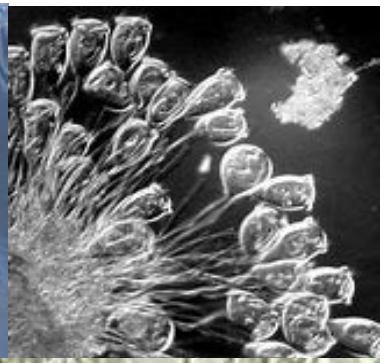
baywork

Bay area water/wastewater workforce reliability

ACTIVATED SLUDGE



Instructor: Monte Hamamoto

Monte Hamamoto

Chief Operating Officer
Silicon Valley Clean Water
1400 Radio Road
Redwood City, CA 94065
(650) 832-6266
mhamamoto@svcw.org

SVCW
Silicon Valley Clean Water
One Drop at a Time

36 years in Wastewater Treatment
Adjunct Professor Water/Wastewater Gavilan College
BS Marine Biology Humboldt State University
AS Water/Wastewater Technology Solano College

Activated Sludge

Activated Sludge – consists of sludge particles produced in raw or settled wastewater (primary effluent) by the growth of organisms (including zoogleal bacteria) in aeration tanks in the presence of dissolved oxygen.

"Activated" – refers to the fact that the activated sludge particles are teeming with:

Bacteria – Fungi - Protozoa

Activated Sludge Process – a biological wastewater treatment process that uses MICROORGANISMS to speed up the decomposition of wastes.

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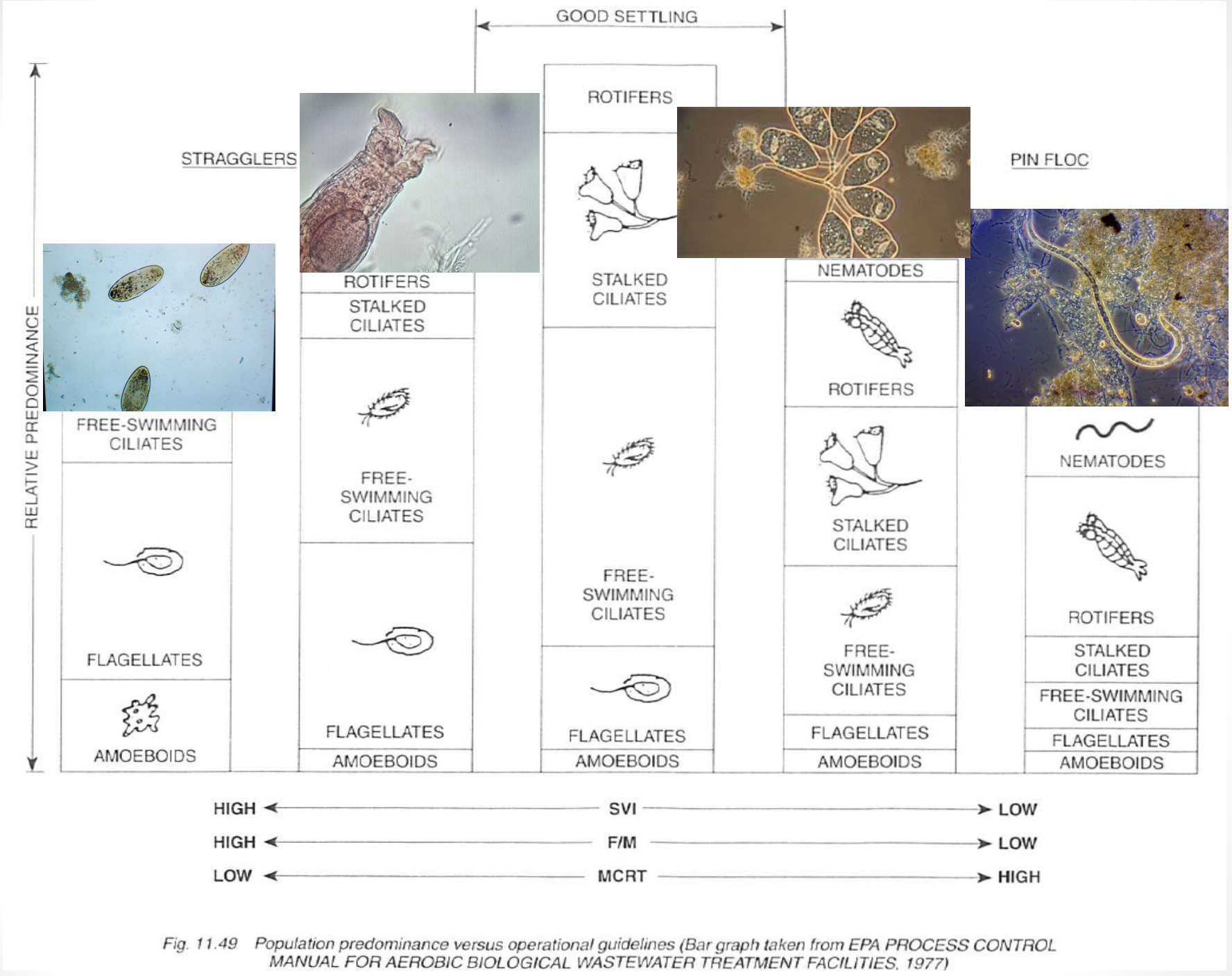

Fig. 11.49 Population predominance versus operational guidelines (Bar graph taken from EPA PROCESS CONTROL MANUAL FOR AEROBIC BIOLOGICAL WASTEWATER TREATMENT FACILITIES, 1977)

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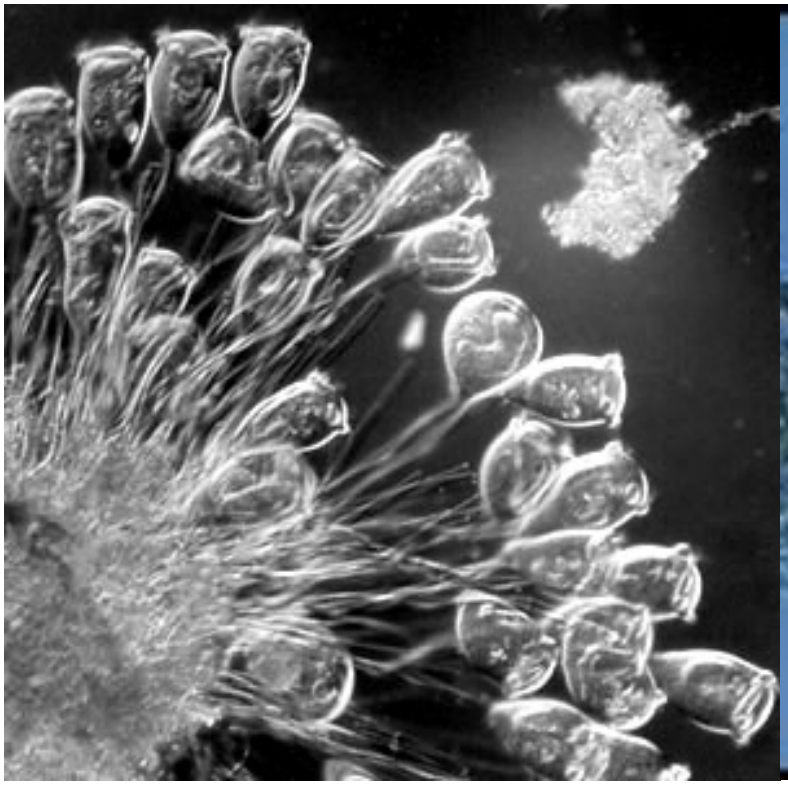
Activated Sludge

- Activated Sludge (Good Microorganisms)



Stalked Ciliates

Rotifers

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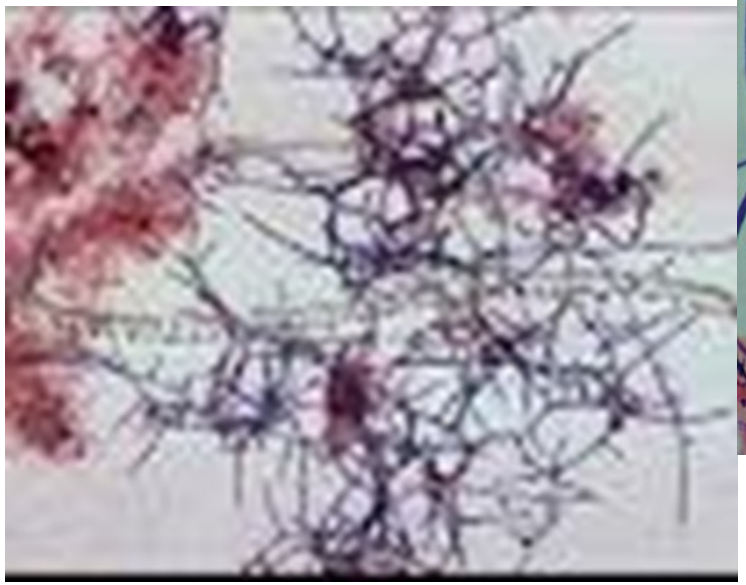
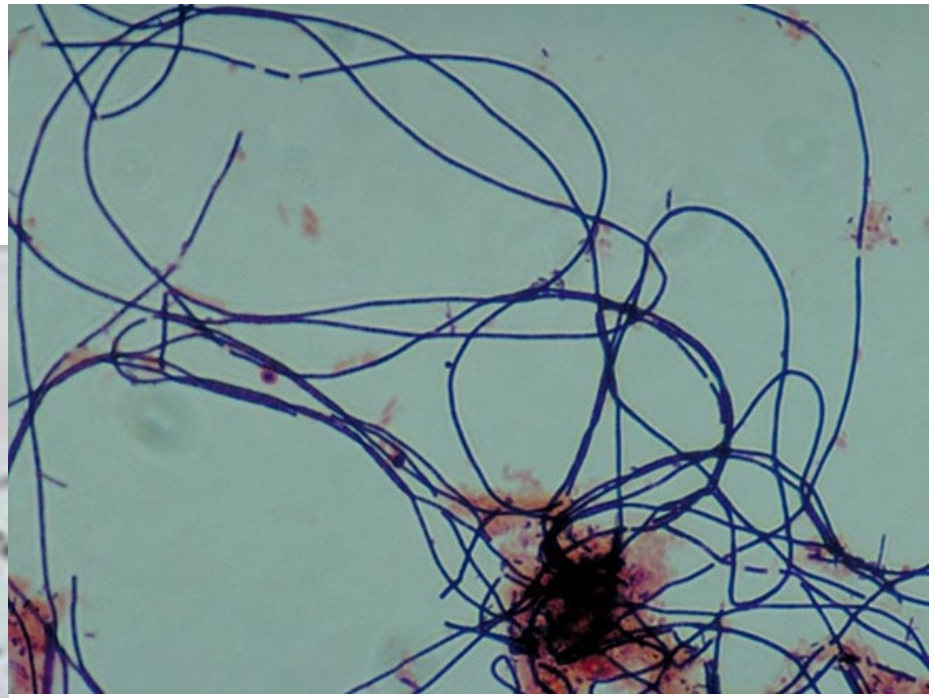
Activated Sludge

