environmental finance center network

MISSISSIPPI STATE UNIVERSITY™
WATER RESOURCES RESEARCH INSTITUTE

Seasonal Challenges, Smart Solutions: Aeration 101

Thursday, September 17th, 2026; 12:00 noon – 1:00 pm CST

Instructor: Dr. Jason R. Barrett, Mississippi Water Resources Research Institute

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

What we will discuss

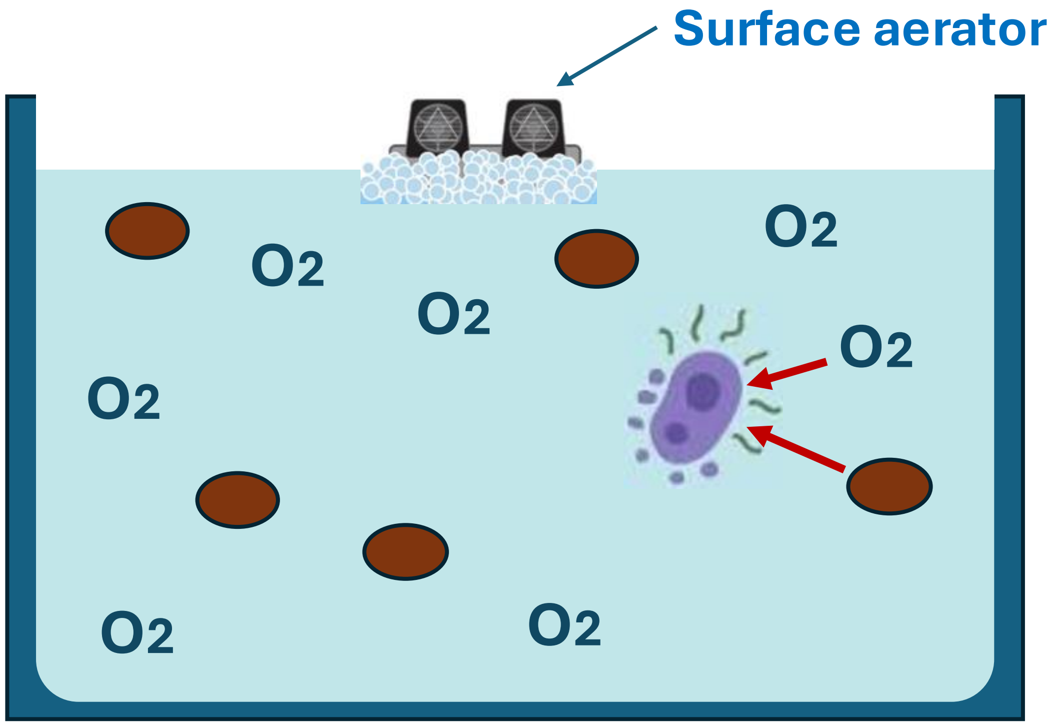
1. **Review the role of aeration** in maintaining healthy lagoon performance

2. **Investigate factors that affect aeration**, such as higher temperatures and increased biological activity.

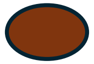
3. **Explore aeration methods and strategies** used to optimize performance in lagoon systems.

As we begin, let's briefly review what we know about lagoon treatment

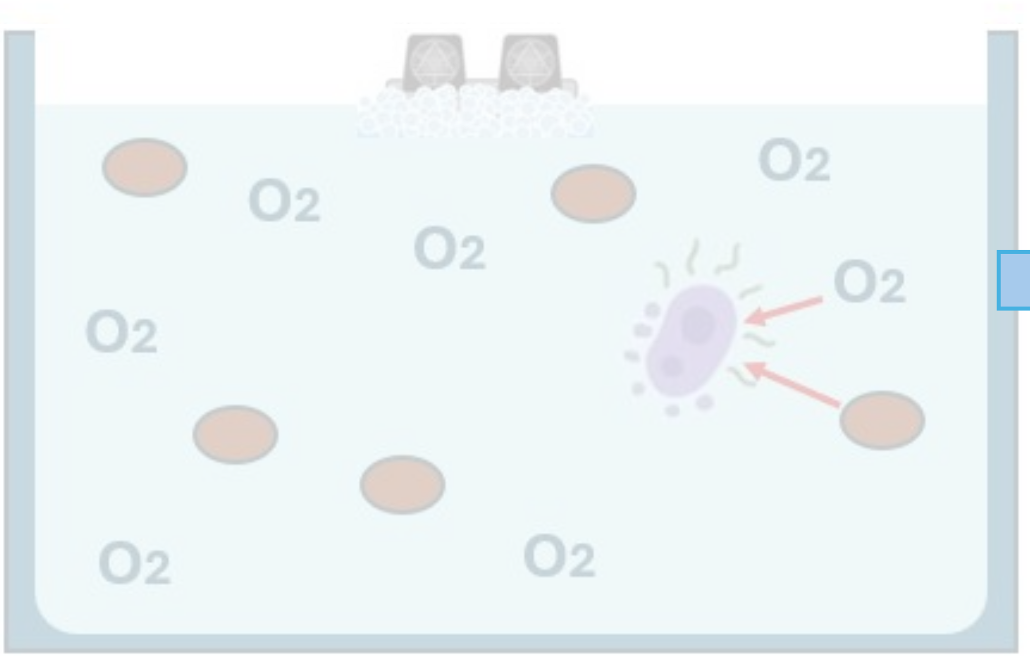
Heterotrophic Bacteria and BOD



1. Heterotrophic bacteria use dissolved oxygen to metabolize BOD. Aerators supply the oxygen source.

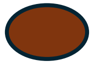
 = BOD  = Dissolved Oxygen  = Heterotrophic bacteria

Heterotrophic Bacteria and BOD



1. Heterotrophic bacteria use dissolved oxygen to metabolize BOD. Aerators supply the oxygen source.

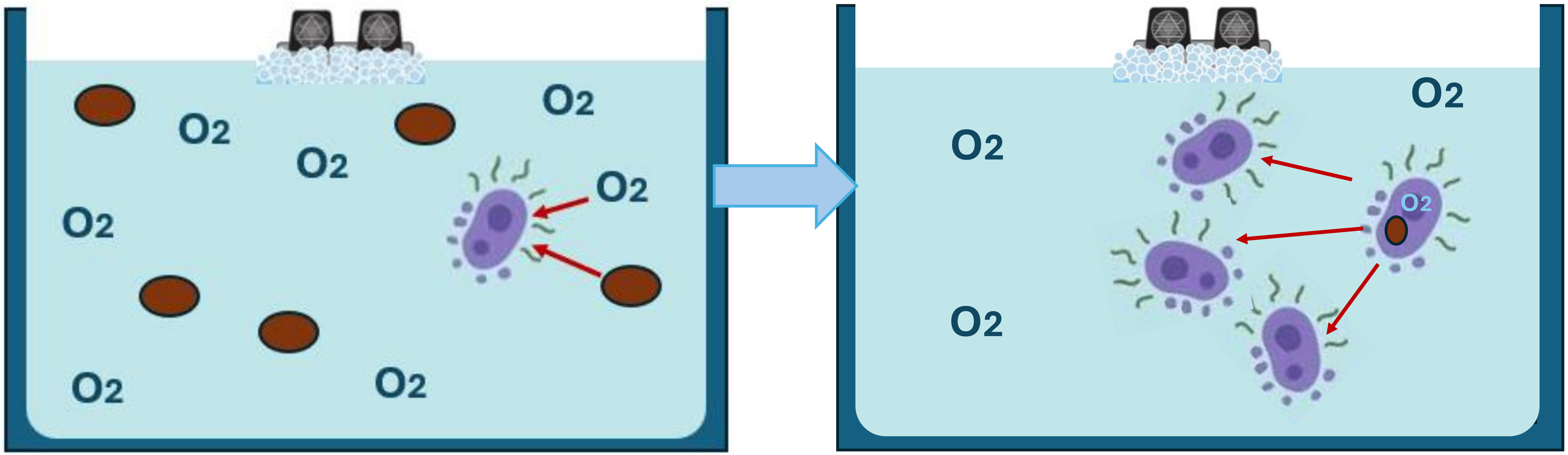
2. BOD is removed and converted to biomass.

