Diagnosing Wastewater Lagoon Problems

Tuesday, August 16th, 2022
1- 2 pm EST

Environmental Finance Center
Syracuse University

Great Lakes Environmental Infrastructure Center
Environmental Finance Center for EPA Region 5

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

Today’s presenters:

Robert Davies, Engineering Intern – Great Lakes Environmental Infrastructure Center at Michigan Technological University

Gregory Pearson, Water and Wastewater Systems Trainer - Great Lakes Environmental Infrastructure Center at Michigan Technological University

- 4th Year Civil Engineering Student, Water Resources focus

Michigan.org: Scenes from Michigan’s beautiful Upper Peninsula.

Michigan Technological University

Great Lakes Environmental Infrastructure Center

Environmental Finance Center for EPA Region 5

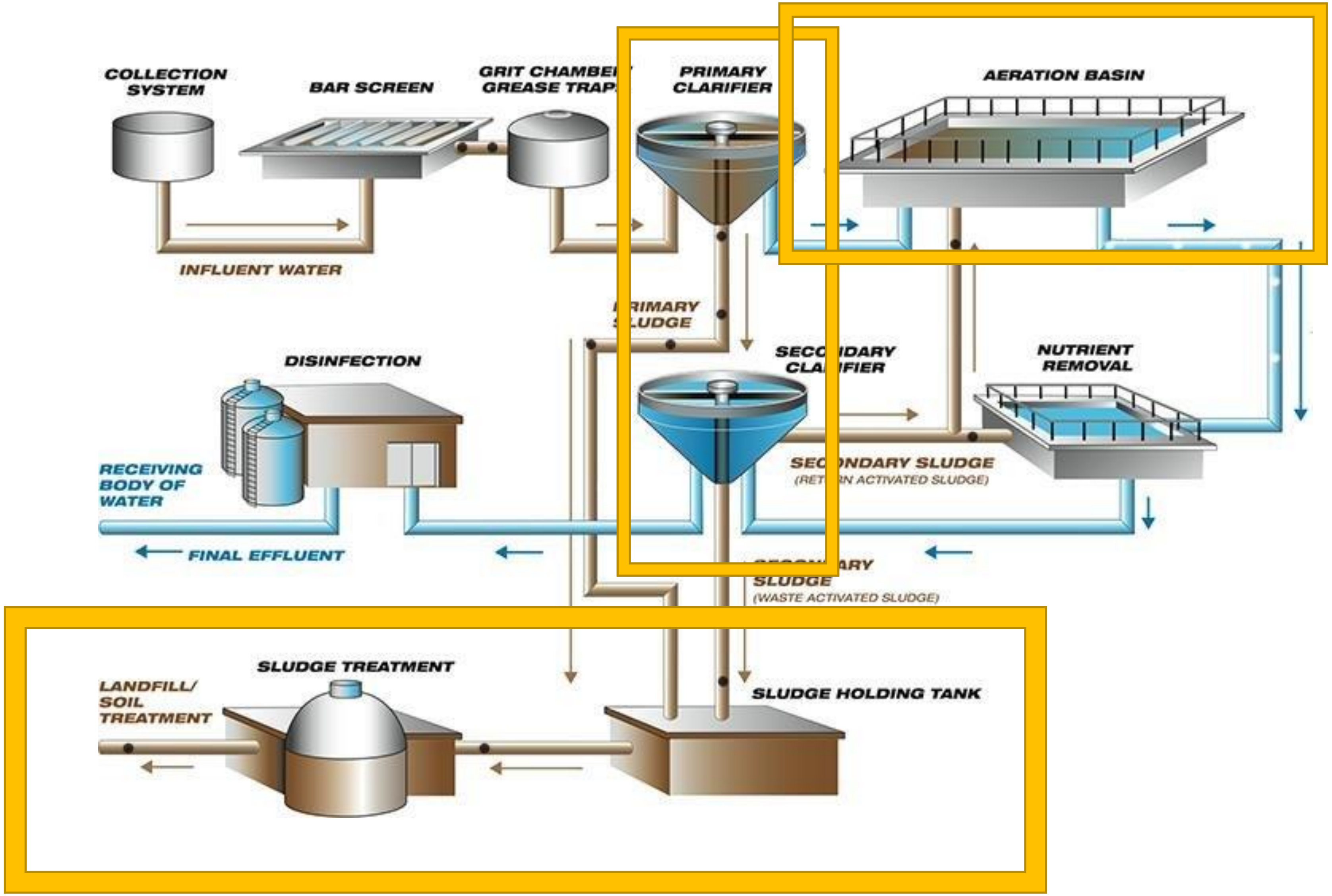
Objectives

- Attendees will…
  - Explain the causes of excess sludge accumulation in wastewater lagoons.
  - Determine appropriate corrective measures for typical lagoon problems.
  - Discuss ways to minimize short-circuiting in wastewater lagoons.
  - Explain facultative and aerobic processes in wastewater treatment lagoons.
  - Discuss methods operators can use to measure and evaluate sludge accumulation.
  - Evaluate costs associated with sludge prevention and removal.

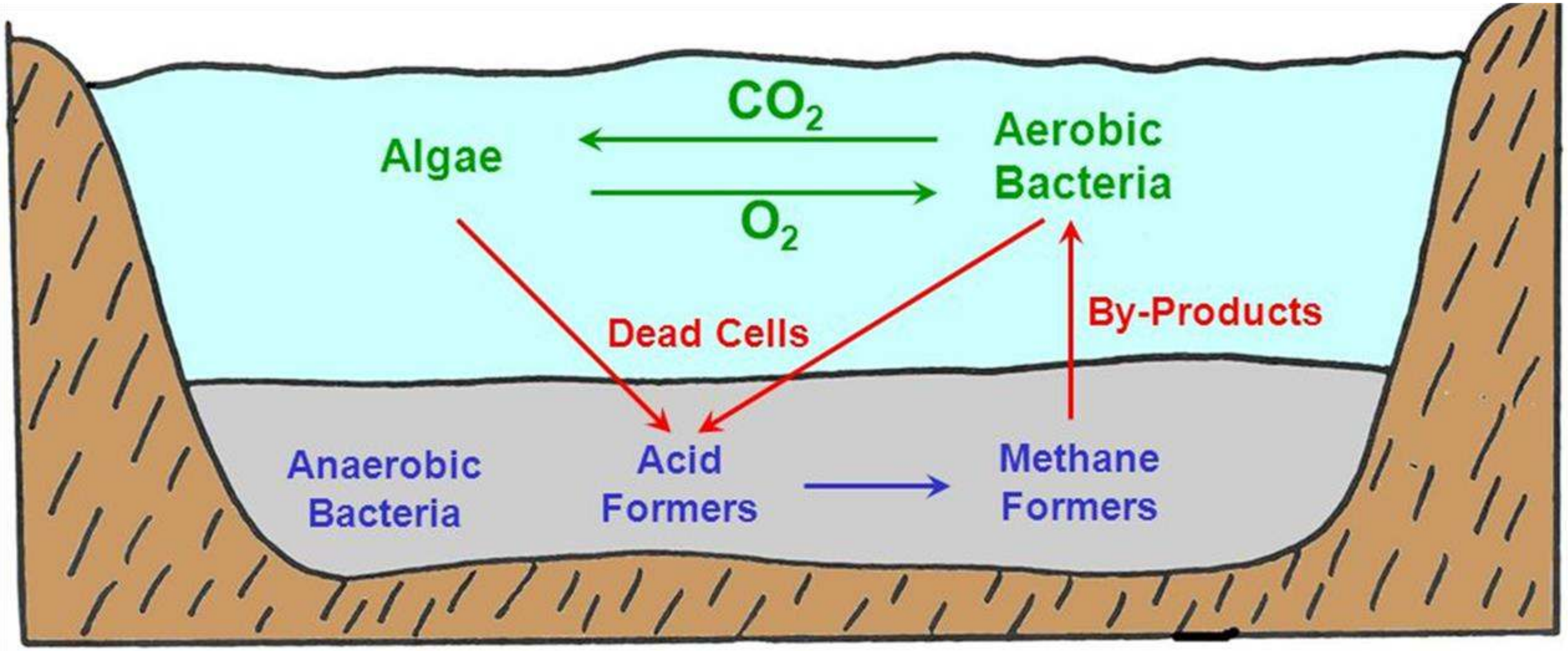
Wastewater Lagoons

- Common components of wastewater systems
  - Relying on natural processes and retention time