- Activated Sludge (Bad Microorganisms)

Filamentous Bacteria





Nocardia

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Activated Sludge

Basic Needs of a Healthy Activated Sludge:

- Food in the form of BOD that the microorganisms can readily assimilate
- Ample supply of oxygen
- Good mixing to create a homogeneous solution of the food-air-microorganisms
- Ability to maintain the desired activate sludge inventory

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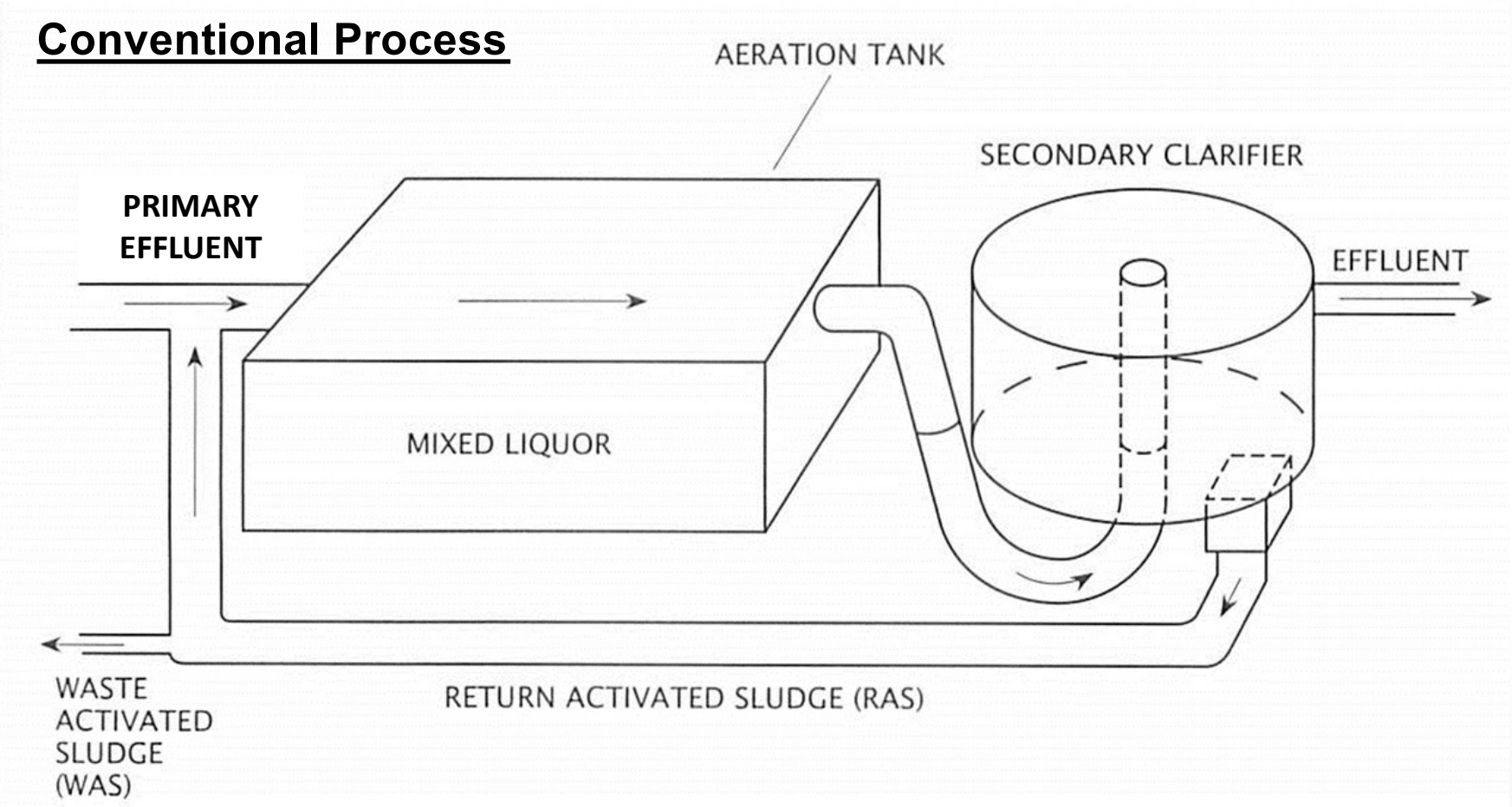
Activated Sludge

Conventional Process



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Activated Sludge

MLSS – The concentration of suspended solids (mg/L) in the mixed liquor of an aeration tank

MLVSS – The concentration of organic or volatile suspended solids (mg/L) in the mixed liquor of an aeration tank. Usually equivalent to concentration of microorganisms in an aeration tank.

FOOD / MICROORGANISM RATIO (F/M Ratio)

- A measure of food provided to the Activated Sludge in an aeration basin

$$\text{F/M Ratio} = \frac{(\text{Flow, MGD})(\text{BOD mg/L})(8.34 \text{ lbs/gal})}{(\text{Aeration Basin Vol, MG})(\text{MLVSS, mg/L})(8.34 \text{ lbs/gal})} = \frac{\text{BOD, lbs/day}}{\text{MLVSS, lbs}}$$

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Activated Sludge

SLUDGE AGE

An indicator of the length of time a pound of solids is kept under aeration in the activated sludge process.

$$\text{Sludge Age, Days} = \frac{(\text{MLSS, mg/L})(\text{Aeration Basin Vol, MG})(8.34\ \text{lbs/gal})}{(\text{TSS in Primary Effluent, mg/L})(\text{Flow, MGD})(8.34\ \text{lbs/gal})}$$

$$= \frac{\text{Suspended Solids Under Aeration, lbs}}{\text{Suspended Solids Added, lbs/Day}}$$

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Activated Sludge

Sludge Age

- HIGH RATE: 0.5 to 2.0 days
  - Operates at the highest loading of food to microorganisms.
- CONVENTIONAL: 3.5 to 7.0 days
  - Most common operation. Approximately 50% of the food to microorganism ratio as the High Rate.
- EXTENDED AERATION: >10.0 days
  - Popular in small package plants, most stable due to light loads and low food to microorganism ratios

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Activated Sludge

MEAN CELL RESIDENCE TIME (MCRT)

an expression of the average time (days) that a microorganism will spend in the activated sludge process.

$$\text{MCRT, Days} = \frac{\text{Total Suspended Solids (MLVSS) in Activated Sludge , lbs}}{\text{Total Suspended Solids Removed from Process, lbs/day}}$$

$$\text{MCRT, Days} = \frac{\text{(MLVSS Aeration, lbs) + (MLVSS Secondary Clarifiers, lbs)}}{\text{(MLVSS removed WAS, lbs/day) + (TSS lost in Effluent, lbs/day)}}$$

SOLIDS RETENTION TIME (SRT)

an expression of the average time (days) that the solids will spend in the activated sludge process.

$$\text{SRT, Days} = \frac{\text{Total Suspended Solids (MLSS) in Activated Sludge , lbs}}{\text{Total Suspended Solids Removed from Process, lbs/day}}$$

$$\text{SRT, Days} = \frac{\text{(MLSS Aeration, lbs) + (MLSS Secondary Clarifiers, lbs)}}{\text{(MLSS removed WAS, lbs/day) + (TSS lost in Effluent, lbs/day)}}$$

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Activated Sludge

- 30-Minute Settleometer (Settling Test, SSV-30)
  - Simulates the behavior of the activated sludge in the Secondary Clarifiers

Good Settling
Dense blanket, clear supernate

Medium Settling
Uniform blanket, PIN-FLOC

POOR Settling
Sludge blanket split,
DENITRIFICATION or ANNOXIC

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Activated Sludge

SLUDGE VOLUME INDEX (SVI)

An indicator of the settleability characteristics of the MLSS. An SVI below 150 indicates a good settling activated sludge.

$$SVI = \frac{\text{(Volume 30 min settleability, mL) / (Volume of sample, L)}}{\text{(MLSS mg/L)}} \times \frac{\text{(1,000 mg)}}{\text{g}}$$

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Activated Sludge

Activated Sludge

- **"RAS" (Return Activated Sludge)** – Activated Sludge that is returned from the Secondary Clarifiers to the influent of the Aeration Basin
- **"WAS" (Waste Activated Sludge)** – Activated Sludge wasted or removed from the Activated sludge System. This is how operators control the microorganism population needed to treat the flow from the Primary Treatment Process (BOD & TSS). WAS is generally thickened and sent to the Digestion Process.