 = BOD

O_2 = Dissolved Oxygen

 = Heterotrophic bacteria

Heterotrophic Bacteria and BOD



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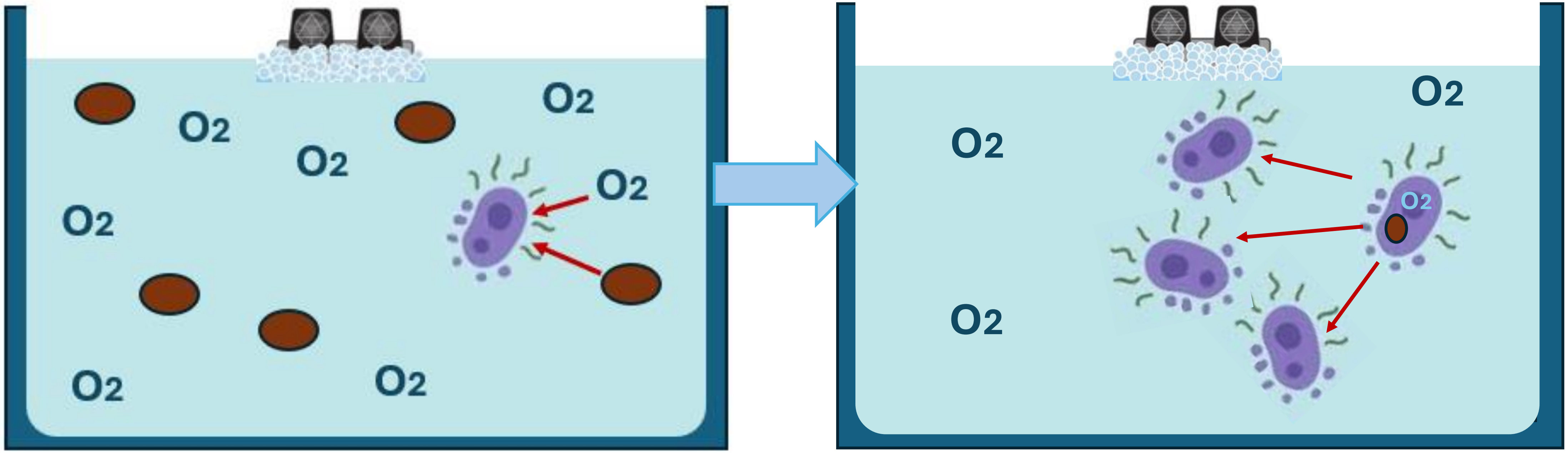
Heterotrophic Bacteria and BOD



Without sufficient dissolved oxygen, BOD removal will be incomplete. The lagoon can also develop anaerobic conditions which lead to odors and septicity. 1 – 2 mg/L DO must be continuously maintained

= BOD O_2 = Dissolved Oxygen   = Heterotrophic bacteria

What problem(s) do we need to solve?

The problem:

Develop an aeration strategy to maintain sufficient dissolved oxygen (DO); especially when temperatures rise.

Challenges

- Oxygen saturation in water decreases as temperatures rise.
- Bacterial metabolism rates increase as temperatures rise.
- NPDES compliance depends on sufficient DO for BOD and Ammonia removal

Solutions:

(1) Correct aeration system sizing

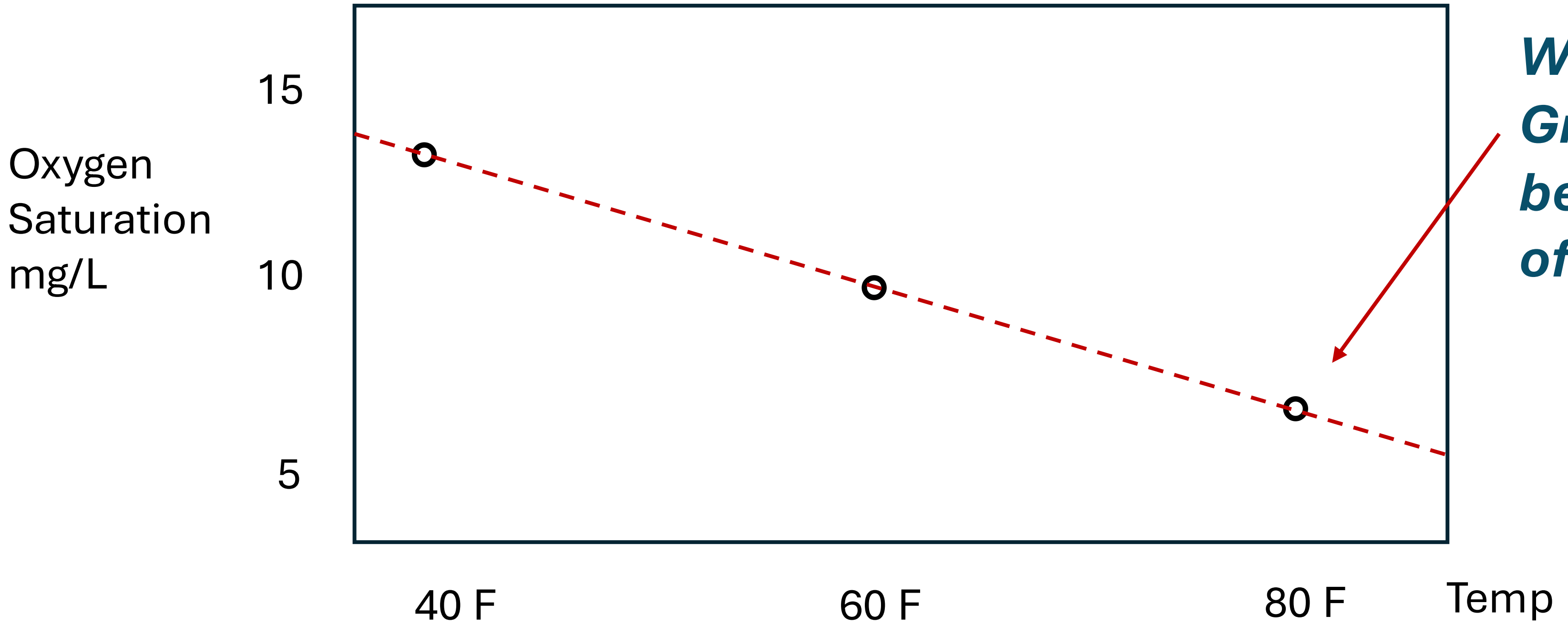
(2) Adequate mixing to ensure contact between BOD, bacteria, and DO

(3) Informed selection of aeration modality, layouts, and operational tasks

Temperature and Maximum Oxygen Saturation

- Winter: At 40°F (4.4°C), water can hold up to 13.0 mg/L of DO.
- Spring/Autumn: At 60°F (15.6°C), max saturation drops to 10.0 mg/L.
- Summer: At 85°F (29.4°C), max saturation plummets to 7.5 mg/L.

Wastewater contains dissolved salts and substances that further reduce saturation capacity by 5% to 15%



Warmer weather also leads to Greater oxygen demand because bacterial metabolism of BOD is at its peak

Oxygen demands

BOD

- 1.5 lbs of oxygen is required for every 1 lb. of BOD

Ammonia

- 4.6 lbs of oxygen is required for every 1 lbs of ammonia

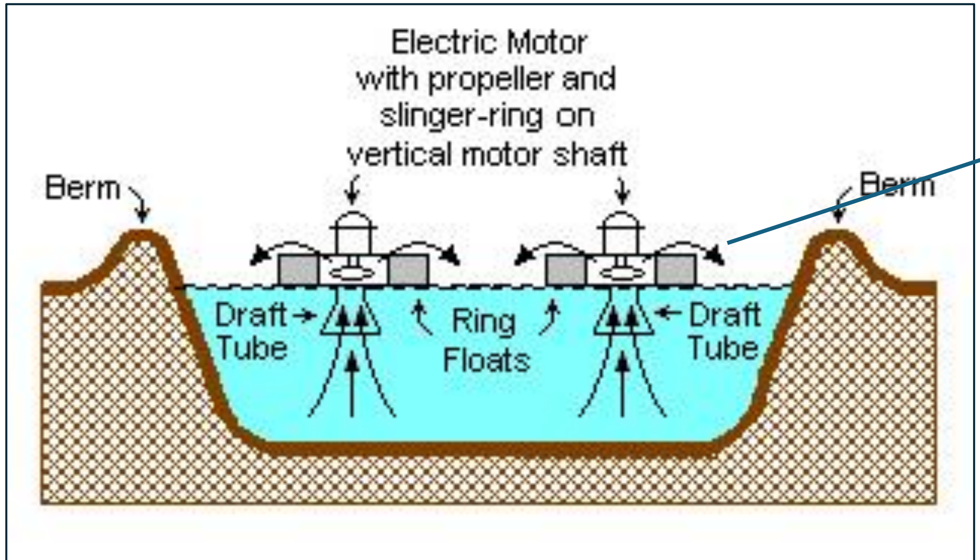
In addition, a continuous level of at least 1.0 to 2.0 mg/L DO is required to support bacterial health and prevent anaerobic conditions.