Lagoon Function



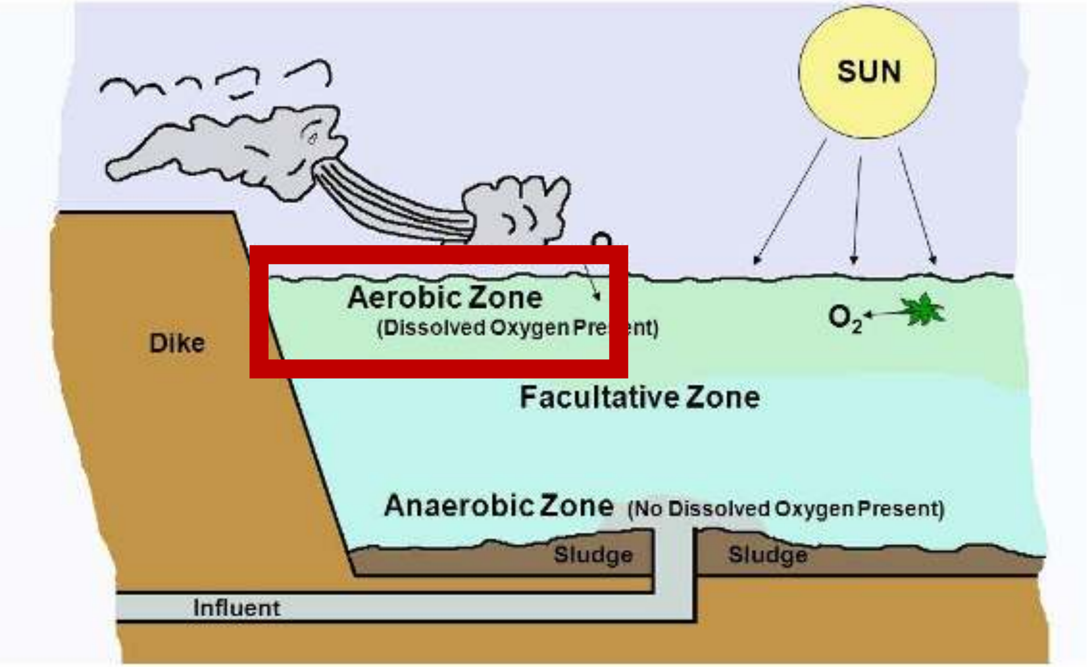
How does the Lagoon Work?



Aerobic Zone

- First two feet of lagoon
- The “Reactor”
  - Control pathogens
  - Removing BOD
  - Generating oxygen
- Reactions happen relatively quick

Zonal Relationships in a Lagoon



Facultative Zone

- Aerobic and anaerobic conditions
- Microbes are very versatile
- Transitional layer

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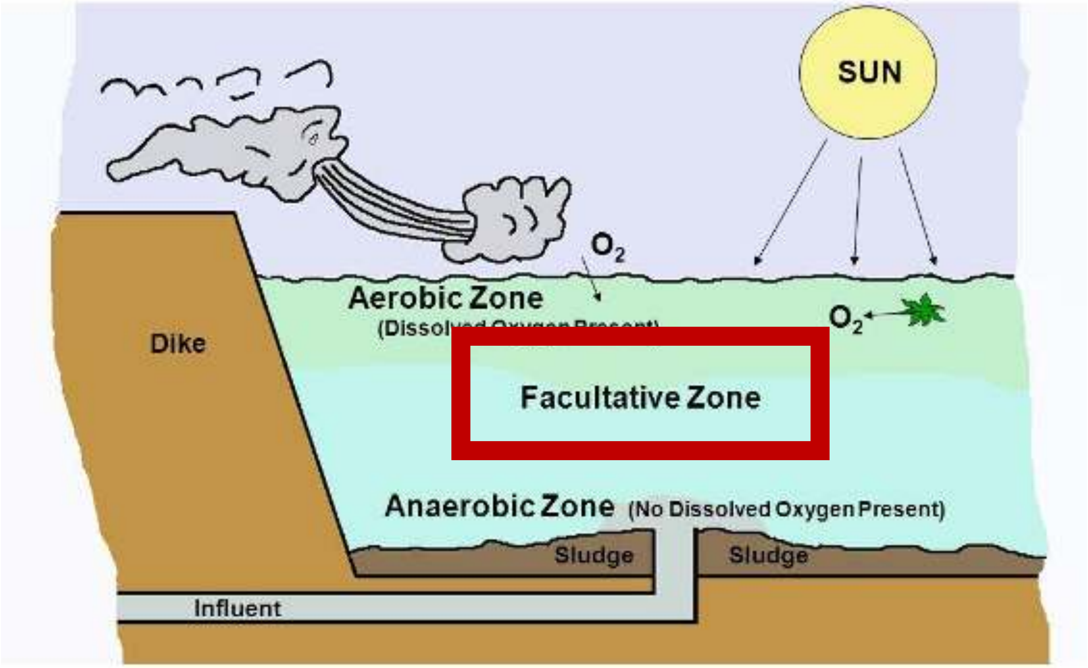
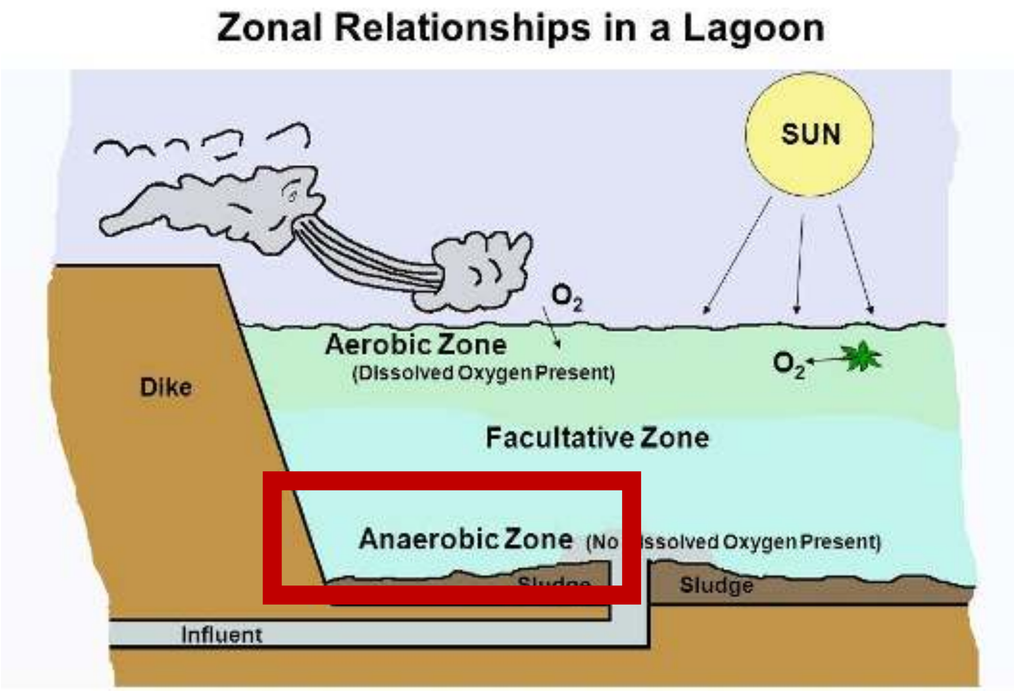


