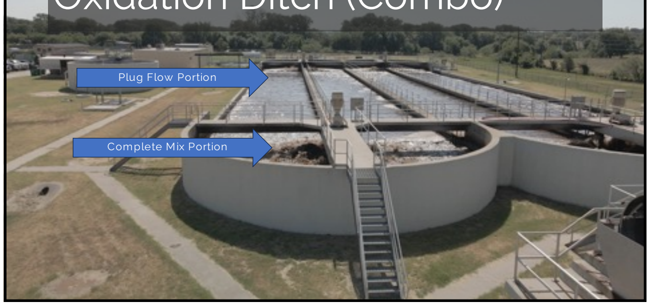
Oxidation Ditch (Combo)



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Sludge Age

Sludge age, MCRT or Solids Retention Time

Average time solids are retained in the aeration tank

$$Sludge\ Age\ (days) = \frac{mass\ of\ solids\ in\ tank}{mass\ rate\ of\ solids\ entering\ tank}$$

$$Sludge\ Age\ (days) = \frac{V_{ab} \times MLSS}{Q \times TSS_{INF}}$$

TSS_{INF} = Total Suspended Solids in aeration tank influent

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Solids Retention Time

$$SRT(days) = \frac{[V_{ab} \times MLSS] + [Vsc \times TSSsc]}{[Q_{WAS} \times TSS_{WAS}] + [Q_{eff} \times TSS_{eff}]}$$

TSS_{SC} = TSS in secondary clarifier

TSS_{eff} = TSS in secondary effluent

TSS_{WAS} = TSS in WAS

OR, if activated sludge is pumped out of the secondary clarifier promptly so that the there are only minimum solids in the clarifier, the secondary clarifier term can be left out of the equation

$$SRT(days) = \frac{[V_{ab} \times MLSS]}{[Q_{WAS} \times TSS_{WAS}] + [Q_{eff} \times TSS_{eff}]}$$

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Solids Retention Time

$$SRT(days) = \frac{[V_{ab} \times MLSS]}{[Q_{WAS} \times TSS_{WAS}] + [Q_{eff} \times TSS_{eff}]}$$

$$Q_{eff} = Q - Q_{WAS}$$

V_{abs} = 1 Mgal (MG)

Q = 4 Mgal/day (MGD)

Q_{WAS} = 0.075 Mgal/day (MGD)

$MLSS$ = 2,400 mg/L

TSS_{WAS} = 6,200 mg/L

TSS_{eff} = 12 mg/L

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Solids Retention Time

$$SRT(days) = \frac{[V_{ab} \times MLSS]}{[Q_{WAS} \times TSS_{WAS}] + [Q_{eff} \times TSS_{eff}]}$$

$$Q_{eff} = Q - Q_{WAS} = 4\ MGD - 0.075\ MGD$$

$$= 3.925\ MGD$$

$$SRT(days) = \frac{1\ (MG) \times 2{,}400\ mg/L}{[0.075\ MGD \times 6{,}200\ mg/L] + [3.925\ MGD \times 12\ mg/L]}$$

$$SRT(days) = 4.7\ days$$

V_{abs} = 1 Mgal (MG)

Q = 4 Mgal/day (MGD)

Q_{WAS} = 0.075 Mgal/day (MGD)

$MLSS$ = 2,400 mg/L

TSS_{WAS} = 6,200 mg/L

TSS_{eff} = 12 mg/L

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Design Characteristics

Process Name	Reactor Type	SRT (days)	F/M (lb BOD/LB VSS · d)	Volumetric Loading (lb BOD/1000 ft3 · D)	MLSS (mg/L)	Total Detention Time (hrs)
High-Rate Aeration	CMAS or Plug Flow	0.5 - 2	1.5 - 2	75 - 150	500 - 1500	1 - 2
Conventional Plug Flow	Plug Flow	3 - 15	0.2 – 0.4	20 - 40	1000 -3000	4-8
Extended Aeration	CMAS or Plug Flow	20 - 40	0.04 - 0.1	5 – 15	2000 - 4000	20 - 30
Oxidation Ditch	CMAS & Plug Flow	15 - 30	0.04 - 0.1	5 – 15	3000 - 5000	15 - 30

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Variables Effecting Process

Collection Systems & Plant Operations

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Collection System Variables

Wastewater typically comes from domestic, commercial and industrial sources. Diurnal, weekly, and seasonal changes in water use will impact wastewater flows from all three source types, but not necessarily equally or in step.

Wastewater characteristics can change as they move through the collection system due to pollutants and chemicals entering the system,

I & I in a sanitary sewer can increase wastewater flow into the plant during storm events

In a combined sewer system typically get increased flows during storm events and spring thaws which can cause hydraulic overload at the plant

Collection system blockages and maintenance events can lead to the release of large volumes of septic wastewater that may cause a shock load on treatment plant systems

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Plant Operational Variables

Changes in Influent characteristics (BOD, COD, TSS, VSS, TKN, Ammonia, Nitrate phosphorus, pH & alkalinity) will impact operation of an ASP.

Plants are designed with ranges in mind, so characteristics have to be monitored and processes have to be adjusted for changes.

Changes in internal recycle flows can also impact an ASP both in terms of flow and loading

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Sewage Haulers

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Safety Considerations

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Typical Hazards

- Drowning – aeration reduces bouyancy
- Slippery edges
- Rotating equipment
- Electrical hazards
- Compressed air
- Biohazards
- Chemical hazards
- Noise
- Confined spaces

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Office Hour Details

Time: Every Tuesday from: 9:00 AM to 10:00 AM PDT
10:00 AM to 11:00AM MDT
11:00 AM to Noon CDT
Noon to 1:00 PM EDT

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