DO Concentration in mg/L	Application or Impact
Below 1.0 mg/L	Ineffective BOD removal and anaerobic conditions
1.0 to 2.0 mg/L	**Ideal range for BOD removal**
2.0 to 3.0 mg/L	**Ideal range for Nitrification of Ammonia**
Greater than 3.0 mg/L	Over aeration resulting in excessive costs

Surface Aerators

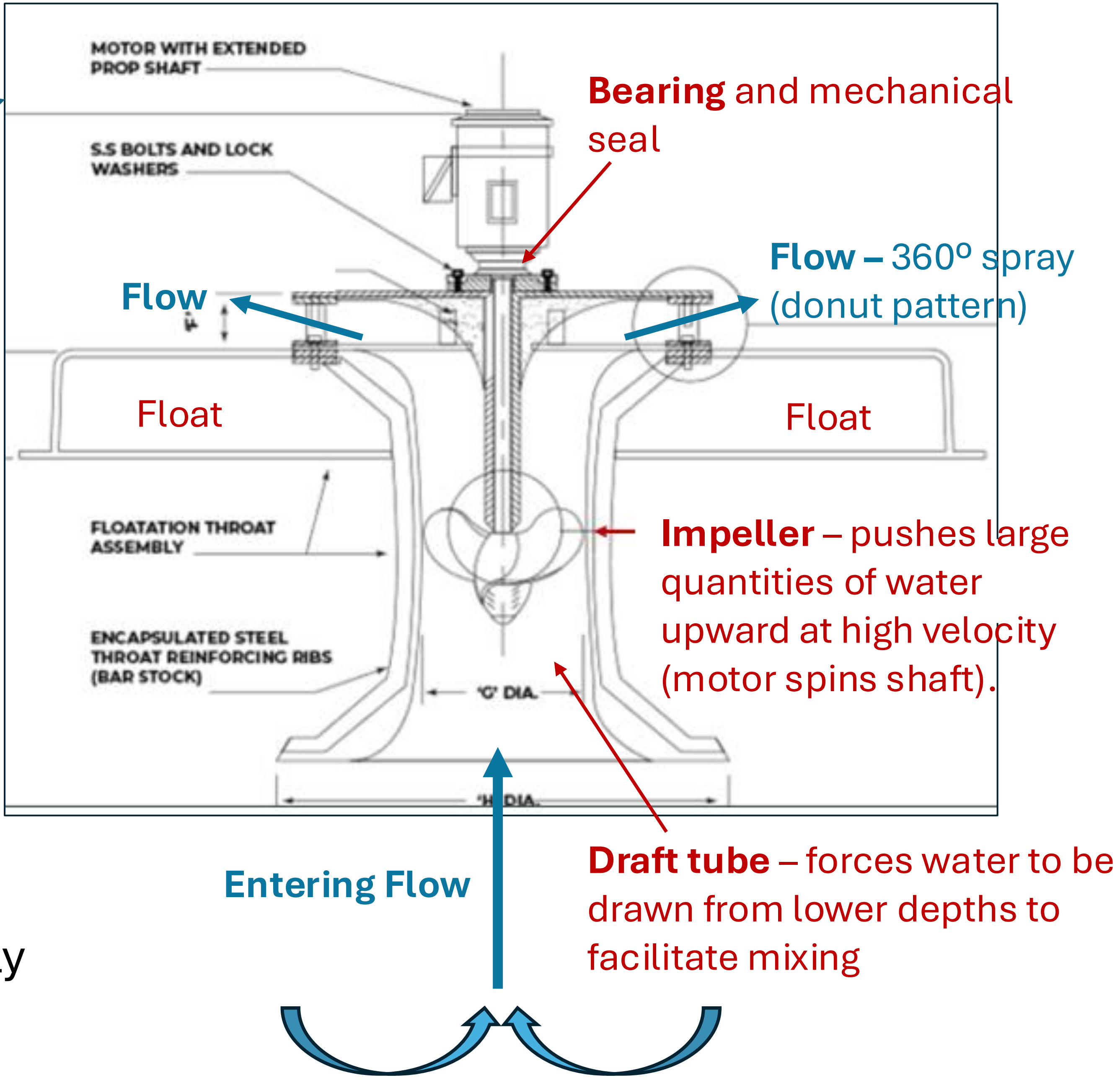
A spinning impeller agitates water to impart oxygen. The motor and unit are supported by a floating frame

- Easiest to Install and Maintain
- Not as efficient as diffused air; uses mor electrical energy
- Provides mixing down to about 5 feet
- Can be moved around horizontally to he direct flow
- Some units have gearboxes for lower speeds and more mixing power



A TYPICAL SURFACE – AERATED BASIN

Note: The ring floats are tethered to posts on the berms.



Common Problems

- Gearbox and Bearing Failures
- Debris wrapping around the shaft
- Seal failure

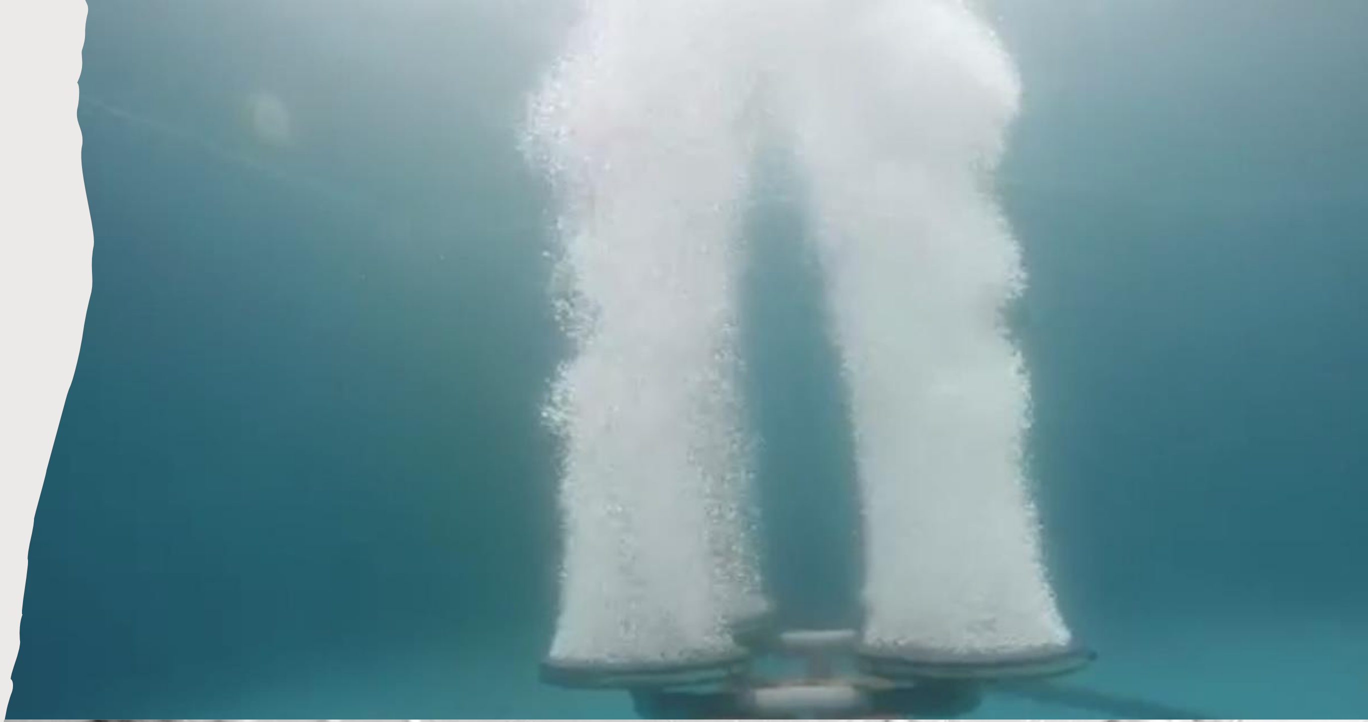
Recommended Maintenance

- Check for debris and lubrication monthly
- Inspect seals and bearings annually.
- Replace bearing and seal +/- 3 yrs

Oxygen transfer of diffused air – fine bubble

Fine bubble transfers 1.6 to 2% O2 per ft.

- **For a 10 ft. depth**, fine bubble diffused air would have an over all 16 to 20% transfer rate, delivering 4+ lbs of O2 per HP-hr.
- **Size of fine bubbles**: 1mm to 3 mm (head of a pin to a mustard seed).
- *Hi surface area compared to volume promotes superior oxygen saturation*.
- Less powerful mixing action.