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Activated Sludge

- Activated Sludge Operation
  - Waste Activated Sludge (WAS)
  - If your PCMP use MCRT to control the Activated Sludge Process:

$$\text{MCRT, Days} = \frac{\text{(MLVSS Aeration, lbs) + (MLVSS Secondary Clarifiers, lbs)}}{\text{(MLVSS removed WAS, lbs/day) + (TSS lost in Effluent, lbs/day)}}$$

$$\text{WAS Lbs/Day} = \frac{\text{(Total MLVSS in Activated Sludge , lbs)}}{\text{MCRT, Days}} - \text{(TSS lost in Effluent, lbs/day)}$$

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Activated Sludge

Activated Sludge

There are two (2) main properties Activated Sludge microorganisms use to bind-up their food:

1. **ADSORPTION** – the gathering of gas, liquid, or dissolved substances on the surface or interface zone of another material. (stick to the surface of the organism)
2. **ABSORPTION** – The taking in or soaking up of one substance into the body of another by molecular or chemical action. (goes into the body of the organism)

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Activated Sludge

Activated Sludge

- **OXIDATION**
  - **Oxidation and Reduction in terms of oxygen transfer**
    The terms **oxidation** and **reduction** can be defined in terms of adding or removing oxygen to a compound.

  - Definition: Oxidation and Reduction with respect to Oxygen Transfer

    Oxidation is the **gain** of oxygen.

    Reduction is the **loss** of oxygen.

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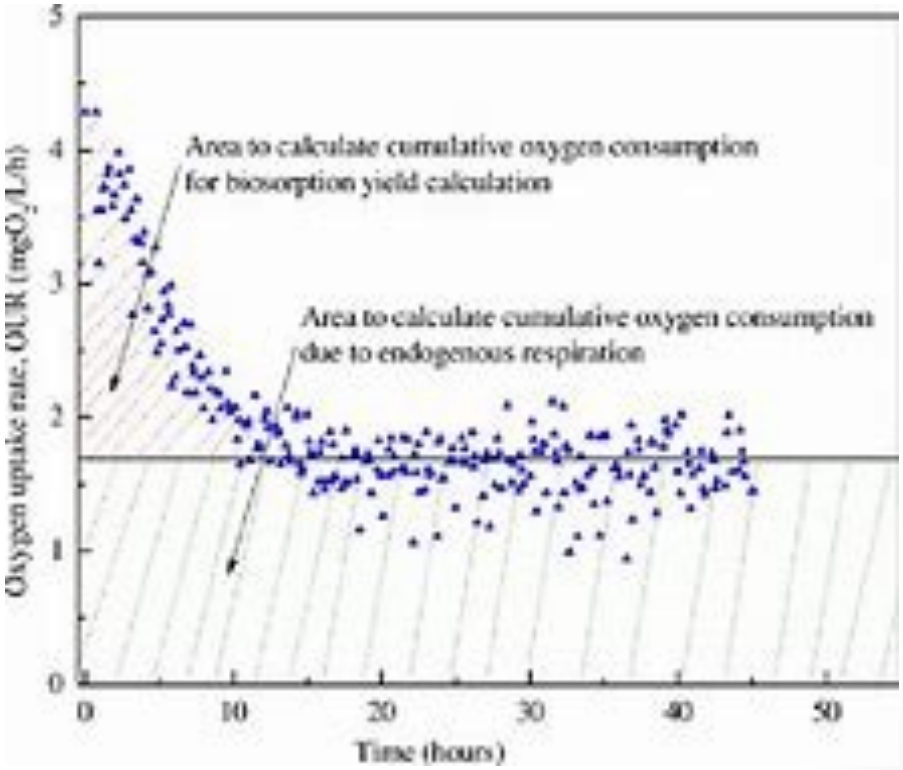
Activated Sludge

Activated Sludge

OXYGEN UPTAKE RATE (OUR)

The rate at which micro-organisms use oxygen while consuming food (BOD) from the wastewater.

Dissolved Oxygen Uptake
(DOUR) Test



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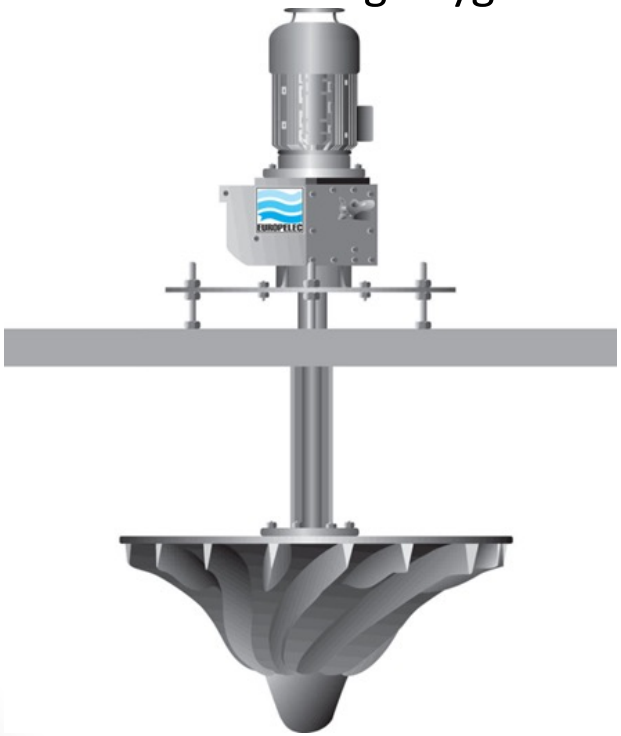
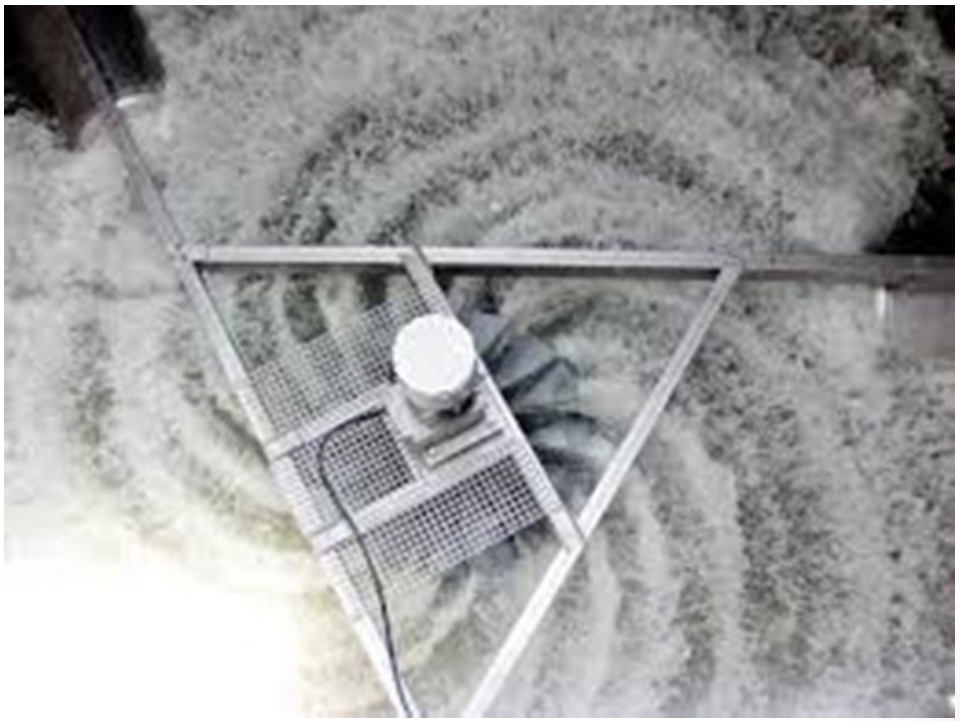
Activated Sludge

Activated Sludge - Aeration

- Three (3) methods to supply dissolved oxygen to the activated sludge microorganisms
    1. **Mechanical Aeration** – utilizes a mechanical mixer to agitate the water resulting in a spray or waves that splash water into the air absorbing oxygen.





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Activated Sludge

Activated Sludge - Aeration

2. **Diffused Air Aeration** – utilizes a diffuser to break up air supplied from a blower into fine bubbles for greater oxygen transfer

Ceramic Head Diffusers

Membrane Sock Diffusers

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Activated Sludge

Activated Sludge - Aeration

3. Hybrid Mechanical Aeration + Diffused Air – utilizes a mechanical mixer to agitate the water dispersing diffused air in the aeration basin.

