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US Territories Wastewater Operator Training Series

Secondary Treatment Part 1- Activated Sludge

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Activated Sludge Process (ASP)

What is the Activated Sludge Process (ASP)?

Secondary Treatment Process

Biological Process

Microorganisms convert dissolved and suspended organics into settleable solids

- Replicates natural process
- Uses microorganisms already present in wastewater

Primary goal is to remove biochemical oxygen demand (BOD)



ASP Details

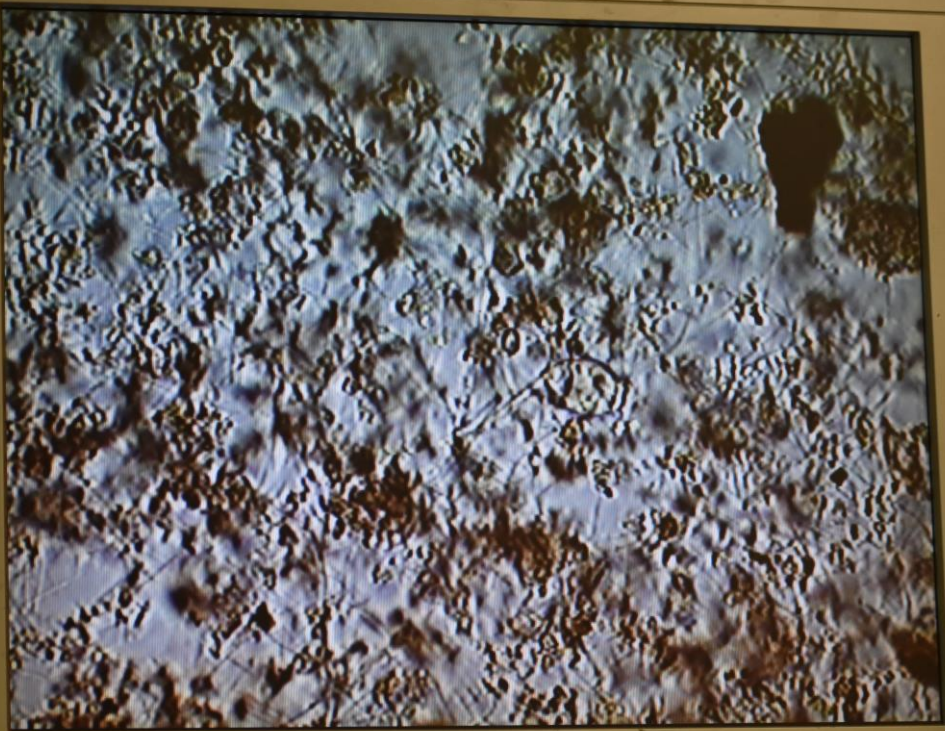
Influent is treated in an aeration tank

Primary effluent mixes with cultivated biomass to create a "mixed liquor"

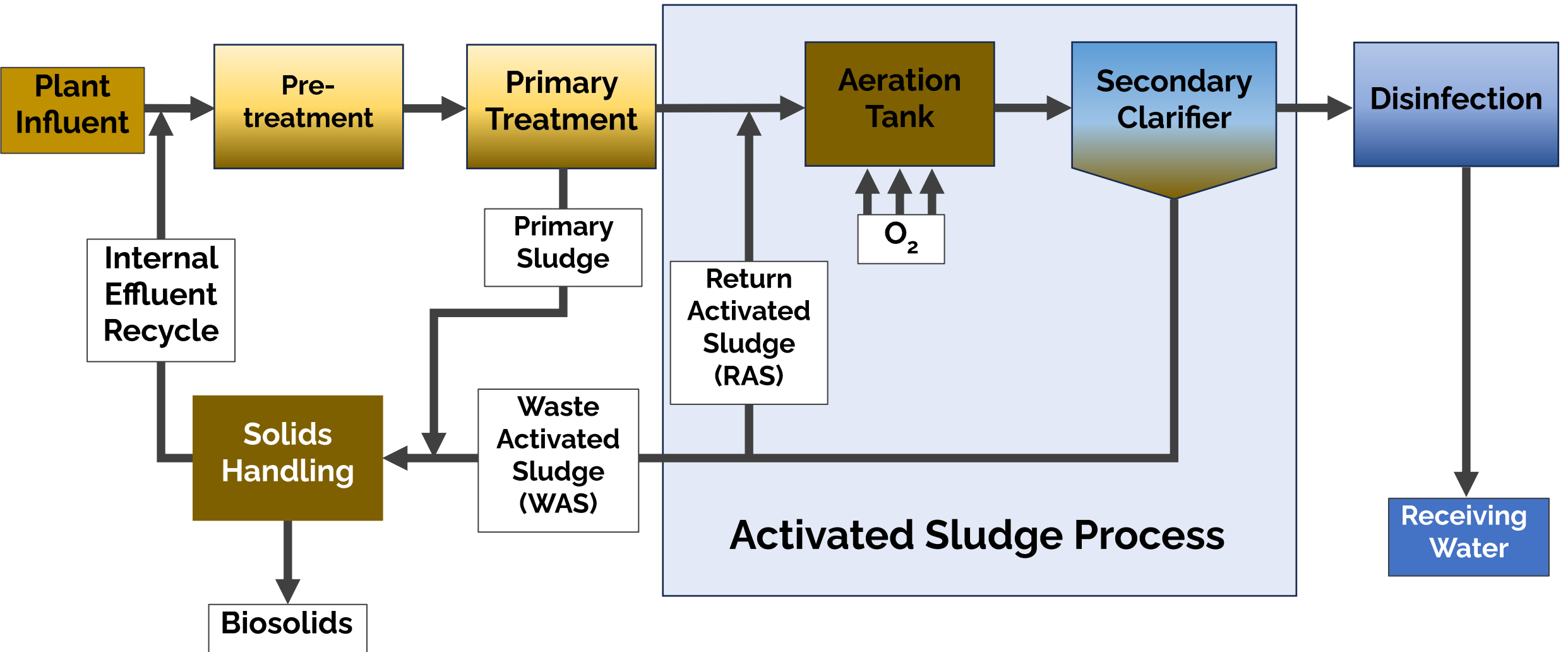
Biomass utilizes dissolved oxygen to consume organics and pollutants, converting them to CO_2 , microbial mass, and water