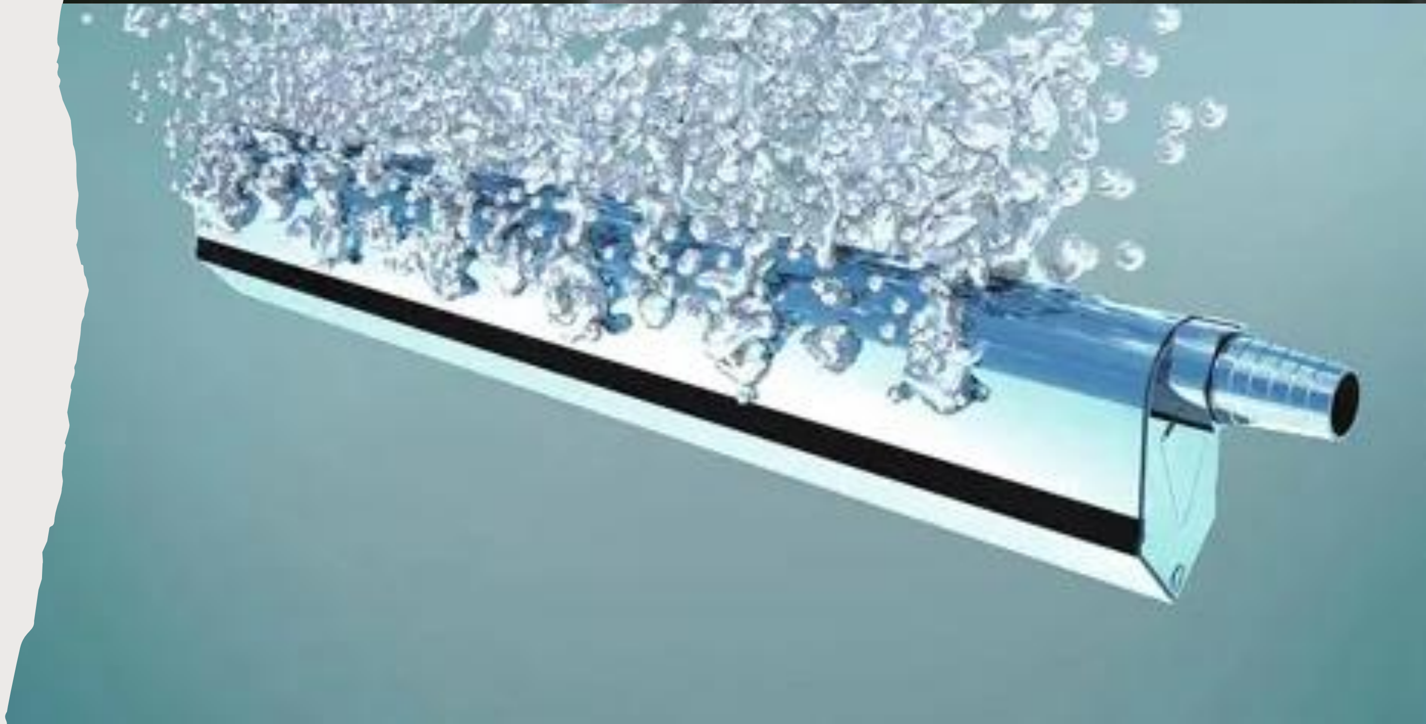
Coarse Bubble

Transfers 0.8 to 1% O2 per ft.

- **For a 10 ft depth**, course bubble diffused air would have a transfer rate of 8 to 10% delivering 2+ lbs of O2 per HP-hour.
- **Size of coarse bubbles**: typically range from 6 to 13 mm (size of a pea to a marble)
- **Much less efficient** than fine bubble (about half).

Why use coarse bubble diffused air?

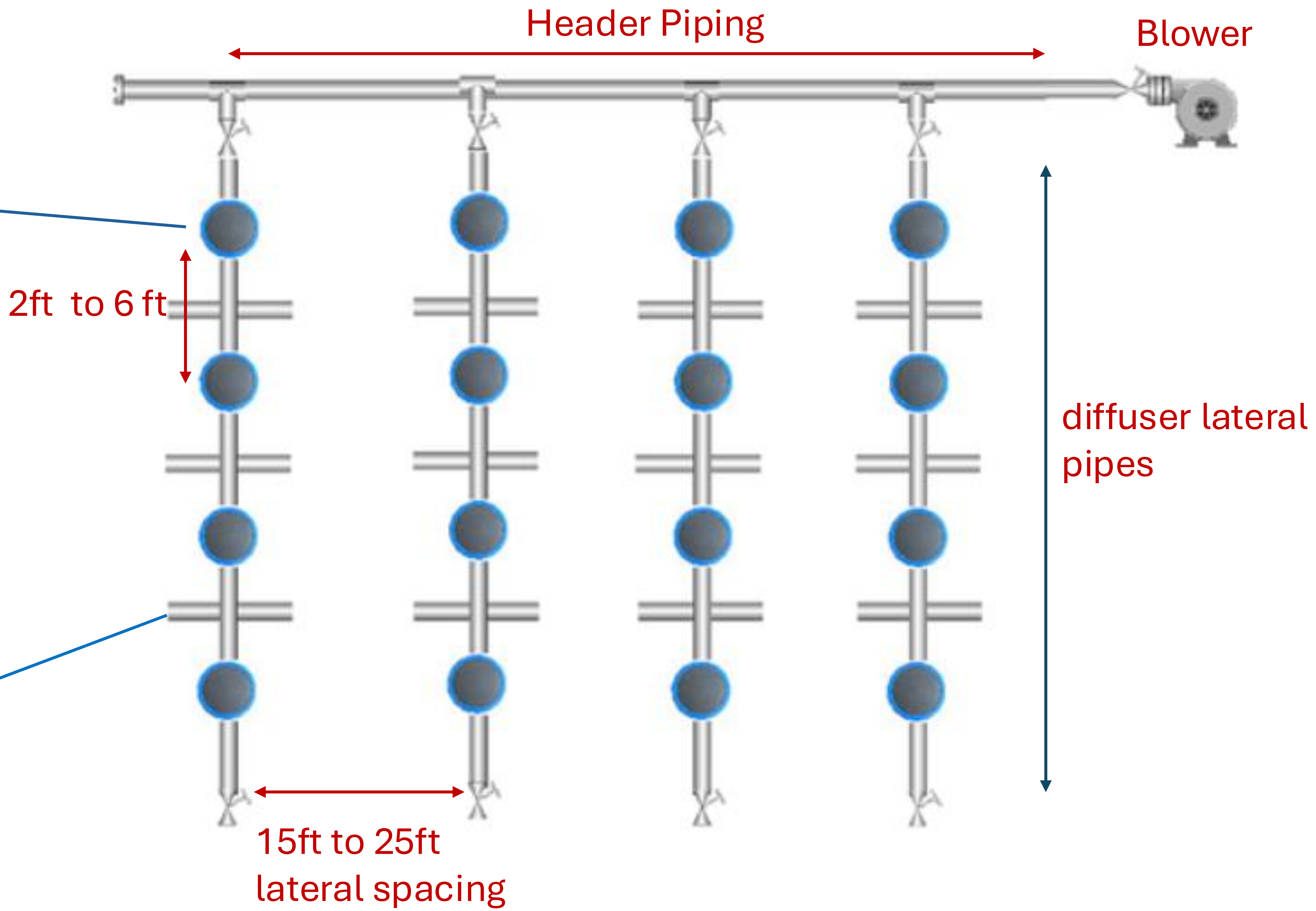
- Enhances mixing
- Much less apt to clog
- In combination with fine bubble



Typical Diffused Air Layout

Fine bubble disk diffuser

A short section of pipe to keep the diffuser laterals from twisting



Diffused air clogging

Fine bubble aerators have very small orifices that can become clogged due to

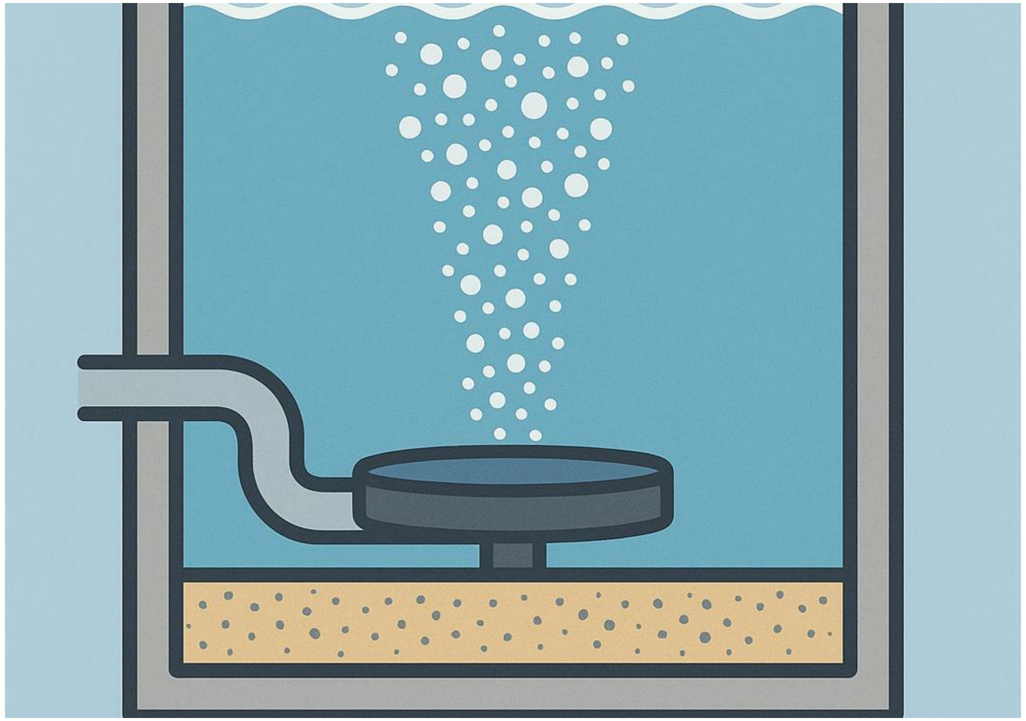
- Biofouling – growth of bacterial slimes
- Scaling – mineral scale deposits
- Sludge solids interfere with air flow

When aeration delivery pressure increases by 10 to 15%, operators have the following options.