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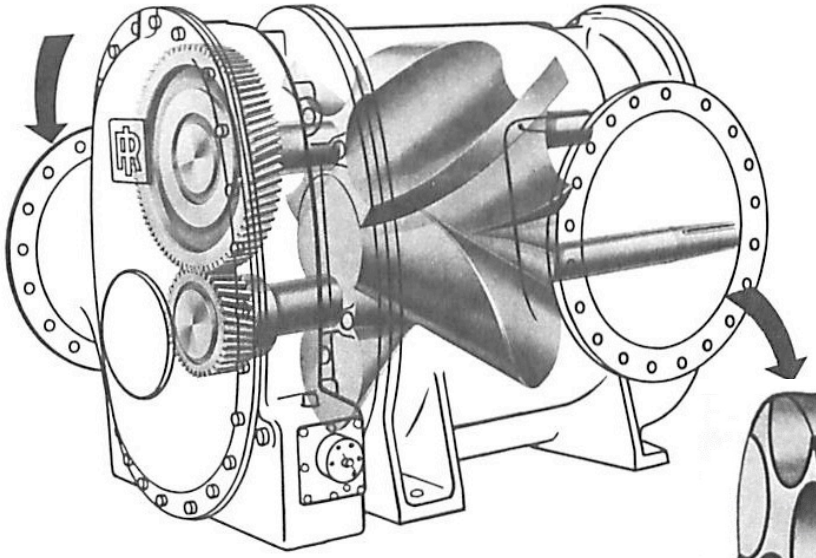
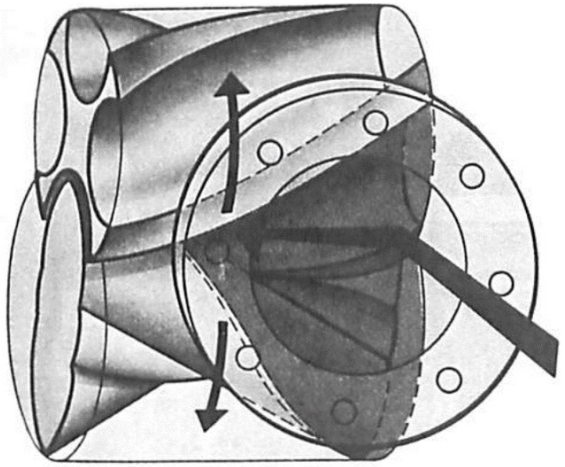
Activated Sludge - Aeration

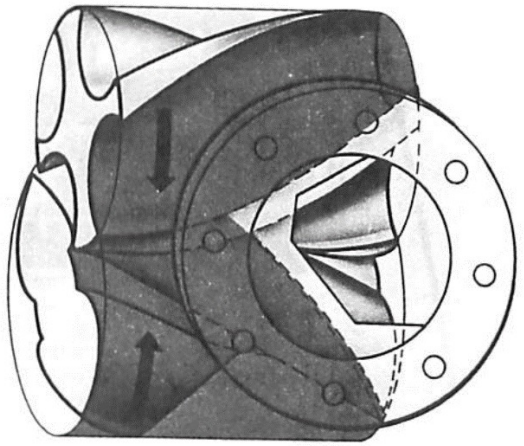
- Positive Displacement Blowers



1. Air enters the compressor at the left and leaves at the right.



2. As the rotors turn away from each other on the inlet side, air is drawn into pockets formed between the rotors and the casing wall.



3. The pockets of air move along and around the rotor axes, then join and diminish in volume, thus compressing the air. The air flow is smooth and continuous, without pumping or surging.

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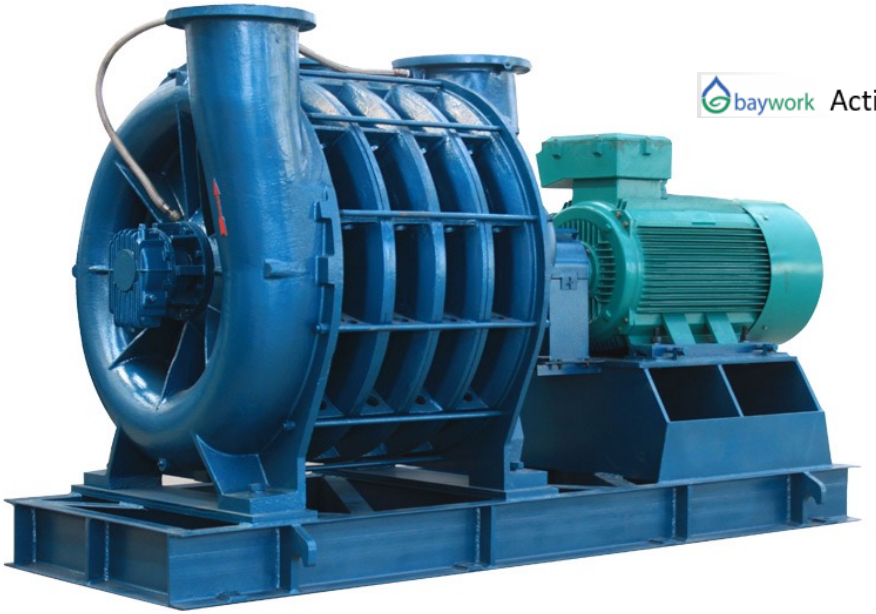
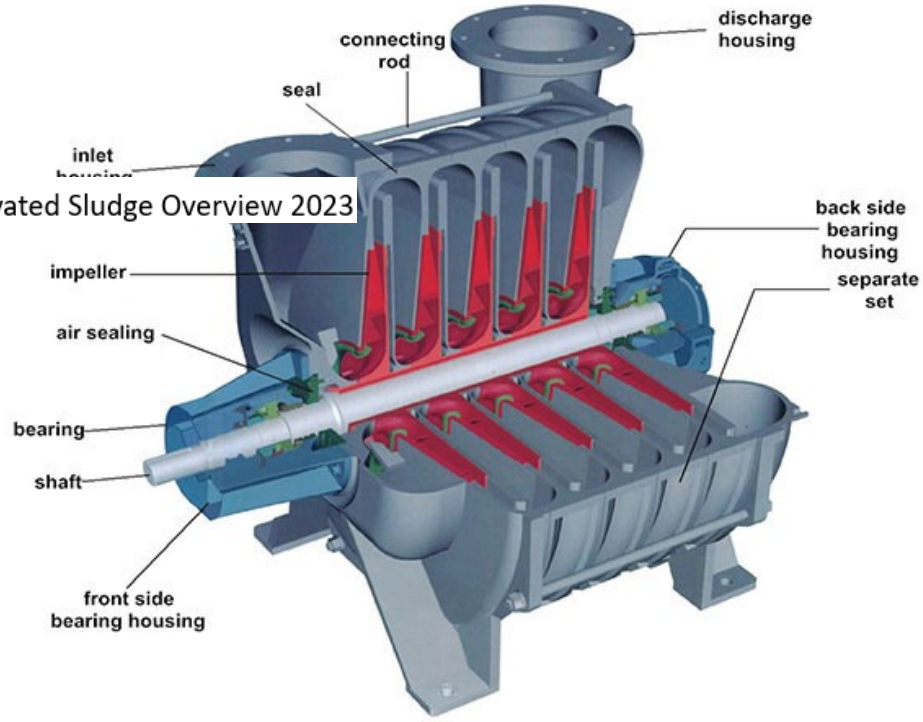
Activated Sludge

Activated Sludge - Aeration

- Centrifugal Blowers





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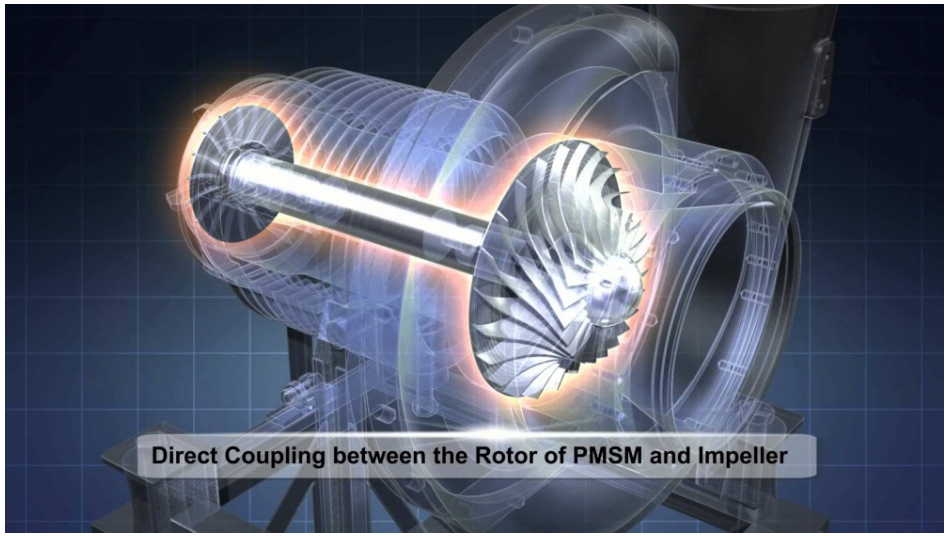
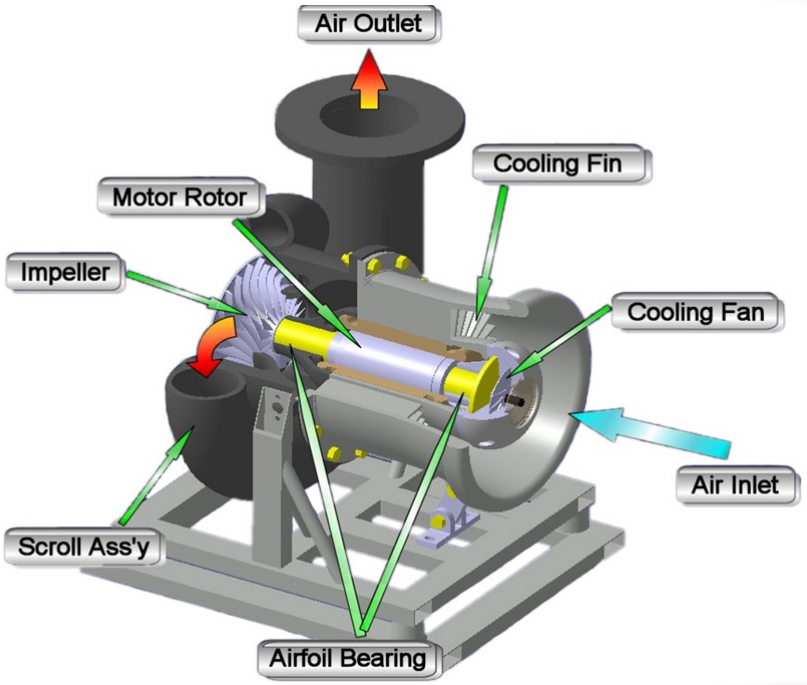
Activated Sludge

Activated Sludge - Aeration

- Turbine Blowers





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Activated Sludge

Activated Sludge Operation

(3) Three areas of major concern for an Operator of an Activated Sludge process:

1. What enters the plant (Influent)
2. The environment for treating waste (Process)
3. What leaves the plant (Effluent)

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Activated Sludge

TABLE 11.1 TYPICAL LAB RESULTS

Test	Location	Common Range	
COD	Influent	250–1,000	mg/L
	Primary Effluent	200–400	mg/L
	Final Effluent (Conv. Act. Sl.)	30–70	mg/L
BOD	Influent	150–400	mg/L
	Primary Effluent	100–280	mg/L
	Final Effluent (Conv. Act. Sl.)	10–20	mg/L
SUSPENDED SOLIDS	Influent	150–400	mg/L
	Primary Effluent	60–160	mg/L
	Mixed Liquor	1,000–4,500	mg/L
	Return Sludge	2,000–10,000	mg/L
	Final Effluent (Conv. Act. Sl.)	1–20	mg/L
DISSOLVED OXYGEN	Mixed Liquor	0.5–4	mg/L
	Final Effl. (Outfall)	2–6	mg/L
CHLORINE RESIDUAL (30 min.)	Final Effluent	<0.1–2.0[a]	mg/L[b]
COLIFORM GROUP BACTERIA, MPN	Final Effluent (Chlorinated)	2–700/100 mL	
CLARITY (Secchi Disc)	Final Effluent	3–8 ft	
TURBIDITY (Turbidimeter)	Final Effluent	1–3 NTU	
pH	Influent	6.8–8.0	
	Effluent	6.9–8.5	

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Activated Sludge

Process Control Management Plan (PCMP)

Activated Sludge – Unit Process Report

Start Date: **04/01/22**
End Date: **04/30/22**
Forecast (Days) : 20

Rpt Date: **04/26/22**

#	Parameter	Units	Total	Average	Min	Max	Trend	Flag	LCL	LWL	Target	UWL	UCL	# Samples
4340	AERATION BASINS 16 AS Average MLSS SCADA	mg/L	31,174	1,247	963	1,515	-14		950	1,000	1,100	1,300	1,400	25
4342	AERATION BASINS 16 AS Average MLVSS Manual	mg/L	3,329	1,110	971	1,195	-16	UCL	700	800	1,000	1,050	1,100	3
4380	AERATION BASINS 16 AS Inventory MLSS SCADA	lbs	576,590	23,064	16,258	32,780	-188		16,000	20,000	26,000	28,000	30,000	25
4381	AERATION BASINS 16 AS Inventory MLVSS SCADA	lbs	510,816	20,433	14,245	28,716	-186		13,000	15,000	24,000	28,000	30,000	25
4343	AERATION BASINS 16 AS Average DO SCADA	mg/L	45	1.8	1.2	2.2	-0		0.9	1.1	1.3	1.8	2.0	25
4345	AERATION BASINS 16 AS Average OUR	mg/L/Hour	678	27	21	39	0	UWL	12	15	20	25	35	25
4347	AERATION BASINS 16 AS Average SSV30	ml/L	4,250	202	120	250	1	UWL	100	125	150	200	250	21
4348	AERATION BASINS 16 AS Average SVI	Ratio	3,454	164	105	221	3		80	90	160	170	200	21
4350	AERATION BASINS 16 AS Average F:M	Ratio	20	0.8	0.6	1.1	0		0.2	0.5	0.7	1.0	1.3	25
4385	AERATION BASINS 16 AS MCRT	Days	41	1.8	0.5	5.1	-0		1.2	1.5	1.7	2.5	2.8	23
4389	AERATION BASINS 16 AS MCRT - Using Lab WAS TSS	Days	41	1.7	0.8	2.6	-0		1.2	1.5	1.7	2.5	2.8	
4351	AERATION BASINS 16 AS Average Load	lbs/KFT3	1,321	52.8	46.1	62.3	0.3		40.0	48.0	55.0	60.0	65.0	25
4360	AERATION BASINS 16 AS WAS Q	MGD	11	0.45	0.29	0.52	0	LWL	0.40	0.50	0.70	0.80	0.90	25
4660	SECONDARY CLARIFICATION 17 SCs Average Blanket	Feet	17	0.7	0.1	5.2	0	LWL	0.5	1.0	2.0	2.5	3.0	25
4358	AERATION BASINS 16 AS RAS Q	MGD	210	8.4	7.0	10.7	-0		5.0	7.0	10.0	11.0	12.0	25
4359	AERATION BASINS 16 AS RAS Q %	%	1,642	66	49	71	-1		30	50	66	75	85	25
4895	SECONDARY EFFLUENT 17Turbidity Daily Average SCADA	ntu	118	4.7	3.9	5.9	0		2.0	3.0	5.0	7.0	8.0	25
4900	SECONDARY EFFLUENT 17 TSS SCADA	mg/L	449	18.0	3.0	49.0	-1	UWL	5.0	7.0	10.0	14.0	20.0	25
4810	SECONDARY EFFLUENT 17 BOD	mg/L	33	16.5	16.0	17.0	-1		8.0	11.0	15.0	18.0	20.0	2

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Activated Sludge

ABNORMAL OPERATIONS

- **Rising Sludge/Bulking**
  - Denitrification (Low DO)
  - Septic sludge in clarifier (Low RAS rate)

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Activated Sludge

ABNORMAL OPERATIONS

- **Toxic Loads**
  - Toxic material dumped into the collection system that enters the treatment plant
  - Toxic to Activated Sludge
  - Acid, Caustic, Solvents, Poisons

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ABNORMAL OPERATIONS

- **Foaming/Frothing**
  - Nocardia
  - Surfactant dump
  - High MCRT

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Activated Sludge

Activated Sludge Operation

- Activated Sludge process is generally robust and can handle periodic "shock loads" of food (BOD).
- When the F/M Ratio is low indicating a low food concentration for the microorganisms, the microorganisms can enter **ENDOGENOUS RESPIRATION**.

ENDOGENOUS RESPIRATION: a situation in which living organisms oxidize some of their own cellular mass instead of new organic matter they adsorb or absorb from their environment

Conventional Activated Sludge (F/M)	**0.2 - 0.5**
Contact Stabilization (F/M)	0.15 - 0.2
Extended Aeration (F/M)	0.01 - 0.07
Step Aeration (F/M)	0.2 - 0.5
Two-Stage Aeration (F/M)	0.07 - 0.15

Pennsylvania DEP (.gov)
https://www.dep.state.pa.us › dep › redesign › calculators

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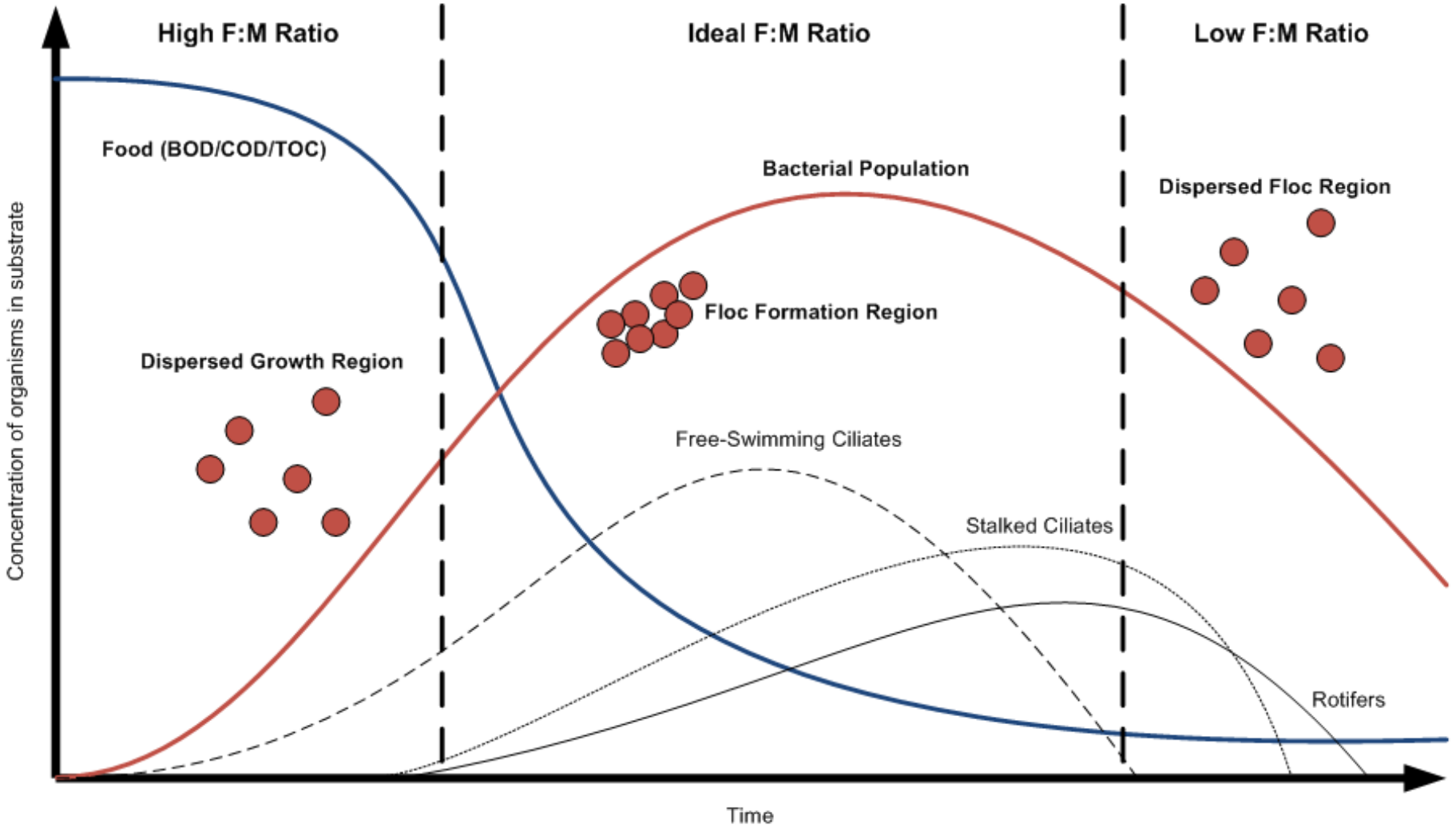
Activated Sludge



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Activated Sludge

FOOD / MICROORGANISM RATIO (F/M Ratio)

- Example:

$$\text{F/M Ratio} = \frac{\text{BOD, lbs}}{\text{MLVSS, lbs}}$$

- Known:
  - Flow = 10.0 MGD F/M Ratio
  - BOD = 120 mg/L
  - Aeration Basin Volume = 1.0 MG
  - MLVSS = 1,500 mg/L
  - Pounds Formula = (Flow, MGD)(Conc., mg/L)(8.34)

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Activated Sludge

FOOD / MICROORGANISM RATIO (F/M Ratio)

BOD, Lbs = (10.0 MGD)(120 mg/L)(8.34)

= 10,008 lbs

MLVSS Lbs = (1.0 MG)(1,500 mg/L)(8.34)

= 12,510 lbs

$$F/M = \frac{10{,}008 \text{ lbs}}{12{,}510 \text{ lbs}}$$

F/M = 0.8

Activated Sludge
Nitrification / Denitrification

Why is Nitrogen a Concern in Wastewater Discharge?