Sludge is settled in a settling tank where is it then:

- Returned to maintain microbial mass
- Wasted



Wastewater Flow Schematic



Goals of Activated Sludge

Activated Sludge Can Remove:

- BOD
- Suspended Solids
- Ammonia
- Nitrates
- Pathogens

And can aid in other pollutant removal!



ASP Components

Activated Sludge Components

Aeration

Mixing

Settling

Influent

Meters, Sprayers,
Recycle Pumps



Important Terms

Aerobic Organisms- Grow and survive in environments with free oxygen

➤ Dissolved Oxygen (DO)- Molecular oxygen available in water

Anaerobic- Environment without free oxygen

Biochemical Oxygen Demand (BOD)- Organic strength of wastewater

Chemical Oxygen Demand (COD)- Oxygen required to chemically oxidize the organics in wastewater

Mixed Liquor- Mixture of microorganisms, organics, and inorganics present in wastewater

➤ Mixed Liquor Suspended Solids (MLSS)- Suspended solid concentration in mixed liquor

➤ Mixed Liquor Volatile Suspended Solids (MLVSS)- Living portion of MLSS

Aeration

Purpose of Aeration:

- Provide oxygen supply to aerobic microbes
- Mixing
- Promoting biological treatment

How is Aeration Accomplished?

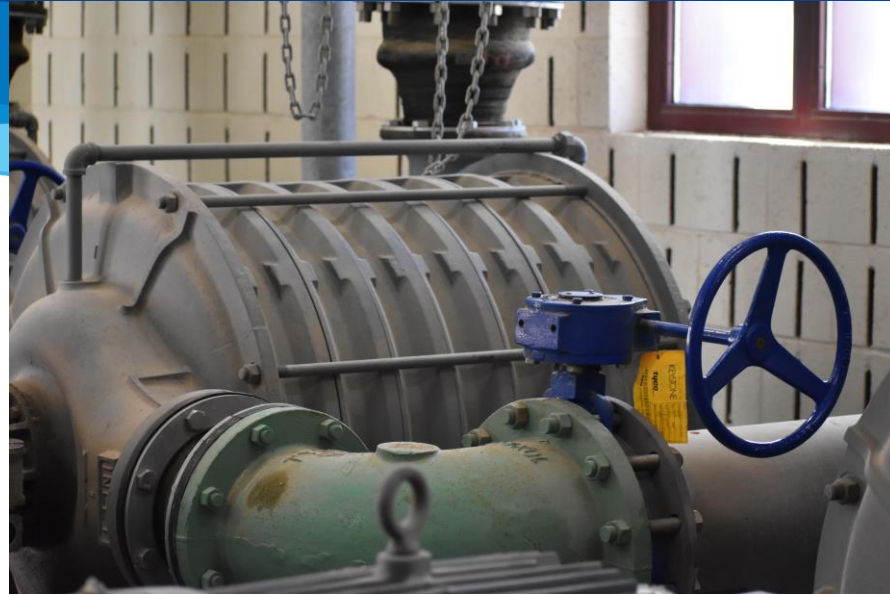
- Diffused Aerators
- Mechanical Aerators
- Jet Aerators