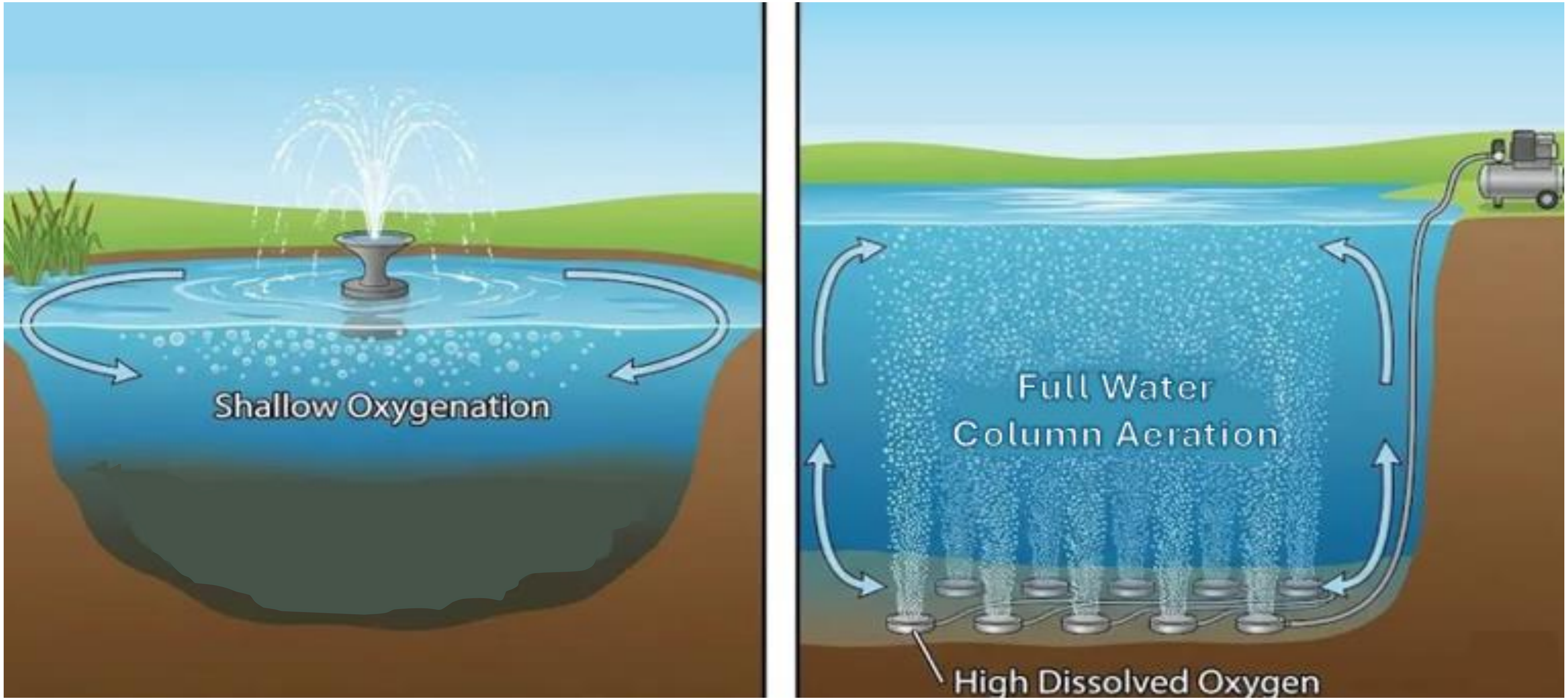
1. Retrieve and pressure wash aerators.
2. Feed a small dose of formic or citric acid through the air header to remove scaling and clogs.

Diffuser clogged with debris

Pressure washing diffuser



Comparing surface aeration and diffused air



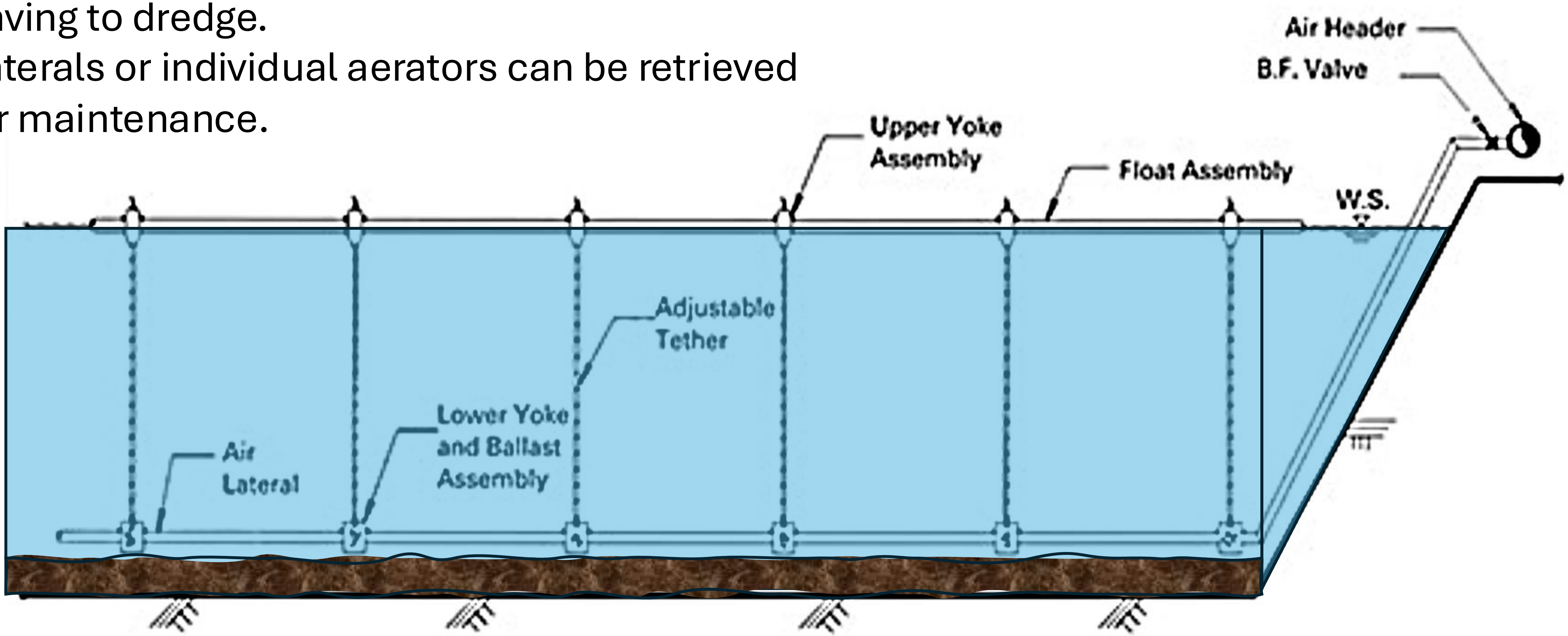
- Surface aeration mixes the top 5 feet.
- Sludge solids continue to accumulate.
- Less efficient but lower capital costs.

- Can aerate the entire water column.
- Fine bubbles are more efficient at transferring Oxygen but provide minimal mixing.
- Full column aeration can reduce sludge

Floating air header pipes

Allows the following advantages

1. Can set aerators above existing sludge without having to dredge.
2. Laterals or individual aerators can be retrieved for maintenance.



Compliance Goals and Lagoon Layout

Parameter	Typical average Influent levels	Typical Permit Effluent Goal	
BOD	200 mg/L	≤ 30 mg/L (30-day avg.)	85% BOD removal
NH_3	30 mg/L	≤ 2 mg/L (30-day avg.)	93% NH_3 removal

Typical 3-cell lagoon layout and the function of each cell.

- 80% BOD Removal
- 1 – 2 mg/L DO

- Nitrification & 20% BOD
- 2 – 3 mg/L DO

- Settling and Polishing
- No aeration

BOD Loading

A domestic wastewater lagoon has an influent flow of 0.25 MGD and a BOD concentration of 200 mg/L. The first cell has an average depth of 10 feet and a surface area of 2 acres.

To calculate BOD loading in pounds per day, we use the following formula:

Flow (MGD) x **conc (mg/L)** x **8.34 lbs/gal**

Lbs/Day BOD = **0.25** MGD x **200** mg/L x **8.34** lbs/gal = $\boxed{\textbf{417}\text{ lbs BOD per day}}$

Loading in lbs/day per acre = $\frac{417\text{ lbs/day}}{2\text{ acres}}$ = $\boxed{\textbf{208.5}\text{ lbs BOD/day per Acre}}$

BOD Loading for aerated lagoons ranges from 100 to 400 lbs/acre/day.
(100–200 for colder climates; 200-400 for warmer climates.)

Next, let's look at how much oxygen we need to deliver

Oxygen and aeration requirements

In our previous example, we found that BOD entered our lagoon at a rate of 417 lb/day. How much oxygen is required for BOD metabolism?