Anerobic Zone

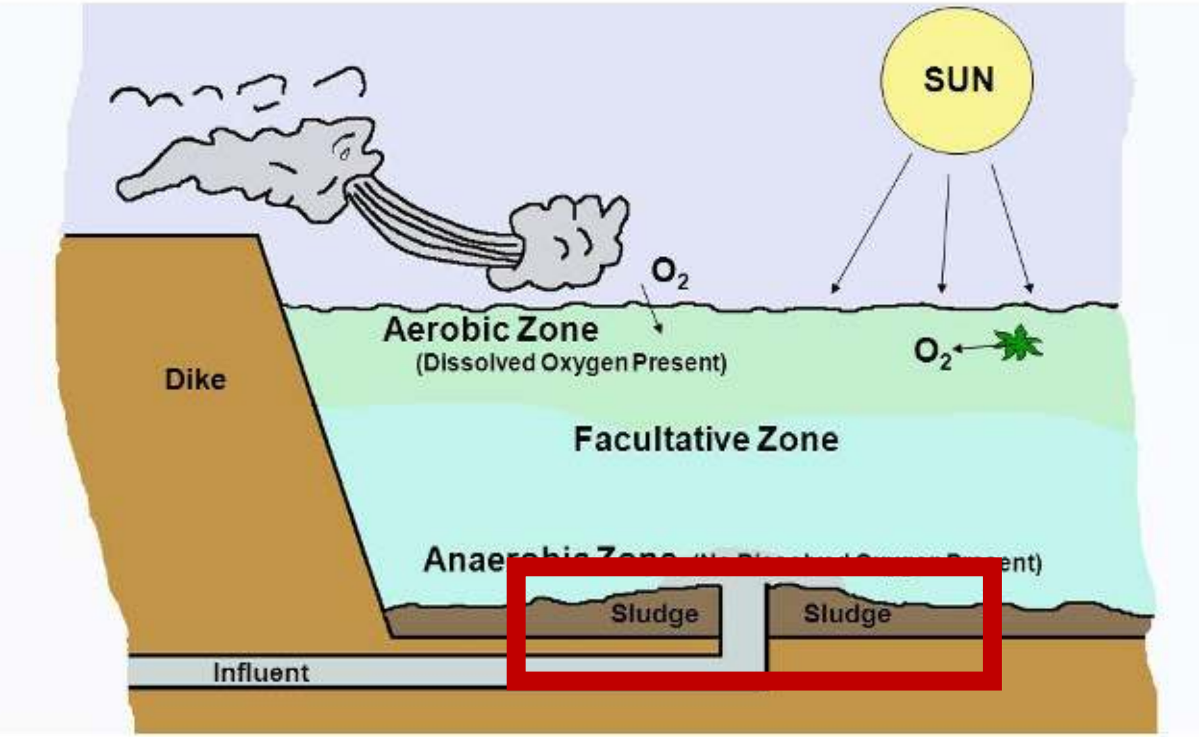
- Low oxygen zone
- “Digester” layer
  - Generates CO2 and other gases
  - Nutrient Retention
  - Helps break down sludge
- Slowest reactions



Sludge

- Settled solids
  - Bacteria, sediment, biologic, etc.
  - Will always accumulate over time
- Critical for proper operation
- Typically planned for removal every 20 year

Zonal Relationships in a Lagoon



The NPDES Permit

- National Pollutant Discharge Elimination System (NPDES)
- Created from the Clean Water Act
- Required for discharge into open water
- Permit derived from susceptibility of receiving water

Effluent Characteristics	Discharge Limitations							Monitoring Requirements	
	Concentration (Specified Units)				Quantity/Loading (lbs/day)			Measuring Frequency	Sampling Type
Parameter	Daily Minimum	Monthly Average	Weekly Average	Daily Maximum	Monthly Average	Weekly Average	Daily Maximum		
Flow (MGD)	-	-	-	-	Report (MGD)	Report (MGD)	-	Daily	Continuous
Dissolved Oxygen (mg/L)	4.0	-	-	-	-	-	-	x Weekly	Grab
pH (SU)	6.5	-	-	8.0	-	-	-	x Weekly	Grab
Total Suspended Solids (TSS) (mg/L)	-	20	30	-	38	58	-	x Weekly	24-Hr Composite
Biochemical Oxygen Demand (BOD_5) (mg/L)	-	20	30	-	38	58	-	x Weekly	24-Hr Composite
Phosphorus, Total (mg/L)	-	1.0	2.0	-	1.92	3.8	-	x Weekly	24-Hr Composite
Ammonia (NH_3-N) (mg/L) (May 1 – September 30)	-	15	-	26	29	-	50	x Weekly	24-Hr Composite
Ammonia (NH_3-N) (mg/L) (October 1 – April 30)	-	-	-	26	-	-	50	x Weekly	24-Hr Composite
E. coli (#/100ml)	-	126	-	410	-	-	-	x Weekly	Grab
Outfall observation (yes/no)	-	-	-	-	Report	-	-	Weekly	Visual
Mercury, Total (ng/L)	-	Report	-	-	Report	-	-	x Monthly	Grab
	12-Month Rolling Average				**12-Month Rolling Average**				
Mercury, Total (ng/L)	-	3.0	-	-	5.8×10^{-6}	-	-	x Monthly	Calculation

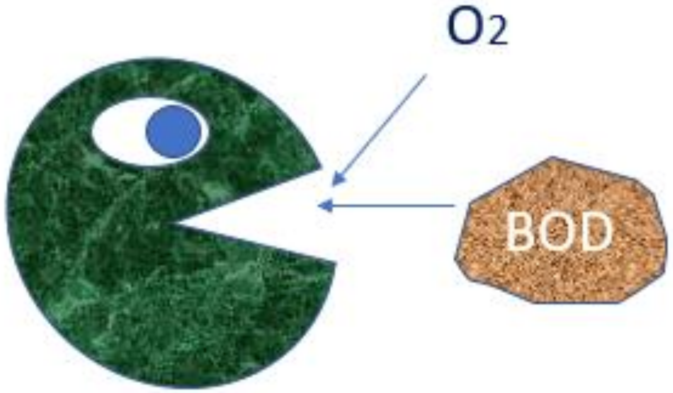
Question

- Is your facility under a NPDES permit?
  - Yes
  - No
  - Unsure

Biochemical Oxygen Demand (BOD)

- Indicates the strength of the waste stream in mg/L. BOD is the food that microorganisms consume during the wastewater treatment process.

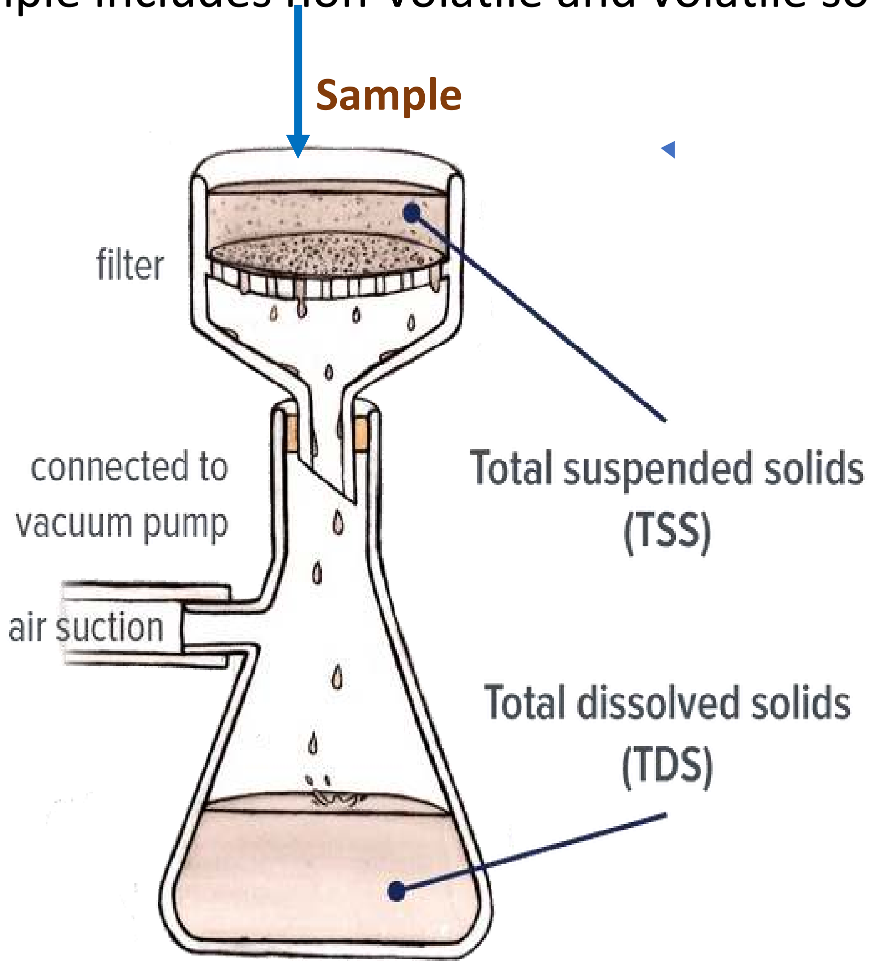
- Determined in a 5-day test that measures how much oxygen is required by bacteria in order to metabolize waste.