Air is provided by:

- Blowers or Compressors
- Distributed through main header to diffuser network on the bottom of the reactor (for diffusers)



Blowers and Aerators



Aerator Operation

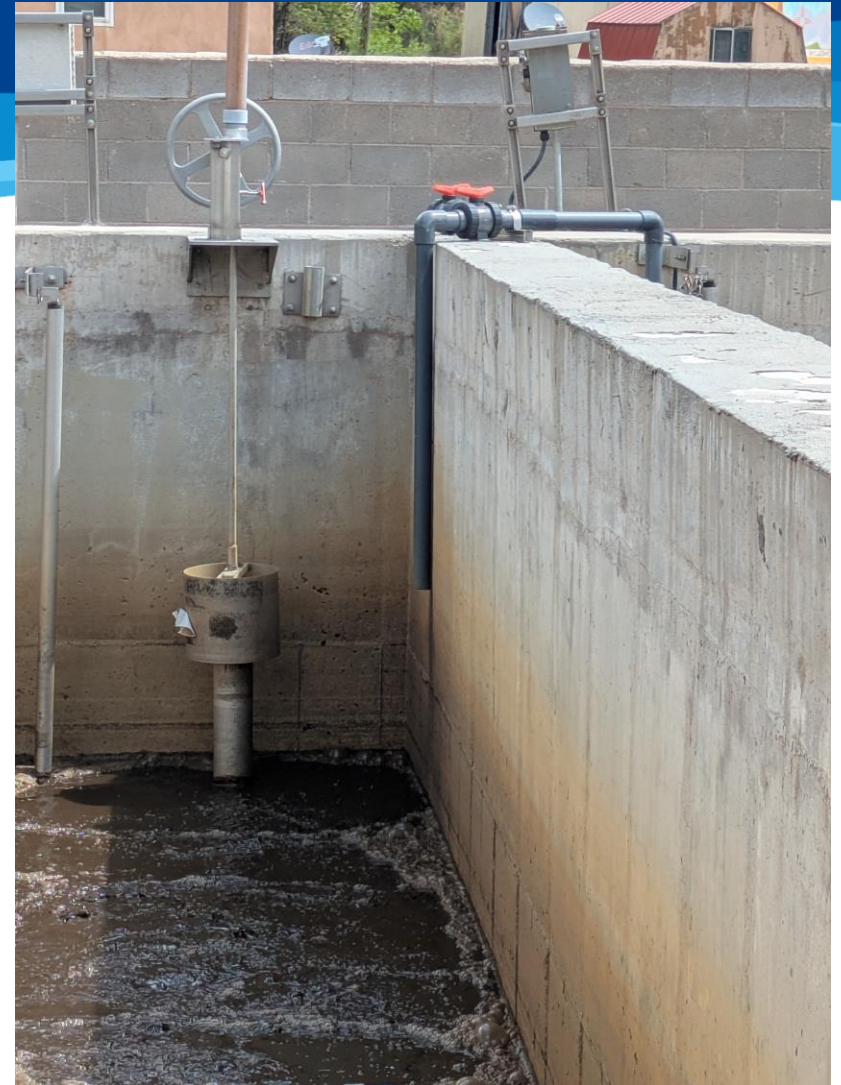
Operators should maintain DO levels and monitor airflow

- Min 1-2 mg/L
 - DO controlled by control valve or blower/compressor output
 - Controls can be manual or automatic
 - Monitored with in situ sensor or handheld probe
- Monitor blower or compressor output
- Clean air-filters regularly