We can estimate by multiplying by 1.5 lbs/oxygen for every 1 lb. of BOD

Oxygen Required: **417 lbs** BOD/day x **1.5** lbs O_2/lb BOD = $\boxed{\textbf{625.5} \text{ lbs/day } O_2}$

Oxygen hourly rate: $\frac{625.5 \text{ lbs/day}}{24 \text{ hrs/day}} = \boxed{\textbf{26.06} \text{ lbs/hr } O_2}$

SOTR (Standard Oxygen Transfer Rate) is the amount of oxygen we must deliver to achieve the target oxygen level. It accounts for the efficiency of oxygen transfer (≈ 60%).

SOTR $= \frac{26.06 \text{ lbs/hr } O_2}{0.60} = \boxed{\textbf{43.4} \text{ lbs/hr } O_2}$

*We find that our aeration system needs to deliver O2 at a rate of **43.4 lbs/day** to meet BOD demand. Let's explore our equipment needs.*

Using SOTR to estimate aeration equipment needs

Surface Aerators

Surface aerators transfer around 2.0 lbs O2 per horsepower-hour

$$\frac{43.4 \text{ lbs/hr O2}}{2.0 \text{ lbs/HP-hr}} = 21.7 \text{ HP}$$

Practical Application: *The utility could use three 10-HP surface aerators. This would provide some level of redundancy and additional air when needed*

Fine-Bubble Diffused Air

Fine-bubble diffused air systems transfer 4 to 5.5 lbs O2 per horsepower-hour

$$\frac{43.4 \text{ lbs/hr O2}}{4.0 \text{ lbs/HP-hr}} = 10.85 \text{ HP}$$

Practical Application: *The utility could install two 15 HP blower motors that could alternate to provide redundancy.*

Ammonia Demand (Cell #2)

A domestic wastewater lagoon has an influent flow of 0.25 MGD and an ammonia concentration of 30 mg/L. In cell 2, BOD has been reduced to 40 mg/L.

Ammonia Loading: 0.25 MGD x 30 mg/L x 8.34 lbs/gal = 62.6 lbs/day NH_3

Oxygen Demand (NH3): 62.6 lbs/day x **4.6** lbs O_2/lb.NH3 = **287.96 lbs/day O_2**

BOD Loading: 0.25 MGD x 40 mg/L x 8.34 lbs/gal = 83.4 lbs/day BOD

Oxygen Demand (BOD): 83.4 lbs/day x **1.5** lbs O_2/lb BOD = **125.1 lbs/day O_2**

Total Oxygen demand for cell #2: (Ammonia and BOD)

287.96 lbs/day + 125.1 lbs/day = 413.06 lbs/day O_2

We can estimate the HP required for aeration in cell #2 using the same method we used for BOD in cell 1. Remember our total oxygen demand.

Aeration needs for cell 2 (ammonia + BOD)

Our total oxygen demand for cell 2 is **413.06 lbs/day**.

1. Divide by 24 hrs/day (to calculate oxygen needed in the wastewater**)**

413.06 lbs/day ÷ 24 hrs/day = 17.2 lbs O_2/hr

2. Divide by 0.60 (to calculate the oxygen we need to deliver with aerators)

17.2 lbs O_2/hr ÷ 0.6 = 28.7 lbs O_2/hr

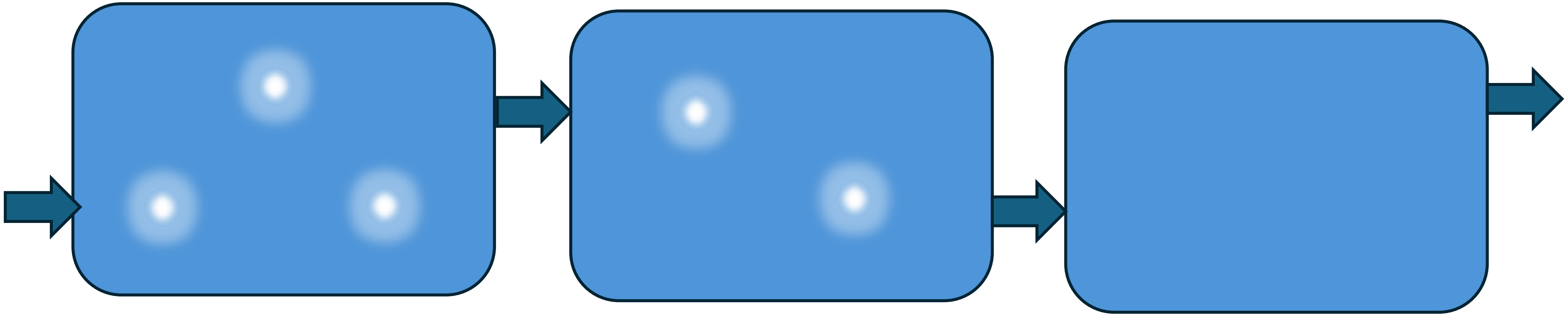
3. **Determine the horsepower of the aeration system**

a. 28.7 lbs O_2/ hr ÷ 2lbs O_2/HP-hr = 14.35 HP for Surface Aeration Two 10 HP Aerators

b. 28.7 lbs O_2/hr ÷ 4lbs O_2/HP-hr = 7.18 HP Fine Bubble Aeration Increase in the capacity of a central blower

What our lagoon looks like after design

Using Surface Aerators



Cell 1: Three 10-HP Surface Aerators for BOD removal (21.7 HP)

Cell 2: Two 10-HP Surface Aerators for Nitrification (& BOD)(14.35 HP)

Cell 3: No aeration to promote settling

Using Fine Bubble Diffused Air

10.85 HP (cell 1) + 7.18 HP (cell 2) = 18.03 HP

*We could use a **20 HP** Centralized Blower System for diffused air*

Innovative aeration methods

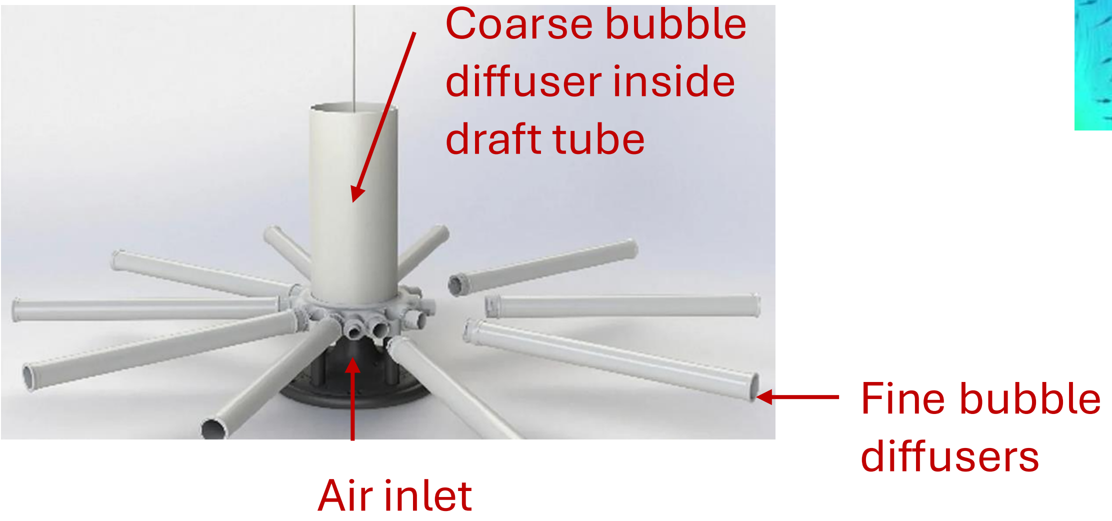
Engineers are continually developing improved designs to maximize aeration efficiency. We will look at three of these.

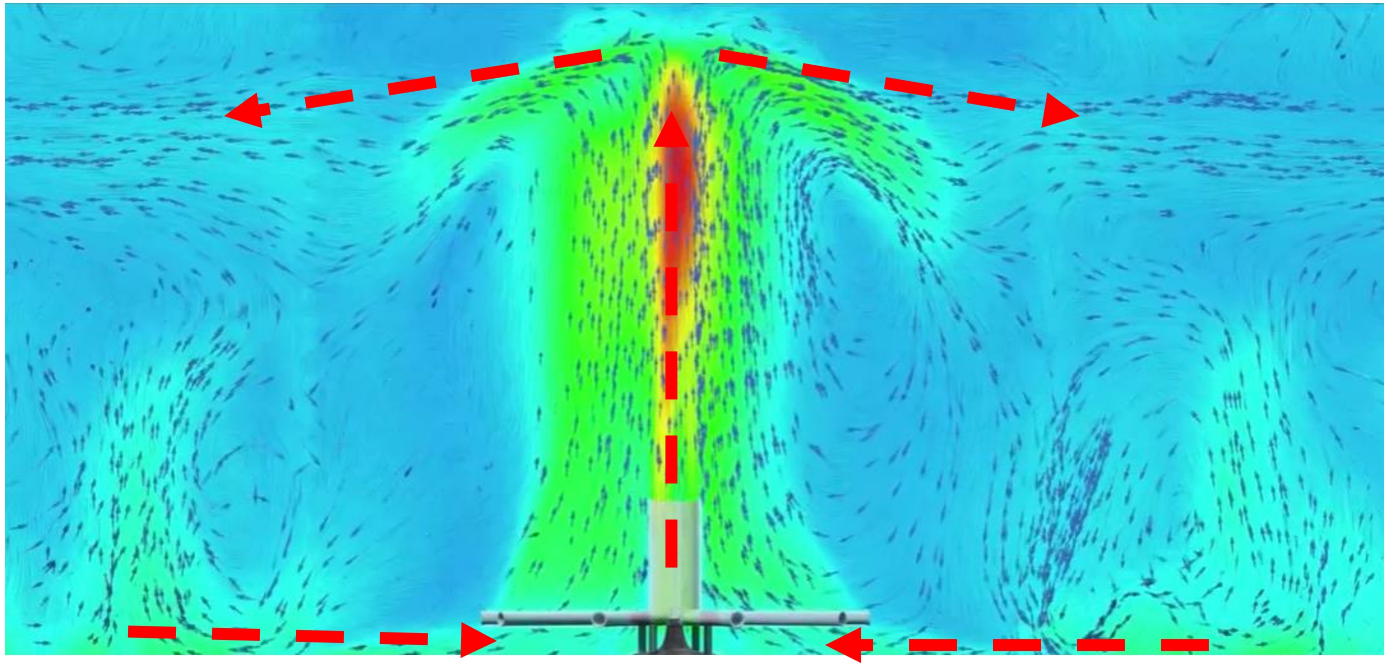
- Combining coarse and fine bubble aeration (Triplepoint®)
- Combining fine bubble aeration and mechanical mixing (Invent®)
- Combining liquid recirculation flow with an airflow (Mixing Systems®)