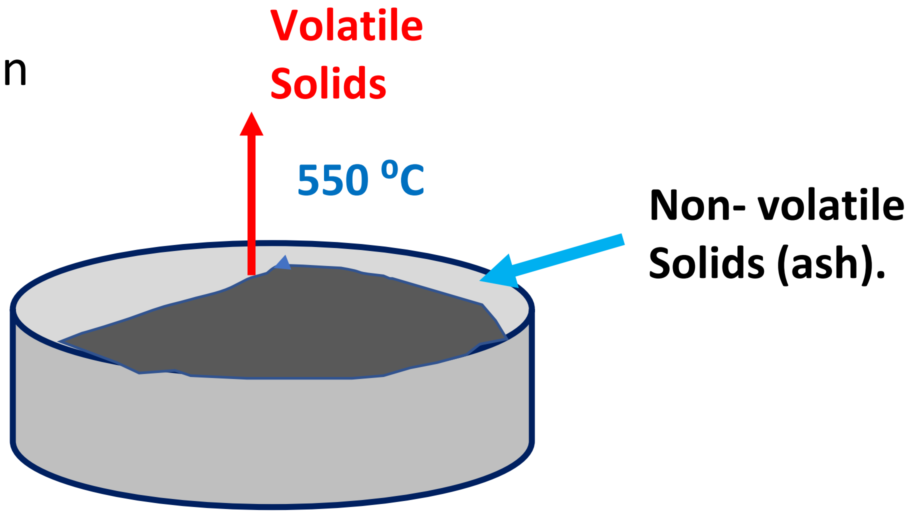


Microorganisms require oxygen to metabolize waste.

Types of Solids

- 0.45-micron filter captures all the suspended solids from a known sample volume.
- Solids are dried and weighed.
- Sample includes non-volatile and volatile solids .





“Campfire” behavior

- Sludge is like a log in fire

Organic Reactions

Total Solids

Inorganic Solids

Organic Material

TSS to BOD Ratio

TSS: BOD Ratio	Cause	Possible Solutions
Less than 1.0	**Old sludge releasing soluble BOD.**	Sludge mixing to reduce VSS content of sludge

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Equal to 1.0	Incomplete treatment due to **short-circuiting**	Baffling to decrease short circuiting. Reduce excess sludge.

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1.5	**Normal** lagoon treatment	

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1.5	**Normal** lagoon treatment	
2.0 to 3.0	**Algal overgrowth**	Aeration and mixing.

When do Problems Arise?

- Permit violations = Potential Environmental Damage
  - BOD
  - TSS
- Problems in a lagoon aren’t always violations

Odors Cause Problems

- Lowell, Michigan Biodigester
  - Shut down after 6 months
  - Largely due to public opinions
- Odors indicate larger problems
  - Increase in anaerobic activity

Question

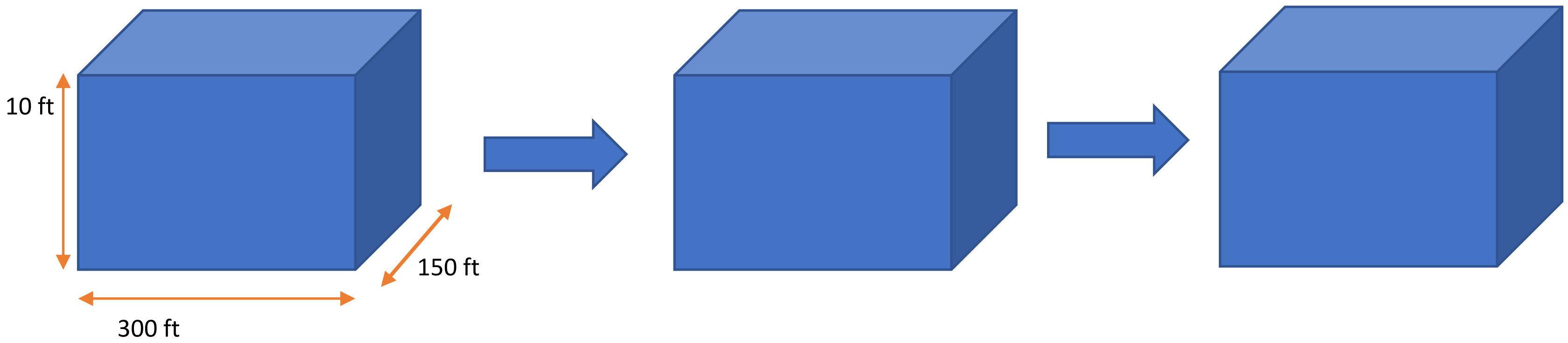
- Which permit characteristic has to do with the ability of an effluent to impair oxygen levels in receiving waters?
  - Total Suspended Solids
  - Biochemical Oxygen Demand
  - Dissolved Oxygen
  - Mercury

When Does Sludge Cause Problems?

- Reduced Lagoon Capacity
  - Capacity is the primary contribution to retention time
  - Feedback loop

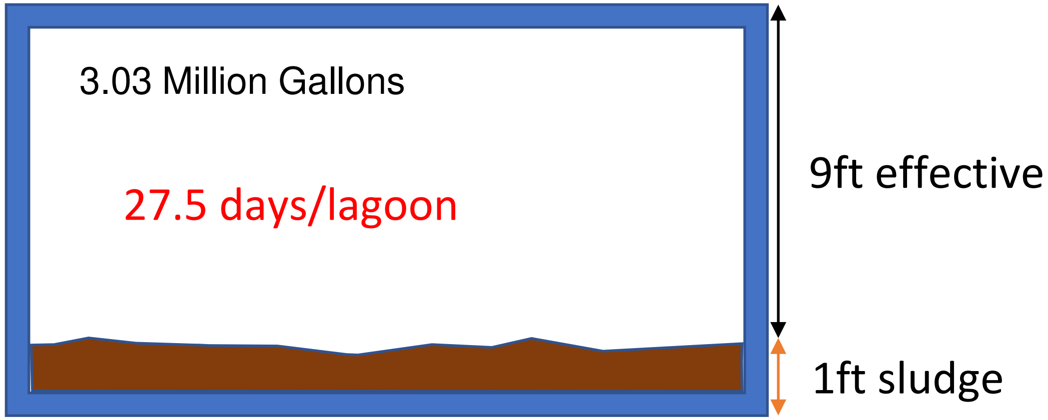
$$\text{Detention Time} = \frac{\text{Volume}}{\text{Flow}}$$

Sample Lagoon

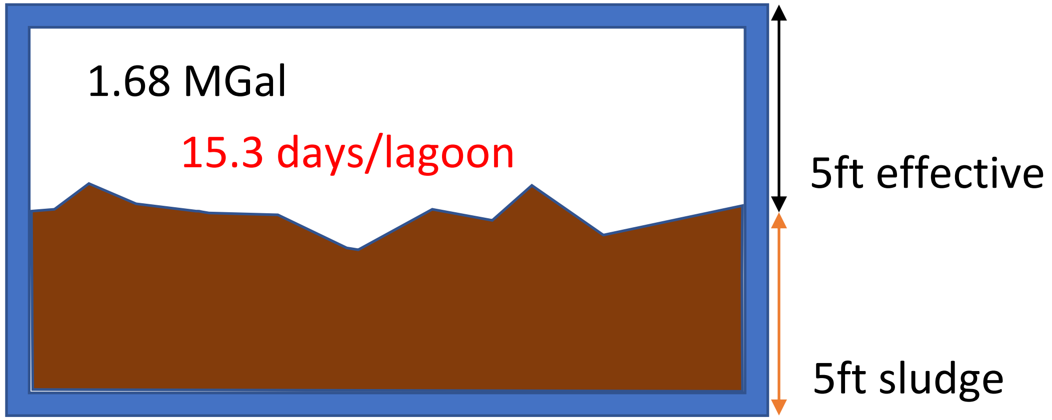


Flow: 11 Thousand Gal/day

Cross section 1:



Cross section 2:



Causes of Sludge Build-up in Lagoons

1. **Normal accumulation of sludge solids**

Inorganic Materials will always build up. Need to minimalize organic materials within the lagoon.