Monitor Diffusers/ Surface Aerators/ Nozzles

- Inspect for clogging and fouling
- Identify dead zones

Purge air lines frequently



Aerator Start-Up

Blowers/ Compressors

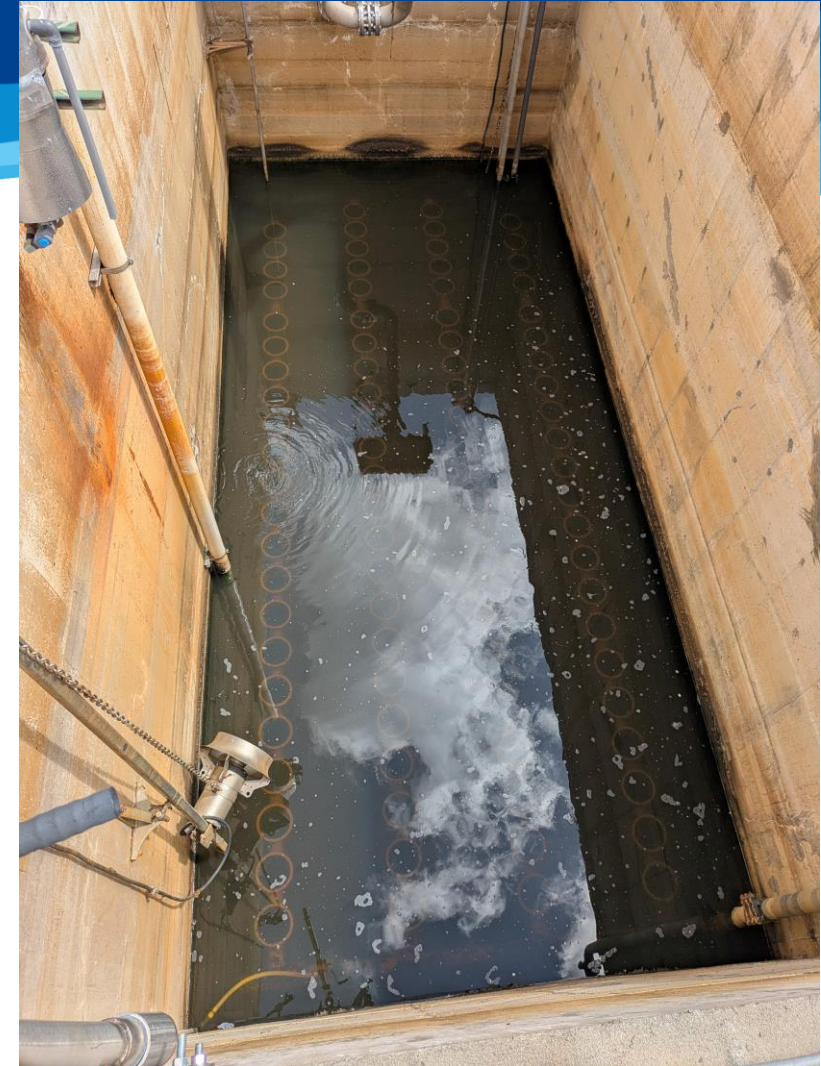
- Check pressure differential and flow according to manufacturer specifications
- Inspect air relief valves and lubrication container

Air Header

- Check line-ups and flow

Diffusers

- Aeration blowers/ compressors should be initiated with flow 1-foot above the diffusers
- Inspect diffusers for unusual air patterns



Mixers



Used to keep solids suspended

- Prevents unwanted settling

Creates uniform distribution of microbes, nutrients and DO

Prevents dead zones

Promotes contact between microbes and nutrients/ pollutants

Mixer Types:

- Mechanical mixers

 - Submersible

 - Important for anaerobic zones

- Diffused air

- Hydraulic Mixing

 - Mixing box

Settling

Separates treated water from solids

Occurs in secondary clarifiers or settling tank

Allows for sludge recycling and wasting

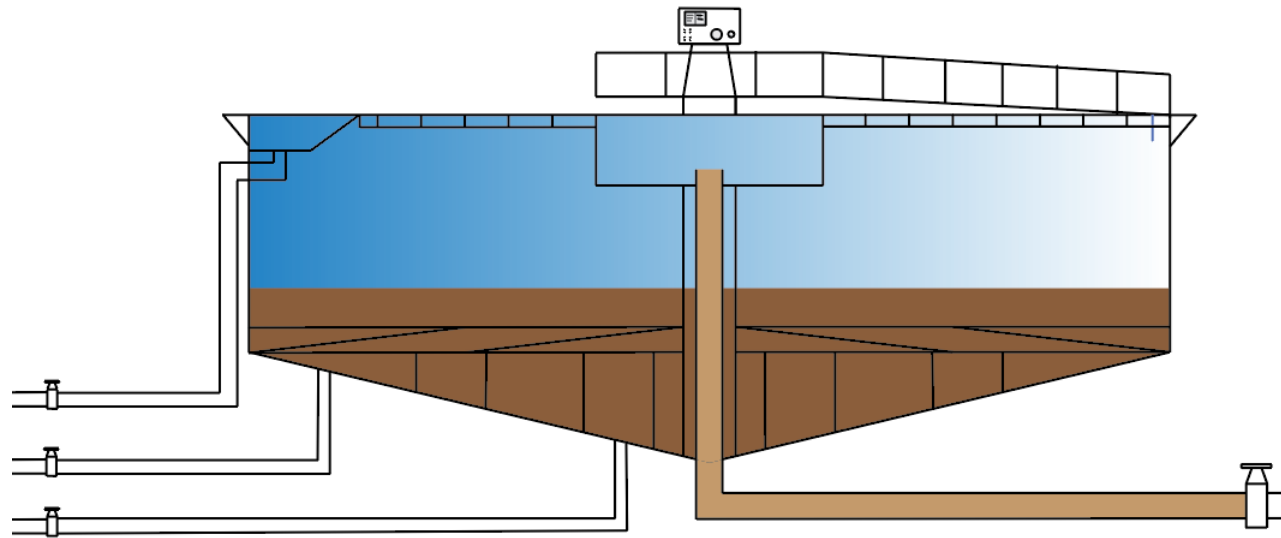
Improves effluent quality

Secondary clarifiers are designed the same as primary:

- Inlet Structures
- Scrapers
- Sludge suction
- Effluent weirs
- Control valves/ walkways/ other support structures



Settling Operations



Maintain flow rates

Monitor sludge blanket depth and surface solids

➤ Core sampling

Control return activated sludge (RAS) and waste activated sludge (WAS)

Monitor signs of poor settling

Frequently inspect mechanical components:
Scrapers, weirs, drives, pumps, etc.

Activated Sludge Influent

Flow is gravity fed or pumped in
Influent controlled by a series of gates or valves

- Flow should not exceed design specifications
- Gates and valves should be exercised regularly
- Can be monitored with BOD or COD analysis

Initial area may be anoxic

- Flow recycled for denitrification sometimes mixed with activated sludge influent



Other Activated Sludge Equipment

Meters

- DO
- MLSS
- Ammonia
- Nitrate

Recycle Pumps

Sprayers



The background features a dense field of 3D question marks. Some are a bright, metallic gold color, while others are a dark, muted blue. They are scattered across the frame, creating a sense of depth and mystery. A semi-transparent dark blue horizontal bar is positioned across the middle of the image, serving as a backdrop for the text.

Poll Question 1

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Poll Question 2

Activated Sludge Biology

Microbial Processes

Aerobic respiration

Aerobic Microbes + O_2 + organic material \rightarrow CO_2 + biomass

Nitrification

NH_4^+ \rightarrow NO_2^- \rightarrow NO_3^- (requires oxygen)

Denitrification

NO_3^- \rightarrow N_2 gas (requires anoxic conditions)

Phosphorus uptake

PAOs (Phosphorus Accumulating Organisms) store P

Microorganisms

Aerobic, anaerobic, and facultative microorganisms are all important in activated sludge processes

Microbes types include:

- Bacteria- 90-95% of activated sludge biomass
- Protozoa
- Rotifers
- Viruses
- Fungi
- Algae

Aerobic Bacteria

Utilize oxygen to consume BOD and increase biomass

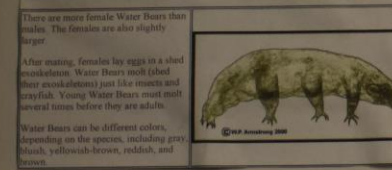
Reproduce relatively quickly

Single-cell microorganisms

Some participate in nitrification

Produce little to no odor

Vulnerable to toxic shock and environmental changes



Facultative Anaerobes

Utilize free or chemically bound oxygen

- Uses oxygen from nitrates or sulfates when free oxygen is unavailable

Present in many wastewater processes

- Provide denitrification in activated sludge

Grow slower in anaerobic conditions and can lead to odors



Filamentous Bacteria

Create mesh-like structure to provide structural support for activated sludge flocs

Flocculation encourages contact with wastewater nutrients and favorable settling

30 different species of filamentous bacteria

Overgrowth occurs due to low DO, high BOD, nutrient imbalances, long sludge age, etc.

- Sphaerotilus natans- low DO
- Nocardia spp. and Microthrix parvicella- low organic loading



Nitrogen Removal

Nitrogen removed through nitrification and denitrification

Ammonia (NH_3)- Toxic and present due to urine

Nitrate (NO_3)- Leads to methemoglobinemia (“Blue Baby Syndrome”)

Ludzack-Ettinger- Activated sludge effluent recirculated to anoxic zones at the beginning of the activated sludge reactor for denitrification

Denitrification must be separated from aeration

Nitrifiers and Denitrifiers

Nitrification:

- Nitrosomonas convert ammonia to nitrite



- Nitrobacter converts nitrite to nitrate



Denitrification:

- Facultative bacteria convert nitrate to nitrogen gas



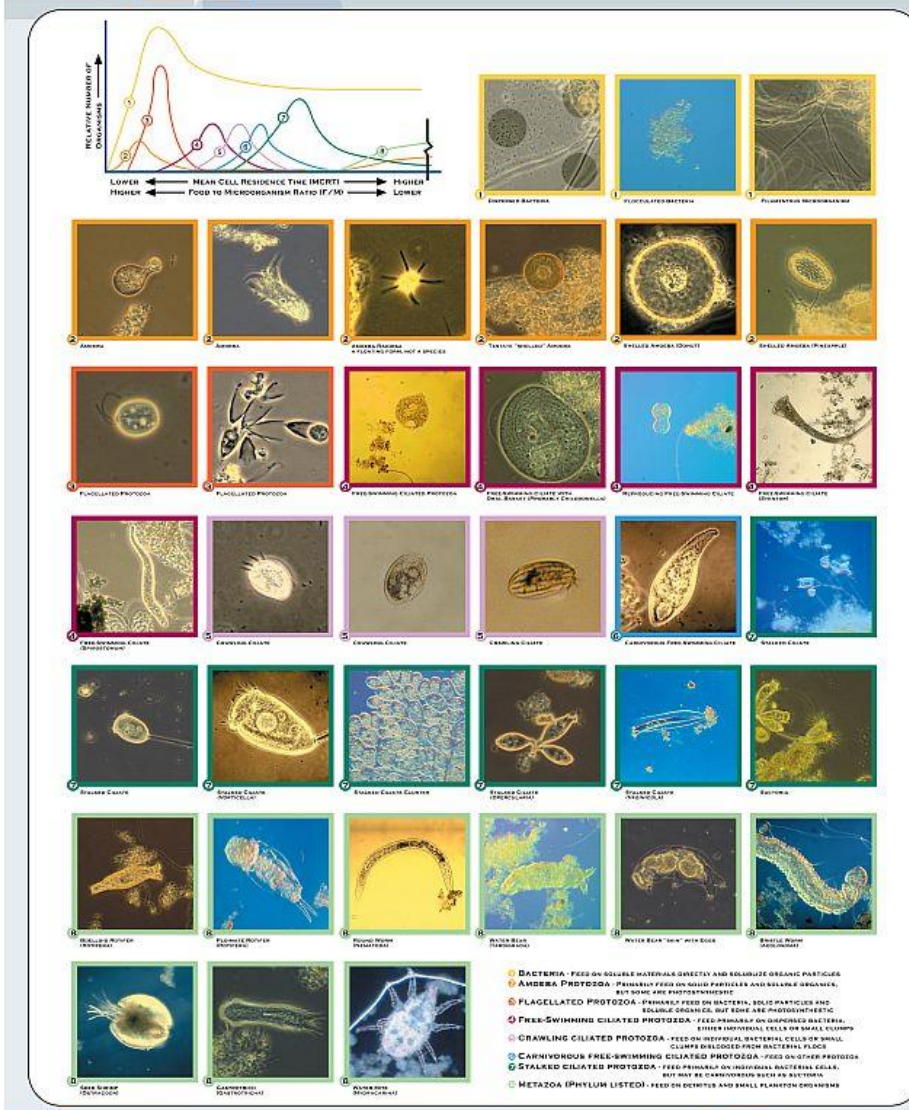
Other Organisms

Protozoa

- Giardia and Cryptosporidium contribute to waterborne diseases
- Amoeba- indicate young sludge
- Free-Swimming and Stalked Ciliates- sludge is approaching stable conditions

Rotifers- Multicellular microbes that are present in older sludge

- May be associated with poorly settling sludge



Microscopic Analysis is Critical



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Poll Question 3

Operational Variables, Characteristics, and Control Basics

Why are activated sludge process (ASP) characteristics and control important?

Biological process with more variables than physical and chemical processes

Operational data must be used to make process control adjustments

Characteristics change daily and the ASP process must be maintained in a balance state

Objectives of ASP:

- Maintain the aeration tank to produce floc-forming bacteria
- Flocculate and settle the flocs inside the secondary clarifier
- Manage the activated sludge to maintain a healthy proportion of microorganisms in the system



Operational Variables



Key parameters that indicate activated sludge efficiency, stability and compliance

Indicate biological, chemical, and physical conditions

Determined using lab analysis, wastewater sensors, calculations, and in the field observations

Activated sludge optimization requires lab analysis and detailed records

Key Parameters



DO- 1-2 mg/L residual required

BOD/ COD- Used to calculate food to microorganism (F/M) ratio and make process adjustments

MLSS

- Used in calculating sludge age, F/M ratio and Sludge Volume Index (SVI)
- Measured with a probe or in the lab
- Lab analysis required filtering and drying at 103-105°C for at least 1-hour

Key Parameters Cont'd

Sludge age- Calculated using Sludge Retention Time (SRT) and Minimum Cell Retention Time (MCRT)

pH- Biological treatment most efficient within pH of 6.5-8.5

- Unusual pH indicates toxic loads and extreme variation harms both microorganisms and damage equipment

Alkalinity- Decreased by nitrification

- Decreases buffering capacity
- May be regulatory parameter

Nutrients- Phosphorus and Nitrogen can be regulatory requirements

- Nutrient imbalance can lead to poor settling, bulking, poor treatment, etc.