Triplepoint Ares® aerator

Design incorporates both coarse and fine bubble aeration.

- Fine bubbles optimize oxygen transfer (90% of air)
- Coarse bubbles optimize circulation and mixing (10% of air)
- Achieves up to 2.4% oxygen transfer per ft. and circulates wastewater at up to 7,800 GPM

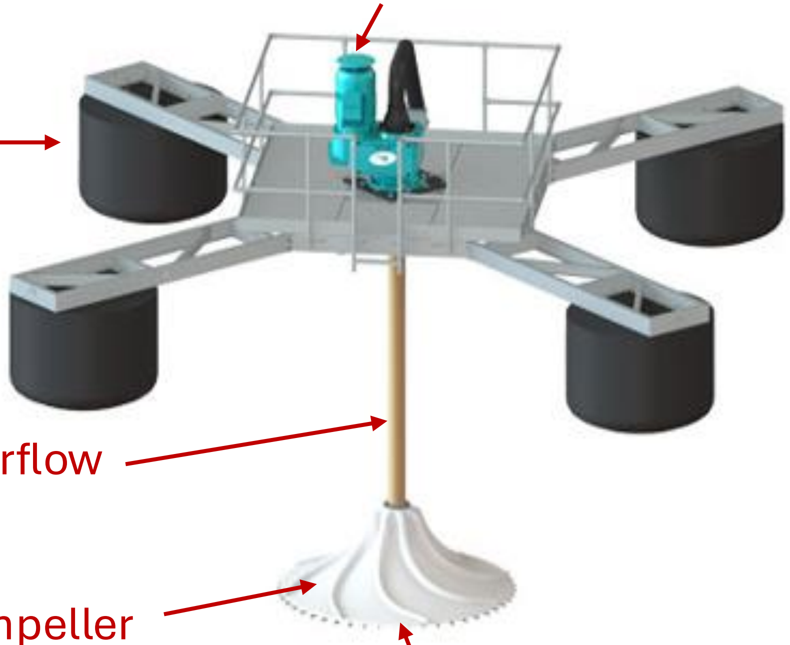




Coarse bubbles create lift, suction, and mixing – bringing BOD, microorganisms, and fine bubble DO into contact

Invent’s Hyperdrive®-Mixing and Aeration System

Design combines fine bubble aeration with mechanical mixing

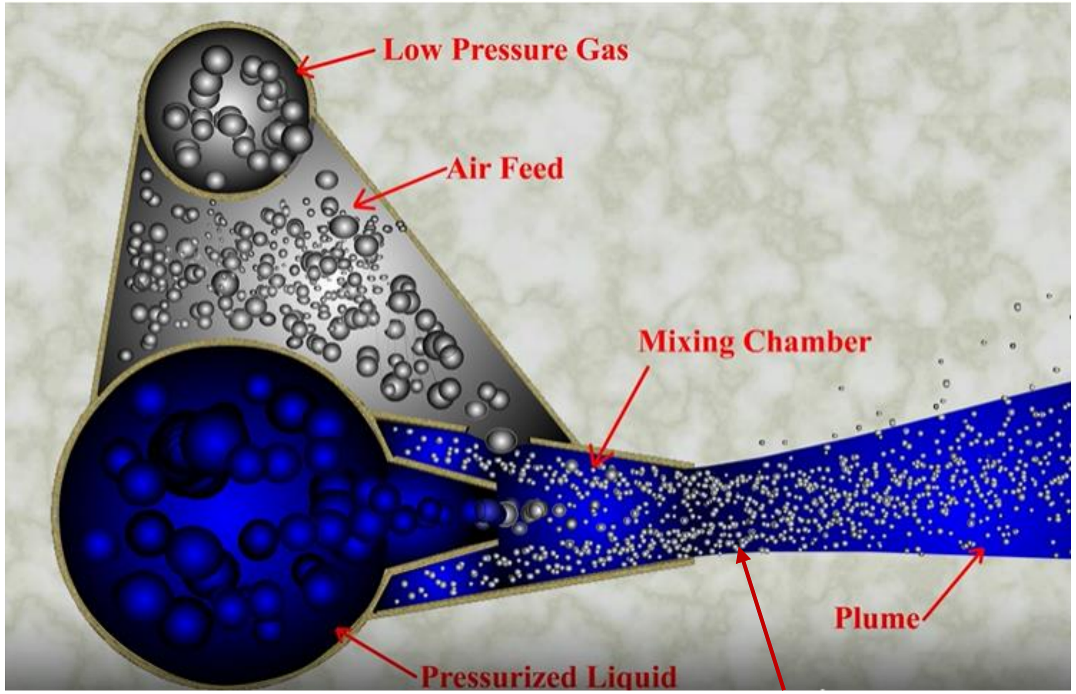


Aerial view of aerator showing how fine bubbles are mixed with wastewater

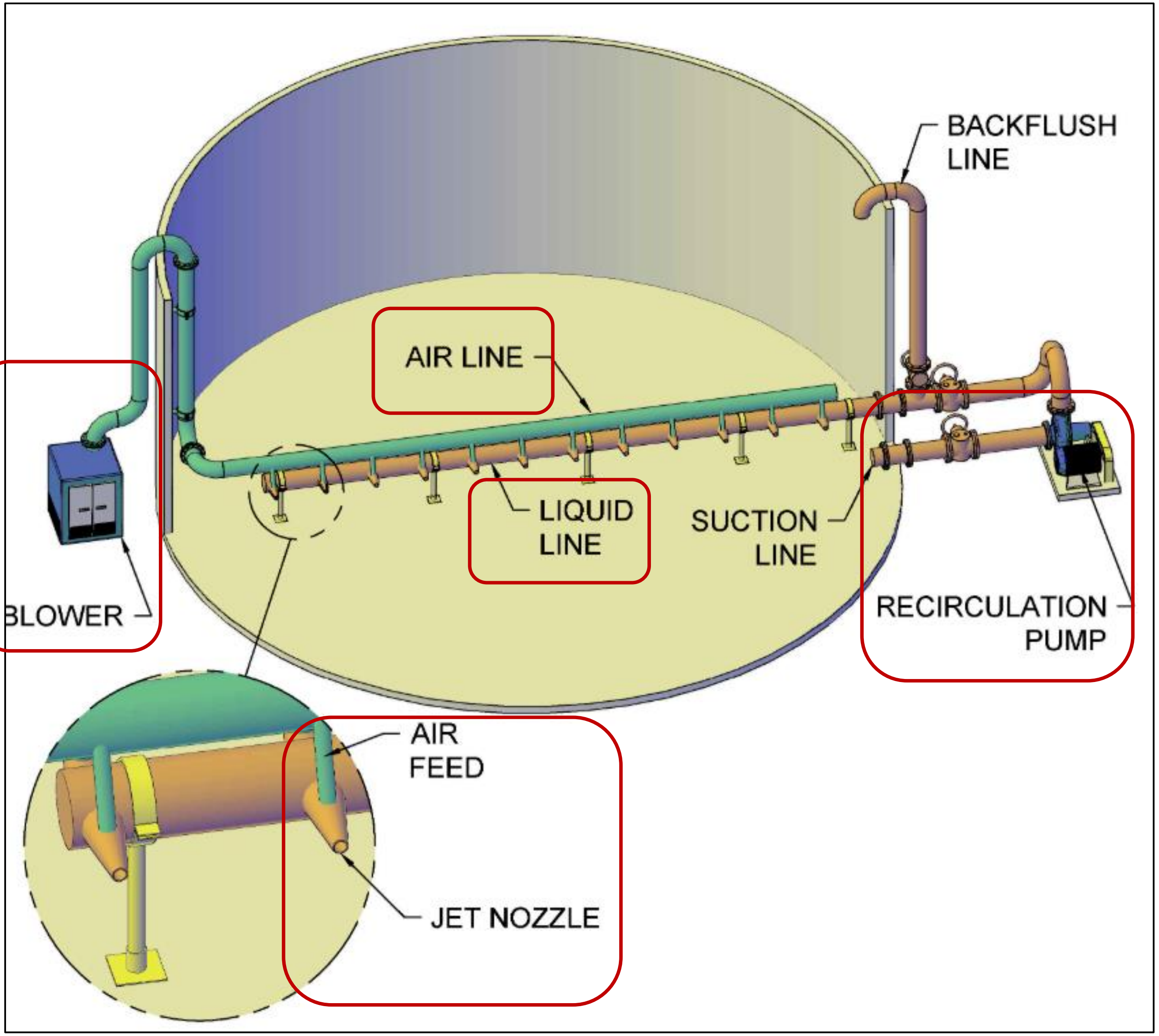
Mixing Systems® Jet Aeration

Design includes a liquid recirculation line with a venturi that draws in oxygen from an air line.