2. **Inadequate mixing**

Mixing ensures that three key elements can be brought into physical contact:

1. Bacteria
2. Dissolved Oxygen
3. BOD

Lagoon with Excess Sludge

Key Points

- Some portion of lagoon sludge is volatile solids which can be further processed.
- Sludge displaces volume, reducing capacity and retention time.

Types of Aerators

Surface aerators are easier to maintain but have less efficient oxygen uptake and circulation.

Diffusers offer more efficient oxygen uptake and minimize dead spots.

Course Bubble

Fine Bubble

Problems Caused by Excess Sludge

1. **Lowers retention time** by taking up treatment volume resulting in incomplete treatment and higher TSS and BOD levels in the effluent.
2. **Odors** produced from noxious gases released with anaerobic decomposition of sludge.
3. **Anaerobic decomposition** occurring in the sludge layer proceeds much slower.
4. **Higher ammonia levels** in effluent due to ammonia released from anaerobic processes.
5. **Lagoon turnover can result in floating sludge** – in some extreme cases creating a thick mat of sludge on the top of the lagoon surface.

Sludge Problems

Bubbles due to gases released from anaerobic decomposition of sludge.

Options for Accumulated Sludge

Removal

- Lagoon dredging is the common method of mechanically removing sludge. Average cost = $350/dried ton.

Aeration and mixing

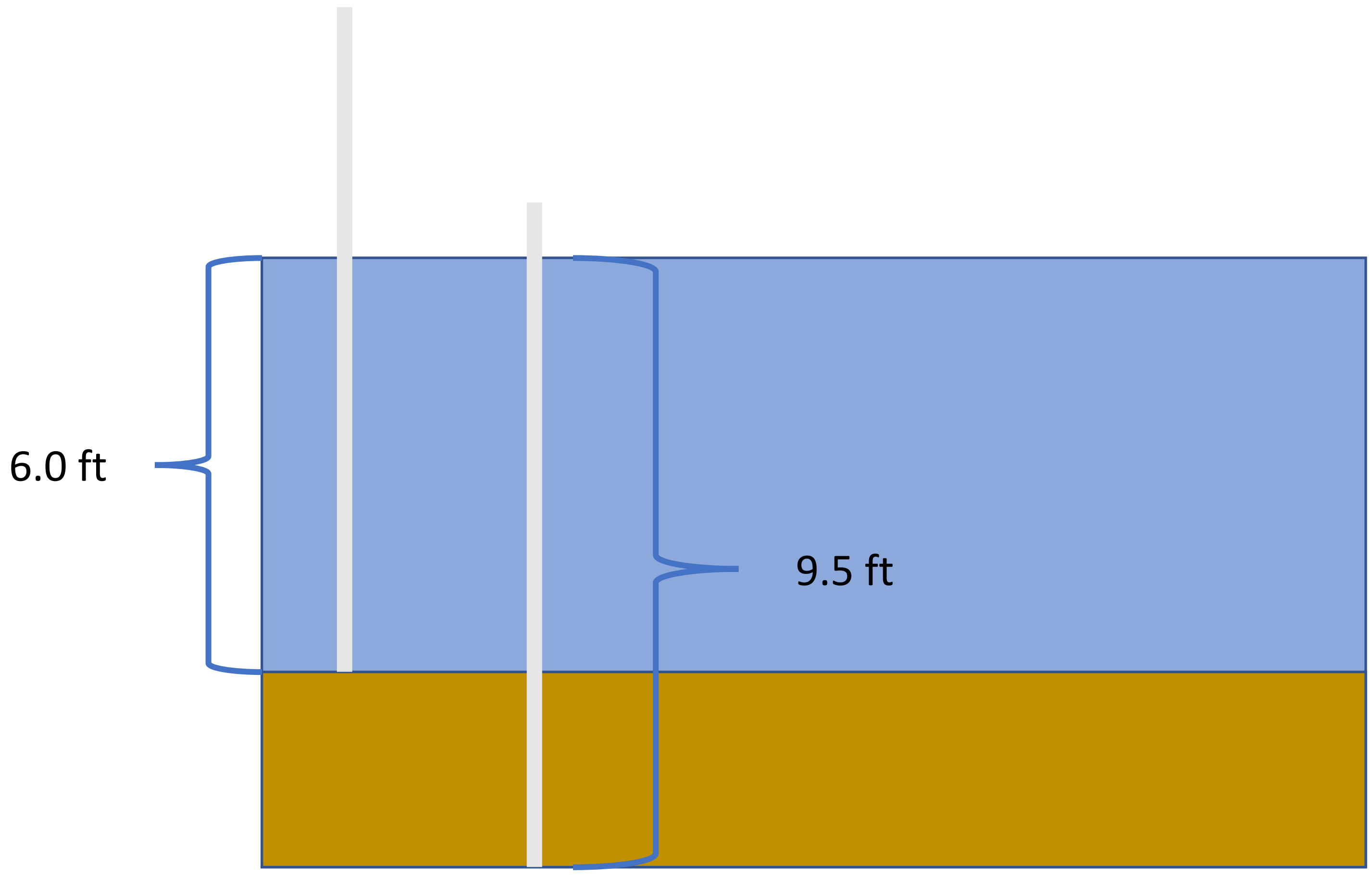
Helps provide aeration and mixing to reduce the volatile, organic portion of sludge at a much faster rate than anaerobic processes.

Bioaugmentation

Adding bacterial and nutrient treatments to jump-start breakdown of the organic portion of sludge.

Methods to Measure Sludge Depth

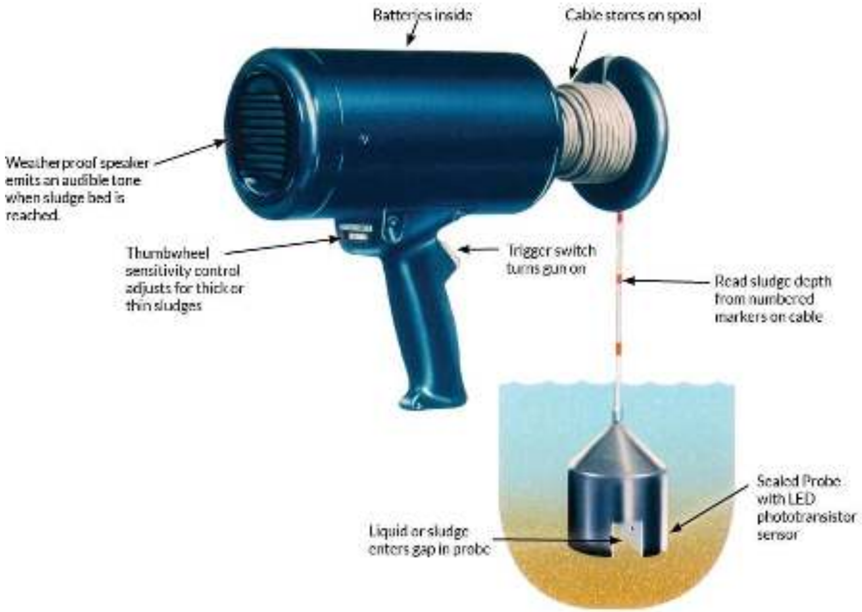
The depth from the surface to the top of the sludge is subtracted from the depth from the surface to the bottom of the lagoon.