- Nitrogen (N) and Phosphorous (P) are nutrients necessary for healthy plant growth
  - Excessive concentrations of (N) and (P) can cause:
    - Excessive plant growth or blooms causing a dramatic drop in dissolved oxygen **(Eutrophication)**
      - Obstructed waterways due to excessive algae growth
      - Fish kills due to lack of dissolved oxygen
    - Could impair drinking water supplies
    - Can cause corrosive water conditions

Activated Sludge
Nitrification / Denitrification

- Drinking Water impairment due to high Nitrate (NO_3) concentrations
  - High NO_3 concentrations in drinking water can cause Blue Baby Syndrome (Methemoglobinemia)

    The use of nitrate-contaminated drinking water to prepare infant formula is a well-known risk factor for infant methemoglobinemia. Affected infants develop a peculiar blue-gray skin color and may become irritable or lethargic, depending on the severity of their condition. The condition can progress rapidly to cause coma and death if it is not recognized and treated appropriately.

Activated Sludge
Nitrification / Denitrification

- Can cause corrosive water conditions

Nitrification can have the adverse impacts of increasing nitrite and nitrate levels, reducing alkalinity, pH, dissolved oxygen, and chloramine residuals, and promoting bacterial regrowth (Wilczak et al. 1996). Table 1 provides a summary of water quality problems associated with nitrification.

Table 1
Summary of Water Quality Problems Associated with Nitrification

Chemical Issues	Biological Issues
Disinfectant Depletion	HPC Increase
Nitrite/Nitrate Formation	Ammonia Oxidizing Bacteria (AOB) Increase
Dissolved Oxygen Depletion	Nitrite Oxidizing Bacteria (NOB) Increase
Reduction in pH and Alkalinity	
DBP Formation due to Mitigation Techniques	

  - Reduction in pH and Alkalinity can cause corrosive water conditions
    - Corrosive drinking water can corrode copper and lead water lines causing the heavy metals to leach into the drinking water

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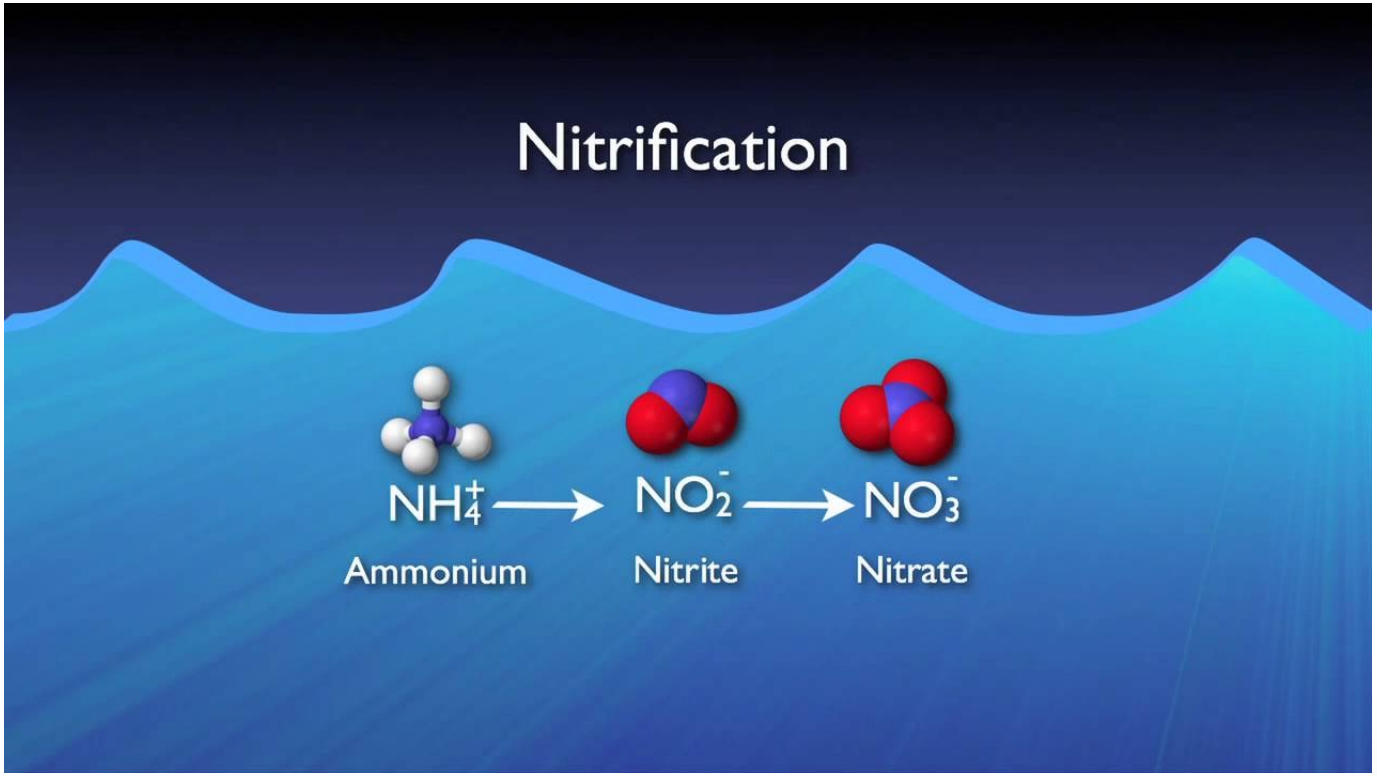
Activated Sludge
Nitrification / Denitrification

Nitrification:

- Aerobic Biological oxidation of Ammonia (NH_3) or Ammonium (NH_4^+) to Nitrate



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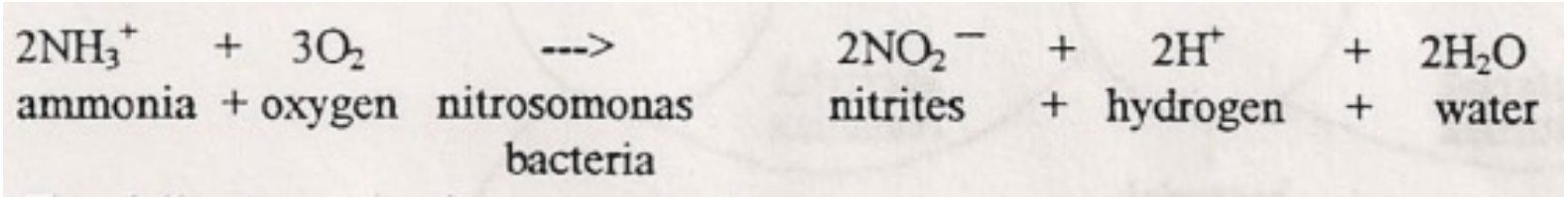
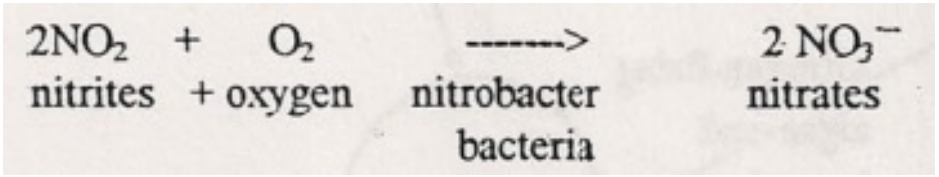
Activated Sludge
Nitrification / Denitrification

The Nitrosomonas group of bacteria, known as nitrite formers, convert ammonia under aerobic conditions to nitrites and derive energy from the oxidation:



Then the "nitrite nitrogen" is oxidized by the Nitrobacter group of nitrifying bacteria, also known as the nitrate formers, into the "nitrate nitrogen" form:



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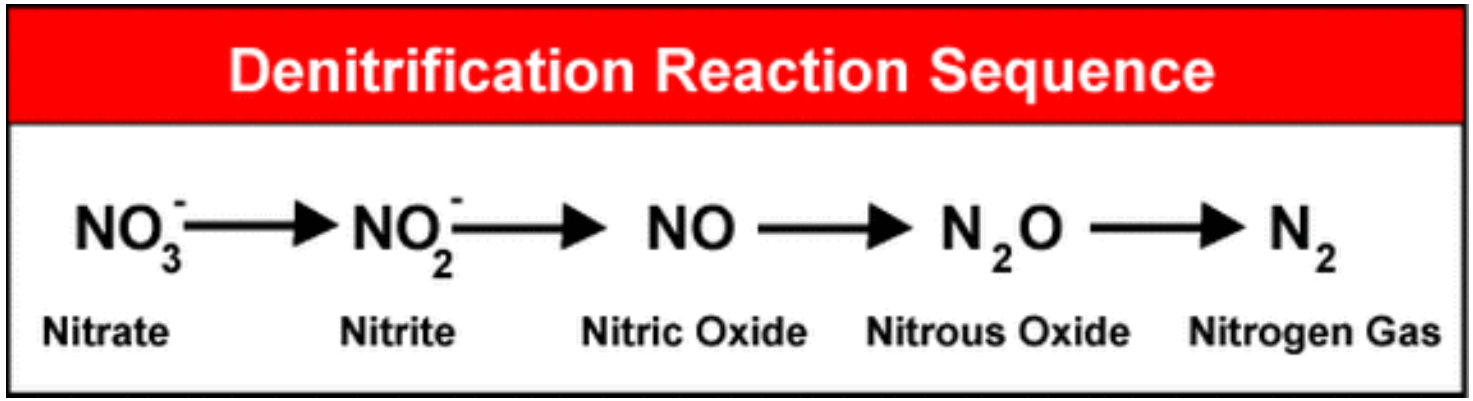
Activated Sludge
Nitrification / Denitrification

Denitrification:

- Anaerobic biological reduction of Nitrate NO_3 to Nitrogen gas N_2



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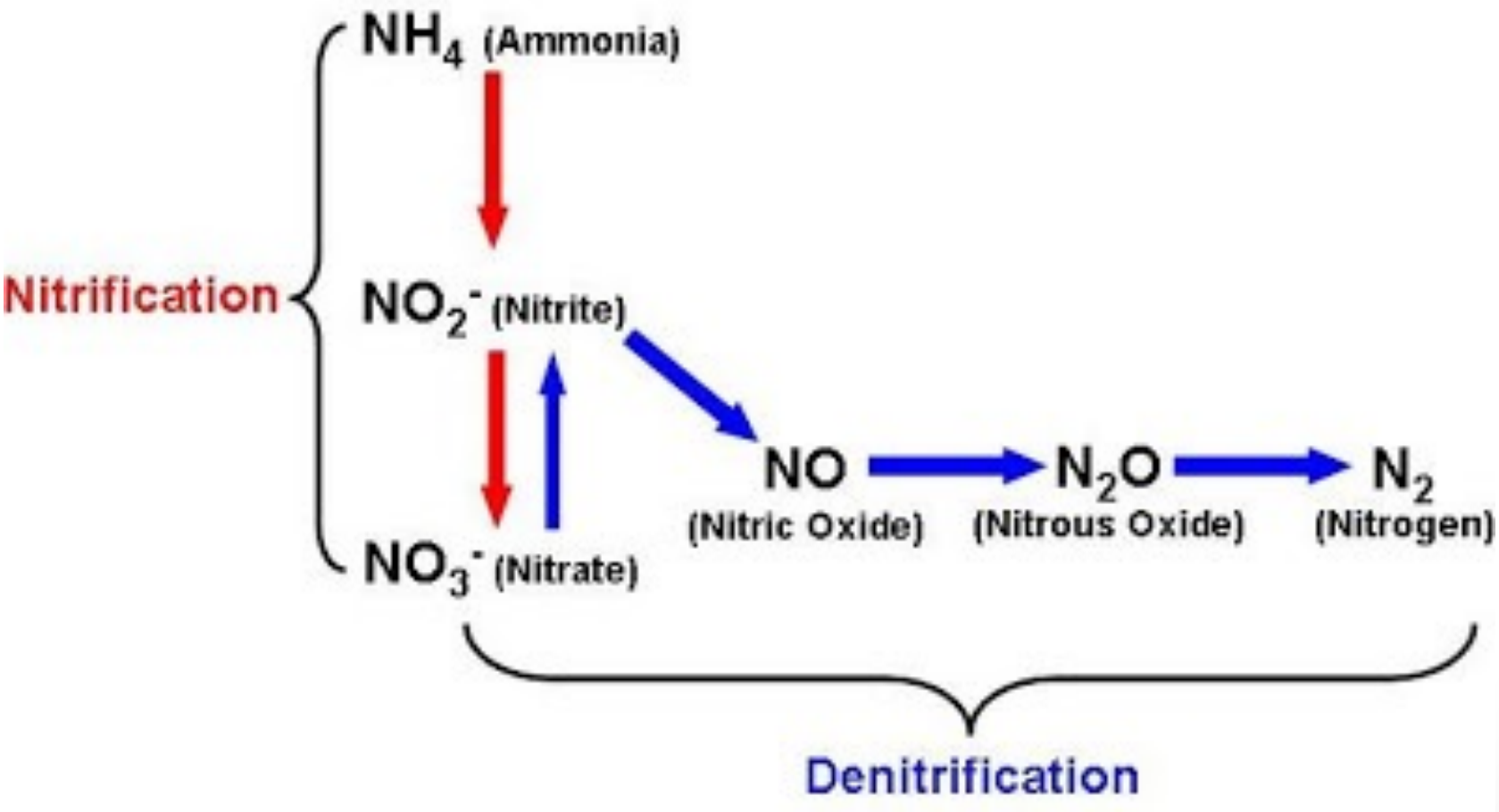
Activated Sludge
Nitrification / Denitrification



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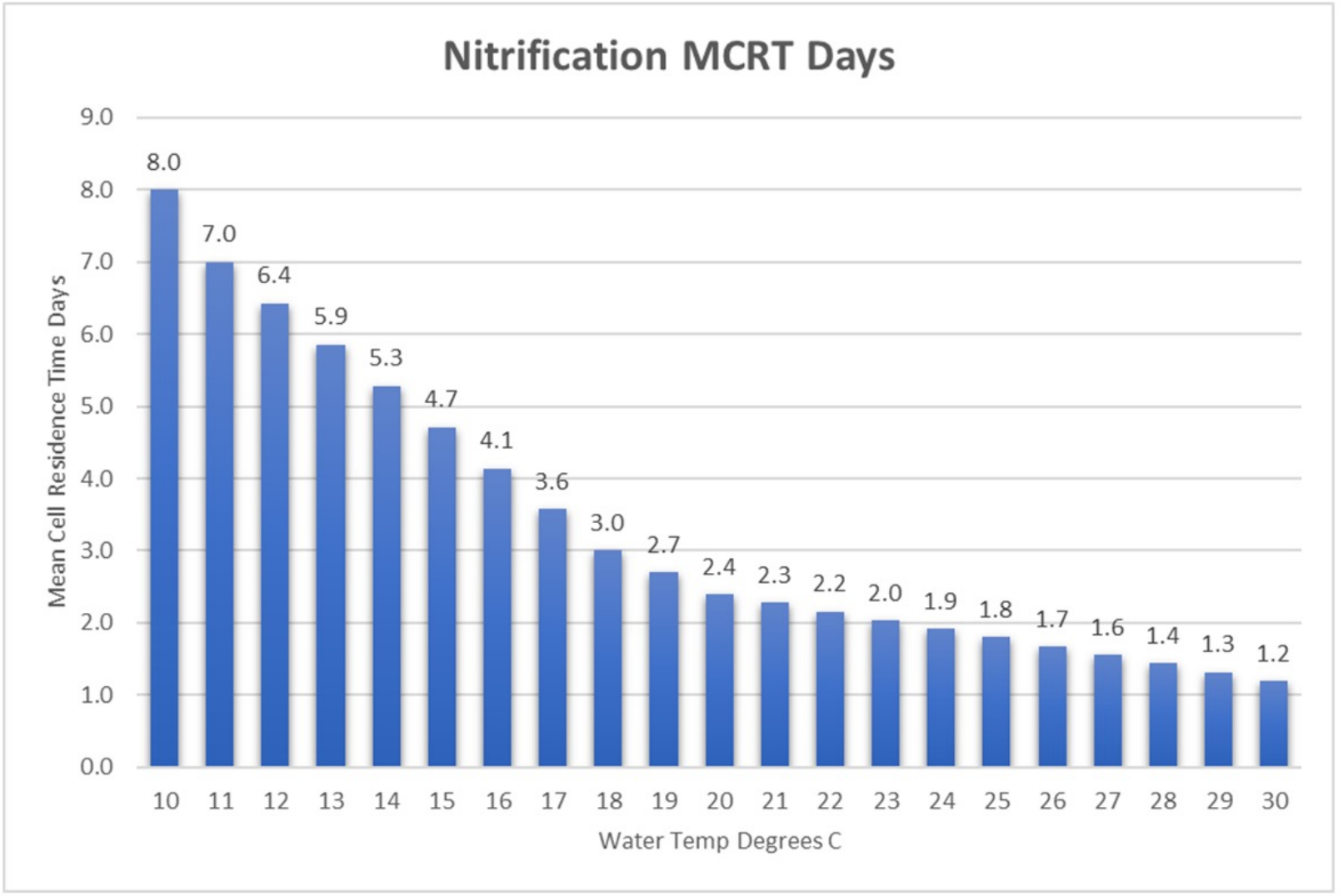
Activated Sludge
Nitrification / Denitrification