Healthy Activated Sludge

Visual

- Solid brown and sometimes grey colored activated sludge
- Diffused air should produce fine, crisp, white bubbles
- Formation of well-structured and dense flocs of microorganisms that settle easily for a distinct and dense sludge blanket

Olfactory (smell)

- Earthy smell- fresh soil
- Lack of foul odors

Unusual Sludge Correction

Unusual color,
aeration or
smells

- Aeration and system assessment

Pin Floc

- Increase F:M or decrease sludge age

Common Issues

Bulking Sludge
Foaming
Settling Problems
Sludge Overproduction
Nutrient Imbalance
Organic Overloading
Poor Flocculation



Sludge Characteristics

SVI- 80 - 120

- SVI is controlled by optimizing MLSS through adjusting RAS and WAS

Secondary Clarifier Depth- 2-3 feet

Mixed Liquor Suspended Solids

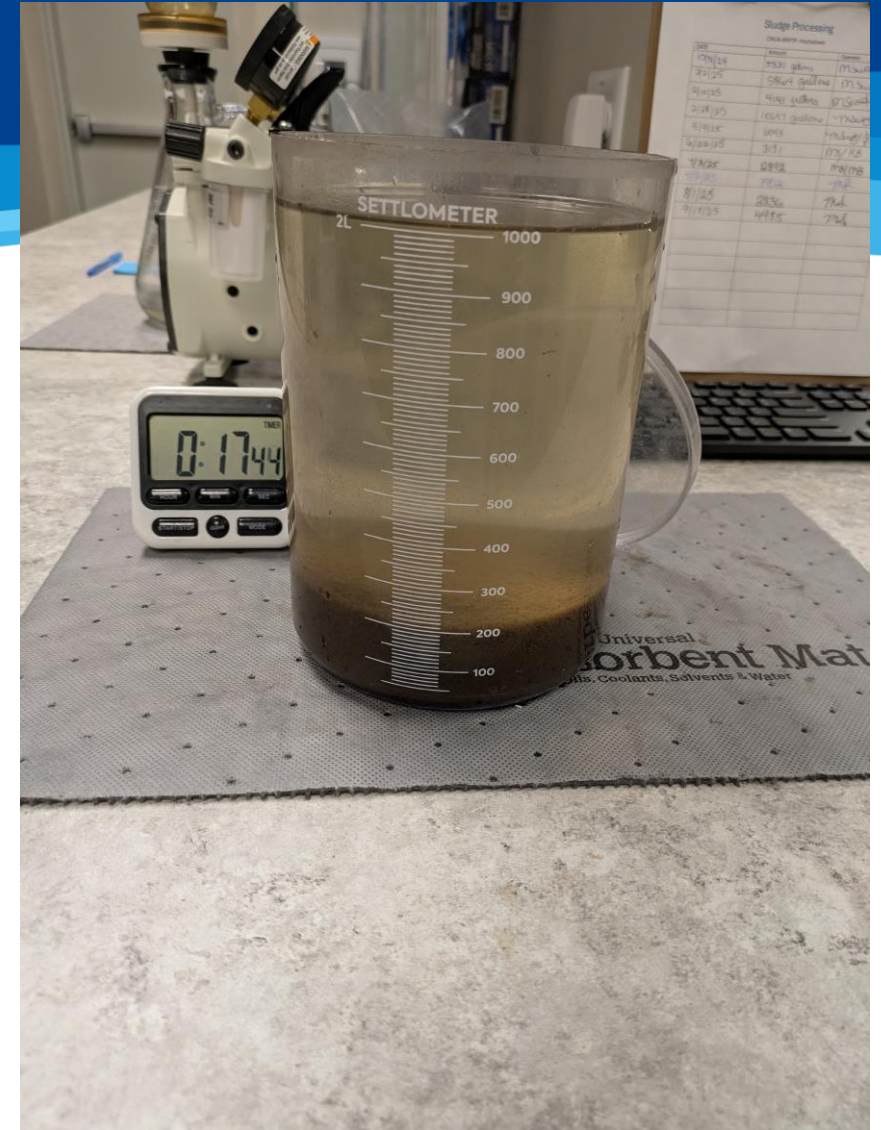
- Concentrations of microorganisms and suspended solids in activated sludge

- 1000-4000 mg/L

F:M ration- 0.2-0.6

Sludge Age- MCRT or SRT

- SRT- 3.5-10.0 days



Dissolved Oxygen (DO)