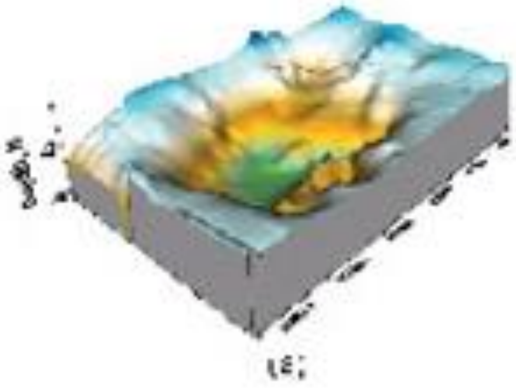


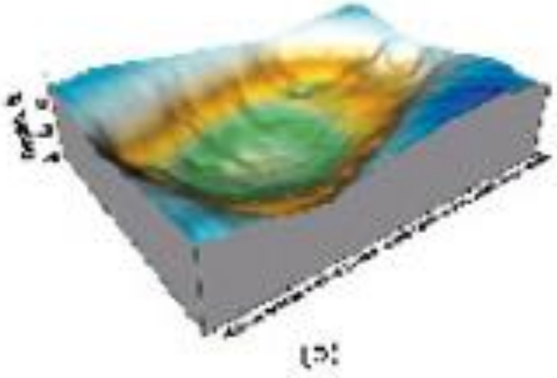
Sludge depth = 9.5 ft – 6.0 ft = **3.5 feet**

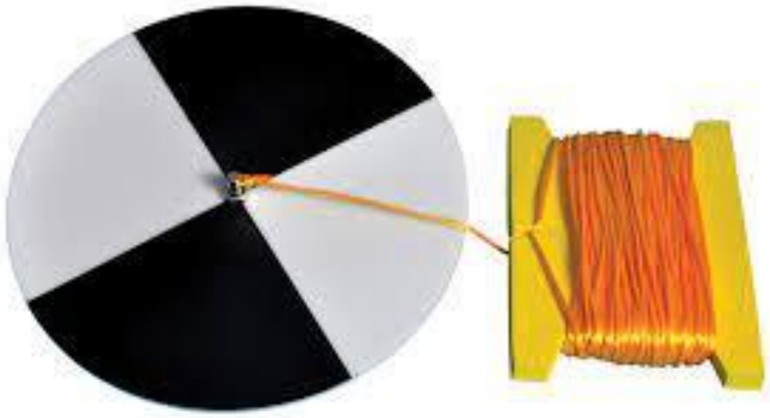
Methods to Measure Sludge Depth

1. **Sludge gun:** Uses an infrared sensor.
2. **Sonar depth finder**
3. **Disk on a rope:** Disc is lowered until it meets resistance.
4. **Sludge judge:** Physically captures sludge inside of a tube sampler.



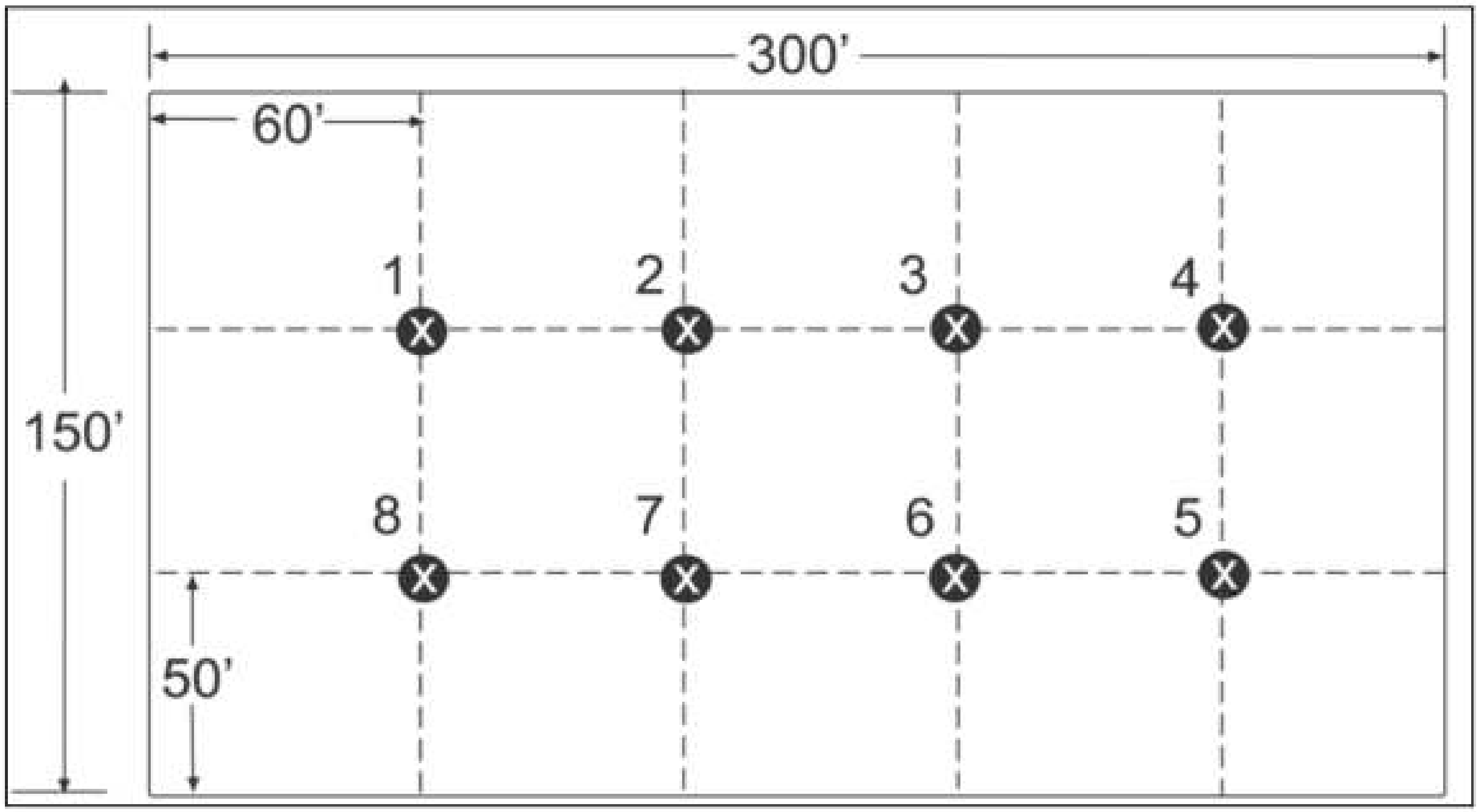






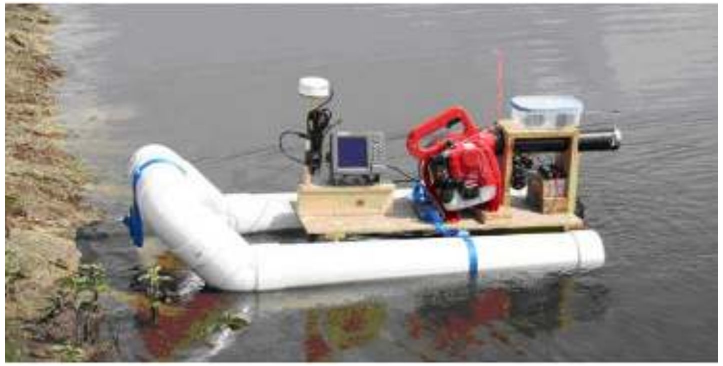
Using a "Sludge Judge" to Measure Sludge Depth

Conducting a Sludge Survey



Sample layout grid for a 150 ft x 300 ft lagoon that identifies sample points where sludge depth will be measured.

Using a flat bottom boat and a sludge gun to conduct a sludge survey.



Remote control sludge survey boat using sonar and GPS technology.

Analyzing Sludge Samples

Lagoon sludge should be analyzed to determine the total solids and the portion of sludge that consists of volatile solids.

If a significant portion of total solids consists of volatile solids it means:

1. A lack of mixing and aeration is causing excessive accumulation of sludge, *and*
2. There are options besides removal to help reduce sludge levels including improved mixing, aeration, and circulation.

Aerating and Mixing to Reduce Sludge

Floating mixers move large volumes of water to circulate DO and prevent stratification.

Diffusers add DO to water and help to raise pH.

Question

- Is your facility actively doing Sludge Surveys
  - Yes
  - No
  - Unsure

Algae – a Leading Cause of Effluent Violations

A recent study in Colorado found that 67% of lagoon compliance violations were the result of algae overgrowth.

Algae Problems

TSS and BOD in effluent

- Each mg of algal TSS results in about 0.5 mg of BOD.
- High TSS and BOD can be often caused by algae.
- Can result in TSS & BOD levels higher than influent.

Nutrient Problems

- Algae cells can store ammonia and phosphorus and release it when they die off.

Odors

- Due to decaying algae.

Sludge accumulation

- When algae cells die, they sink to the bottom and accumulate as sludge.