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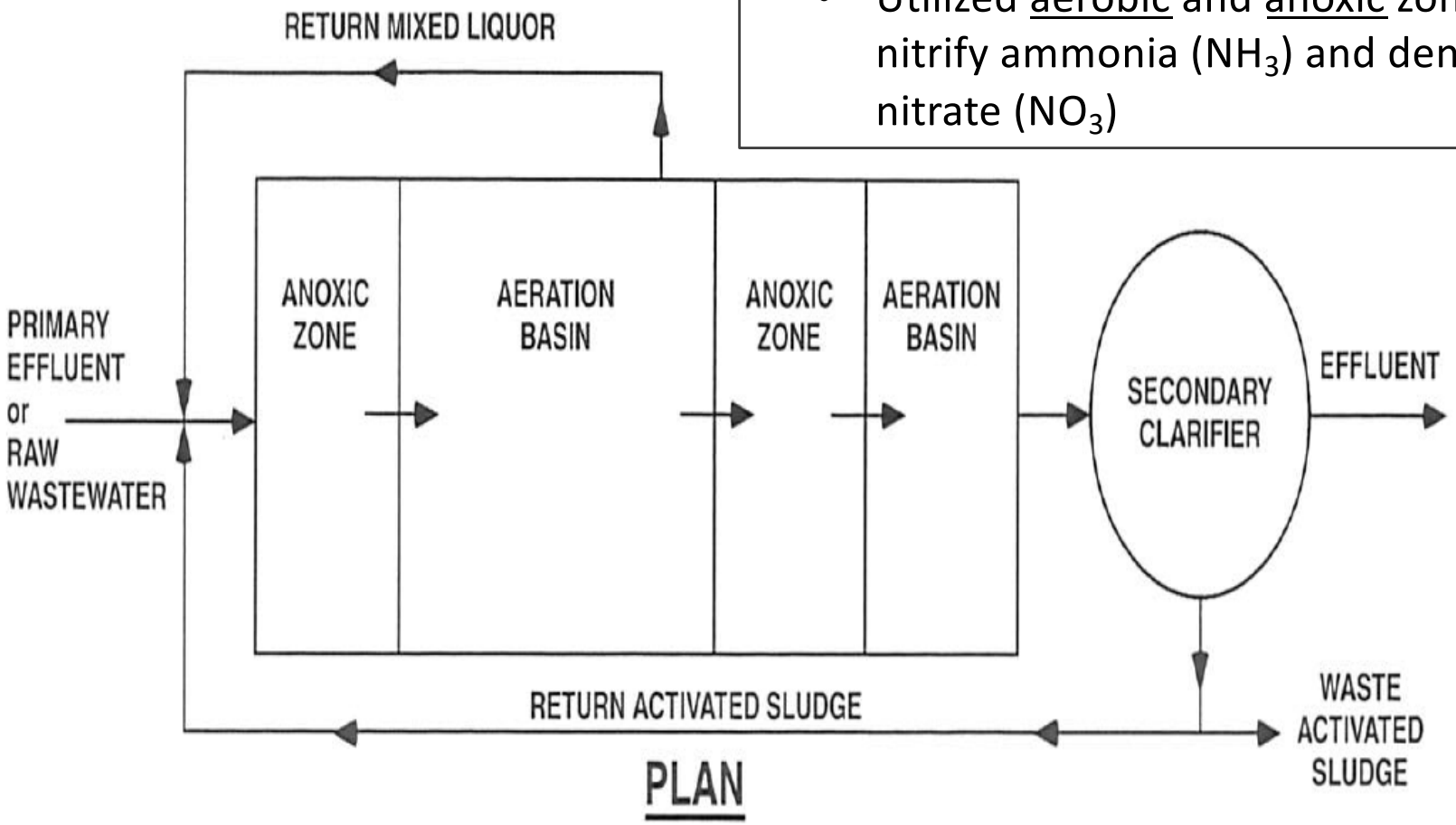
Activated Sludge
Nitrification / Denitrification

Bardenpho Process

- A conventional Activated Sludge process that removes Nitrogen compounds
- Utilized aerobic and anoxic zones to nitrify ammonia (NH_3) and denitrify nitrate (NO_3)



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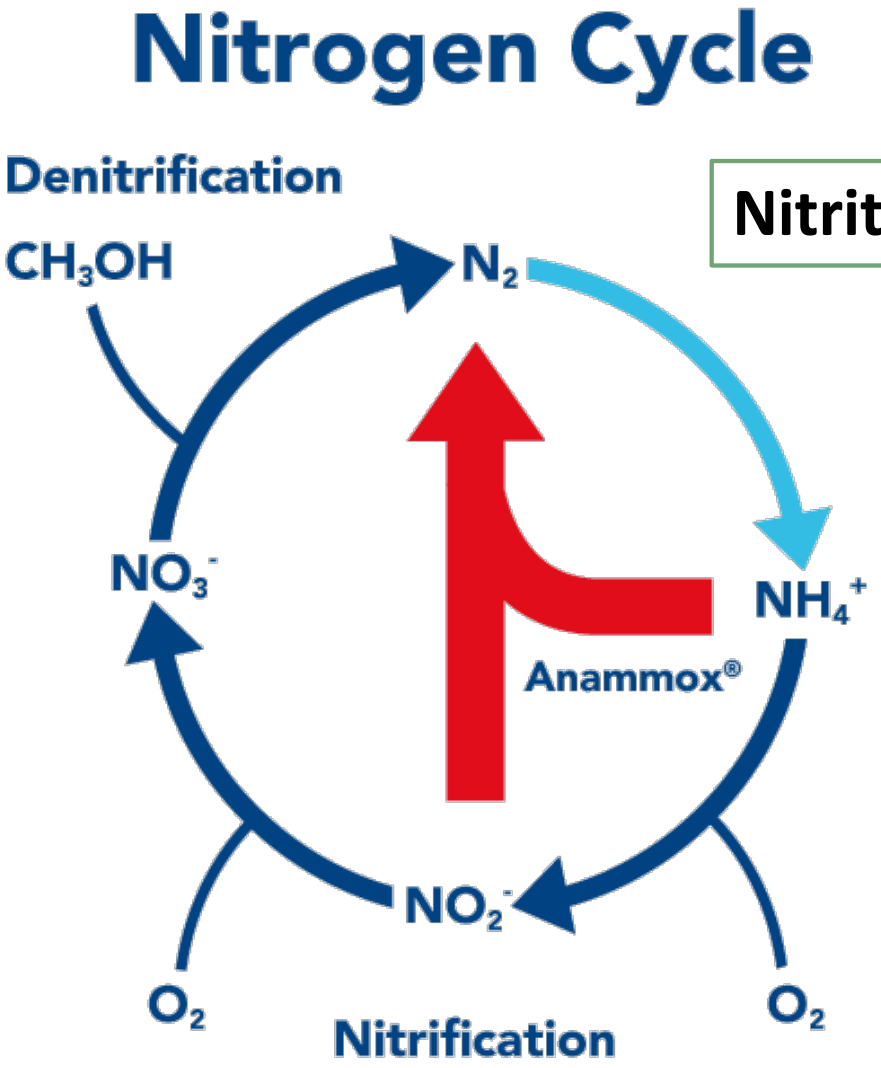
Activated Sludge
Nitrification / Denitrification



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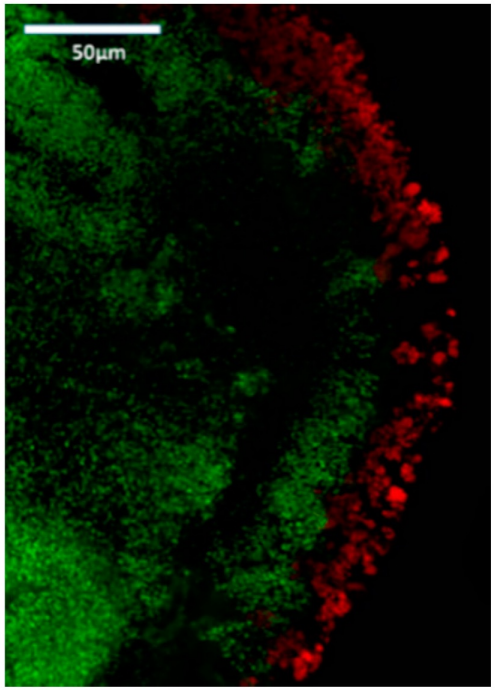
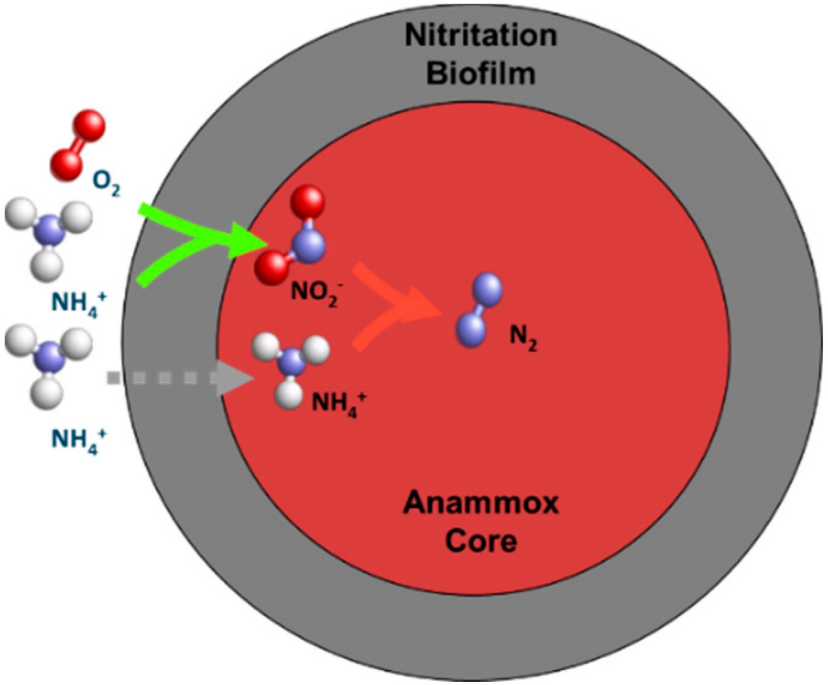
Activated Sludge
Nitrification / Denitrification

- Granular Activated sludge
- Anammox Bacteria
- Simultaneous Nitrification/Denitrification





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Bay area water/wastewater workforce reliability

CALIFORNIA WATER BOARDS

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