DO concentration .5-4.0 mg/L

- Provides final electron acceptor for aerobic respiration and nitrification
- DO provides oxygen for aerobic activity
- Can be somewhat analyzed visually



Dissolved Oxygen Issues

Can be observed or analytically determine

Inadequate Aeration

High Temperatures

Clogging and Fouling

High Organic Loading, Microbial Overgrowth, and Excessive solids

Toxic shocks

Ammonia and TKN

Ammonia Influent 10- 60 m/L

Ammonia Effluent 1-10 mg/L

- Untreated ammonia and TKN results in eutrophication in receiving waters
- Urine>Urea>Ammonia
- Ammonia can be analyzed with laboratory analytics or a probe.

Ammonia Troubleshooting

- DO should be increased to remove elevated ammonia concentrations
- Increase recirculation
- Optimize pH or add alkalinity



Nitrate

Nitrate Effluent < 10 mg/L

- Nitrate is a nitrogen compound found in wastewater and the by-product of nitrification.
- Removed by denitrifying bacteria in the absence of oxygen.
- Large amounts of nitrate in water used as a drinking water source can result in methemoglobinemia.

Nitrate Removal

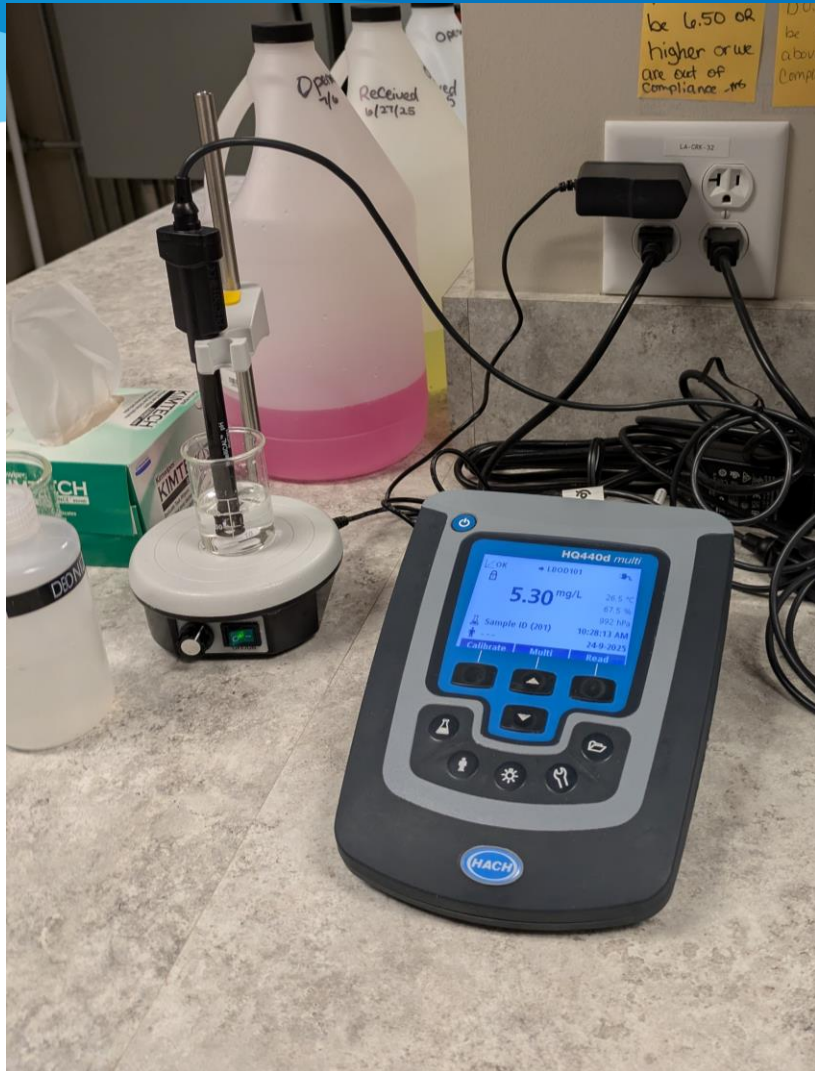
- Add anoxic zone
- Increase recycle rate (modified processes)



Typical ASP Lab Results

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

BOD/ COD analysis



Measurement of oxygen consumed by wastewater over specific time frame

BOD- Standard Methods 5210

- Prevalent method
- DO measured before and after 5-day incubation at 20°C

COD- Standard Methods 5220

- Measures potassium dichromate consumption over 2-hour period
- Total test time = 3-4 hours
- Faster method used to determine wastewater strength

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Poll Question 4

Questions?

CONTACT INFORMATION



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