Algae Solutions

Chemical treatment

- Chemicals such as copper sulfate can kill algae, but could also upset the treatment process or create regulatory problems.

Barley straw

- As barley straw decomposes it releases chemicals that inhibit algae growth.

Shading

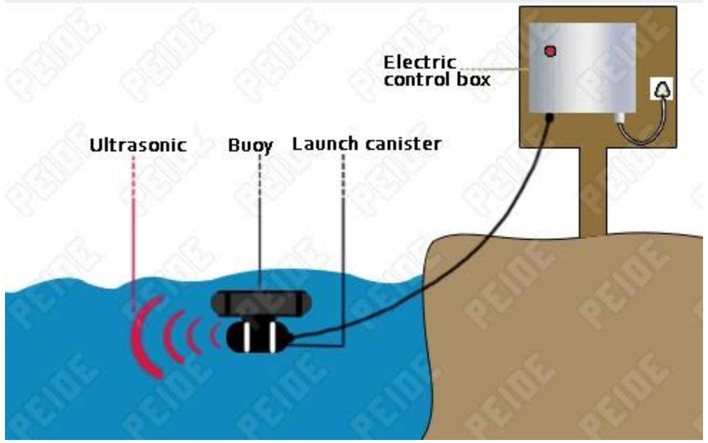
- Floating spheres can starve algae of sunlight necessary for growth.

Aeration and mixing

- Prevents algae from having sufficient time and environment for growth. Mixing and aeration creates turbulence at the surface of the water.

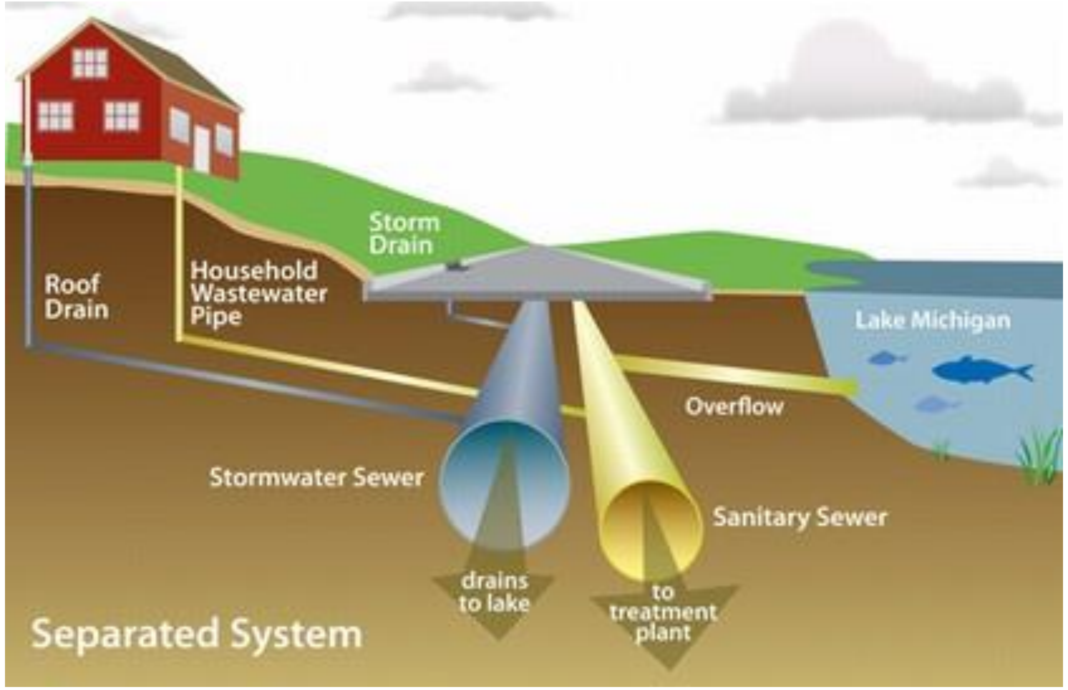
Ultrasonic algae control

- Sound waves at specific frequencies cause damage to algae cells preventing growth.



Understanding what is coming in is critical for maintaining balance

- Sanitary? Stormwater? Combined?

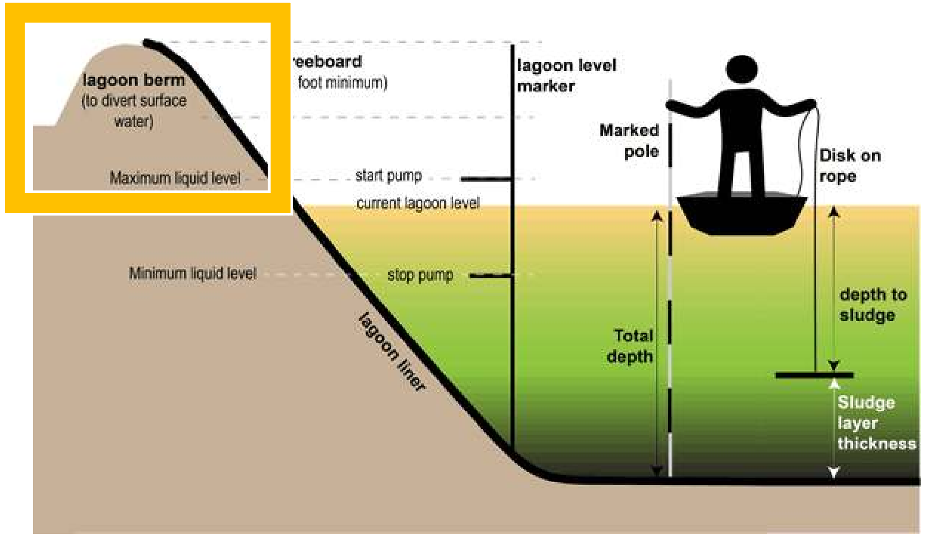


Surroundings

Miscellaneous Influent

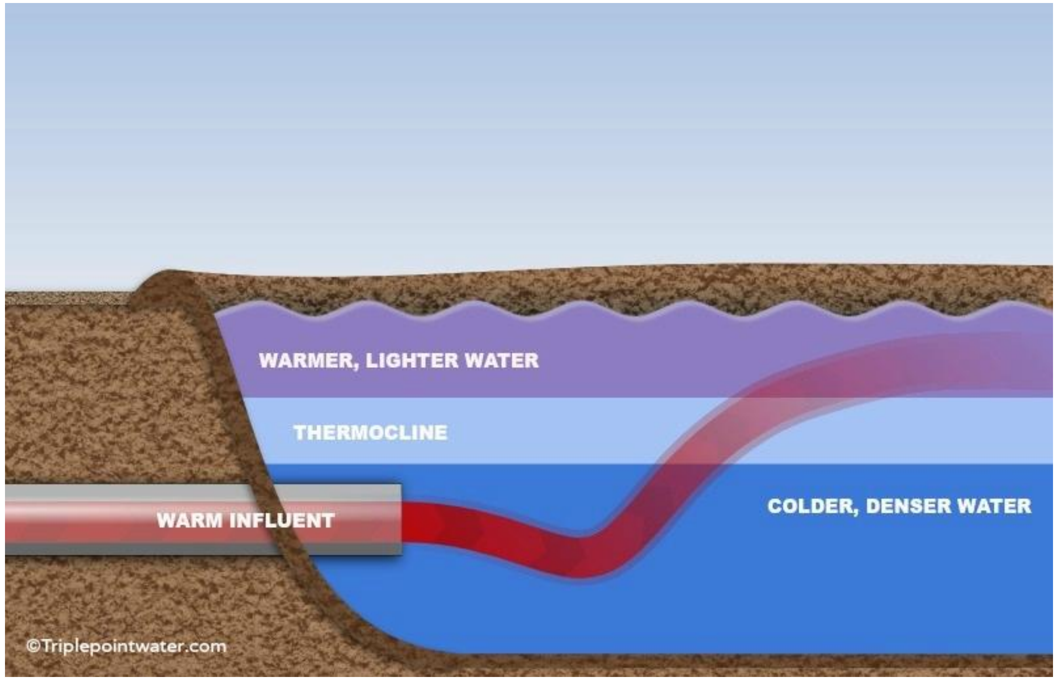
Controlling Influent

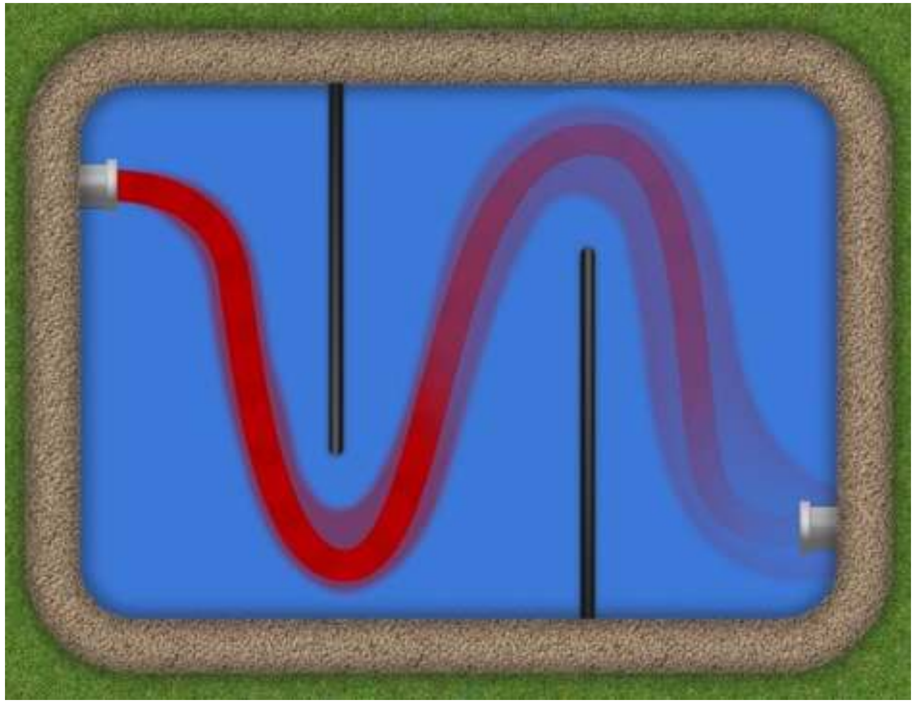
- Equalization basin
  - Auxiliary lagoon
  - Buffers primary lagoon
- Lagoon berm
  - Protects from outside environment.



Problems to Consider

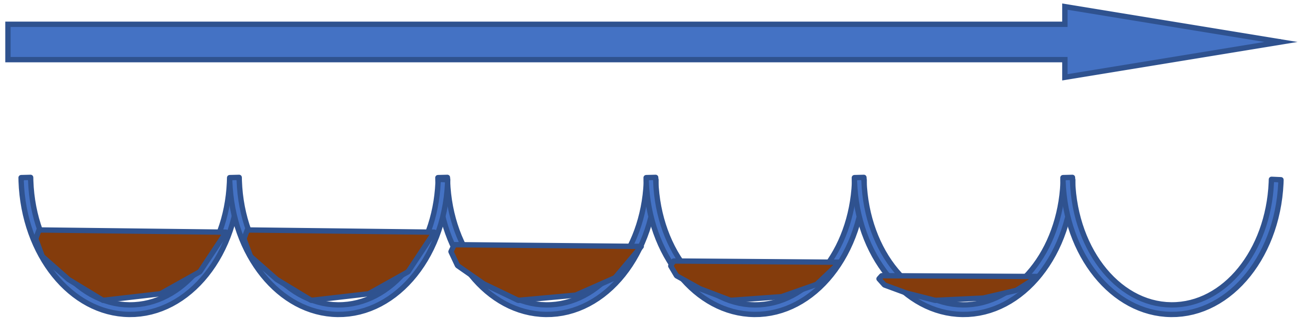
- Thermal short circuiting
  - Cold water sinks warm water rises
  - Easily solved through pumping/mixing or baffling





Additional Problems To Consider

- Effluent contamination
  - Lagoon could be operating as intended
    - Pipe traps debris
    - Debris enters effluent at exit



Question

- What type of sewer system is your facility located on?
  - Combined
  - Sanitary
  - Other
  - Unsure

Seasonal Issues

- Seasons in a year bring their own challenges
  - Temperature fluctuations
  - Precipitation changes
  - Population changes

Winter

- Largest diversion from the norm
- Colder temperatures
  - Freezing pond
  - Lower oxygen content
- How to manage?
  - Maximize liquid levels
  - Increase retention times

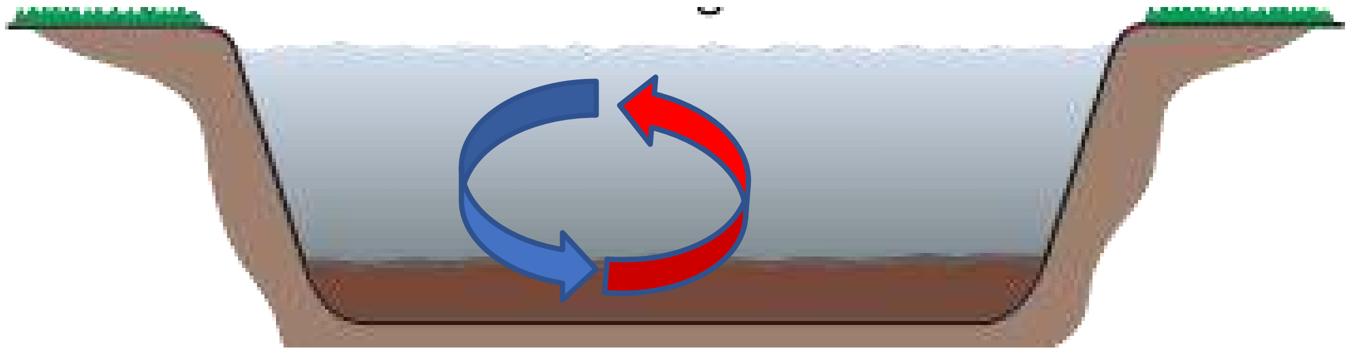
Spring

- Bounce back from winter
  - Increase in odors and oxygen demand.
- Aerate, Aerate, Aerate!
  - Have to compensate for increased BOD.
  - Many areas need more aeration during spring than normal.

Lagoon Turnover

Stratification: If a lagoon is unmixed, cold denser water will remain at the bottom and warmer water at the top during warmer months. This is called thermal stratification.

Lagoon turnover: Temperature changes in fall and spring can cause the layers to mix.



Problems Resulting from Turnover

1. Odor: Sludge at the bottom of the lagoon is disturbed, releasing hydrogen sulfide gas (H2S).
2. Floating sludge: The physical process of mixing and gases released from sludge can cause sludge to rise.
3. Treatment challenges: Spike in BOD, TSS, and other parameters such as ammonia.

Preventing Lagoon Turnover

1. **Increased circulation** to prevent stratification from occurring in the first place.

2. **Increase aeration** to provide sufficient dissolved oxygen. This is especially important in the spring when temperatures rise and previously untreated BOD that accumulated during the winter begins being consumed by bacteria.

3. **Increased mixing** to prevent excessive sludge accumulation.

Question

- What time of year is the lagoon experiencing a large increase in BOD?
  - Summer->Fall
  - Spring->Summer
  - Winter->Spring
  - Fall->Winter

Summary

- Lagoons rely on natural reactions to treat waste.
- Proper mixing and aeration is key to proper maintenance.
- A reduction in retention time typically results in less treatment.
- Controlling sludge is the primary key to maintaining lagoon.

Thank you for attending!

Email:
Robert Davies: redavies@mtu.edu
Greg Pearson: gpearson@mtu.edu

EFCN Website: https://efcnetwork.org/
Lots of resources and training opportunities!

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

Resources

- https://www.epa.gov/sites/default/files/2014-09/documents/lagoon-pond-treatment-2011.pdf
- https://www.waterworld.com/wastewater/article/16214985/case-study-wwtp-lagoon-retrofit-with-solarpowered-mixers-solves-shortcircuiting-problems
- https://lagoons.com/blog/sludge/lagoon-sludge-survey/#:~:text=The%20thickness%20of%20the%20sludge,the%20top%20of%20the%20sludge.
- https://water-treat-tech.com/sludge-surveys/
- https://lagoons.com/blog/sludge/wastewater-lagoon-sludge-treatment/
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