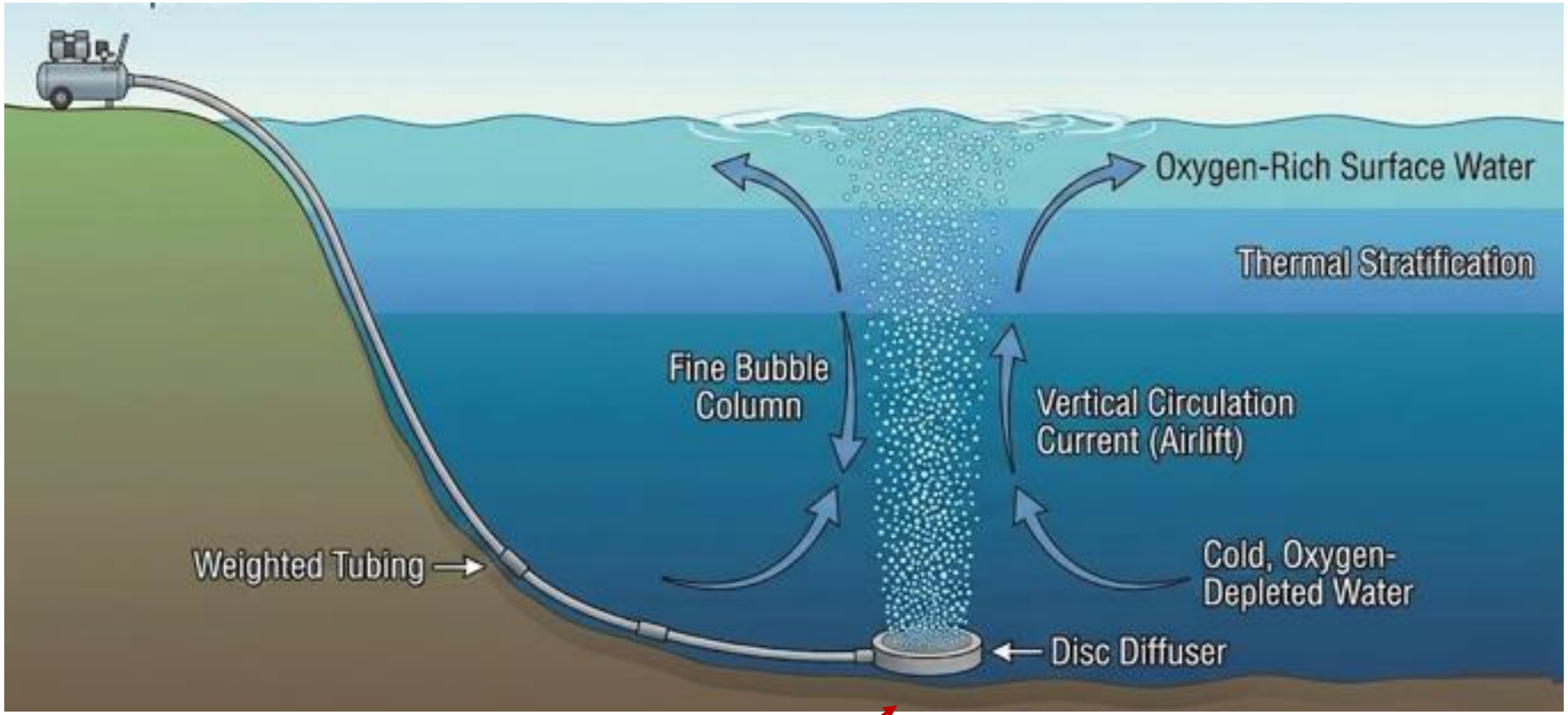
- Creates micron-sized bubbles
- Jet nozzles create horizontal mixing of diffused air.



Venturi



Retrofitting a lagoon with diffused air



Full column aeration with diffused air can help prevent stratification and facilitate mixing.

Coarse bubbles facilitate mixing but are less efficient. **Fine bubbles** are more efficient but provide less mixing
Depth should be 8+ feet for efficient use of diffused air.

An important decision is placing the diffusers at the bottom of the lagoon or raising them above the sludge zone.

On the bottom: Requires removing sludge (expensive) but can prevent excess sludge buildup.
Above sludge layer: Sludge will continue to accumulate but does not require removing sludge.

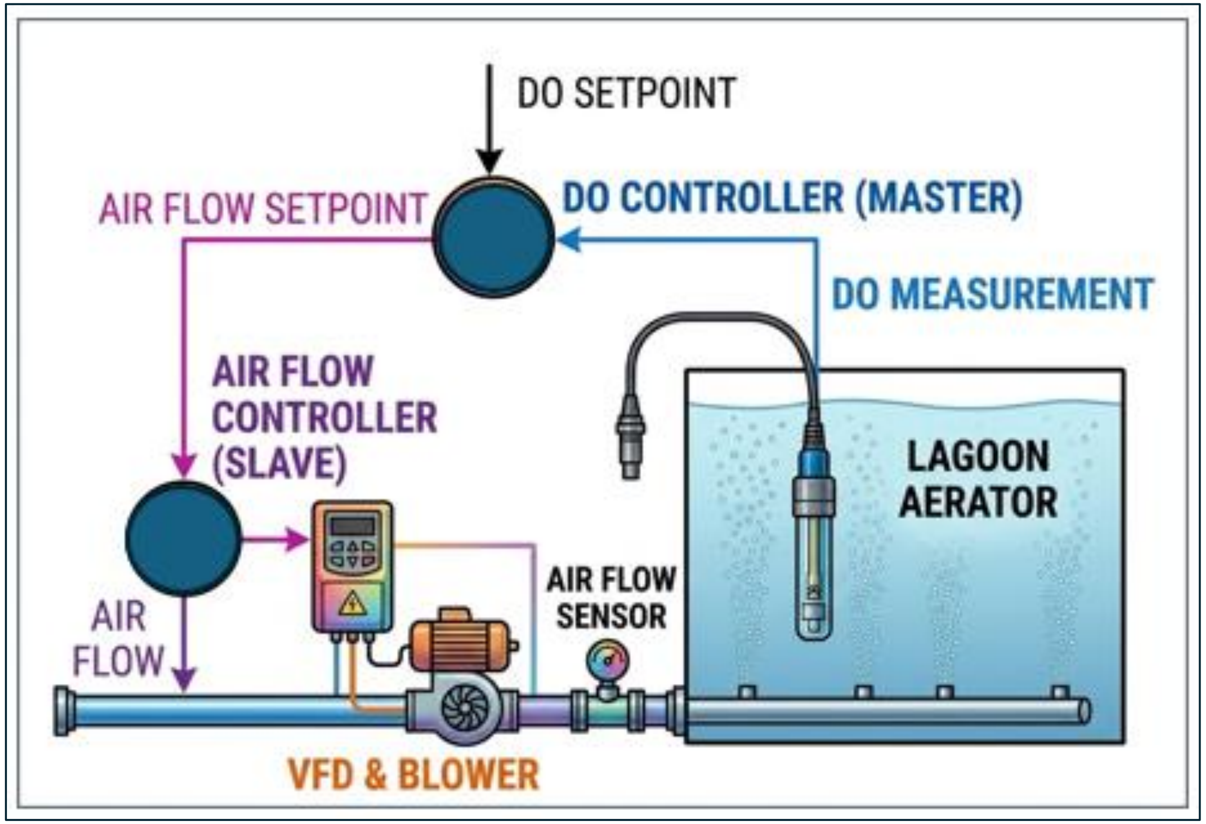
Indicators that additional aeration is needed

- **Odors from hydrogen sulfide gas**. This indicates that anaerobic processes are occurring in the sludge zone. Mixing and aeration can prevent this.
- **Filamentous Bacteria growth**. An indicator of low DO
- **High BOD in effluent** or less than 80% BOD removal in lagoon cell 1

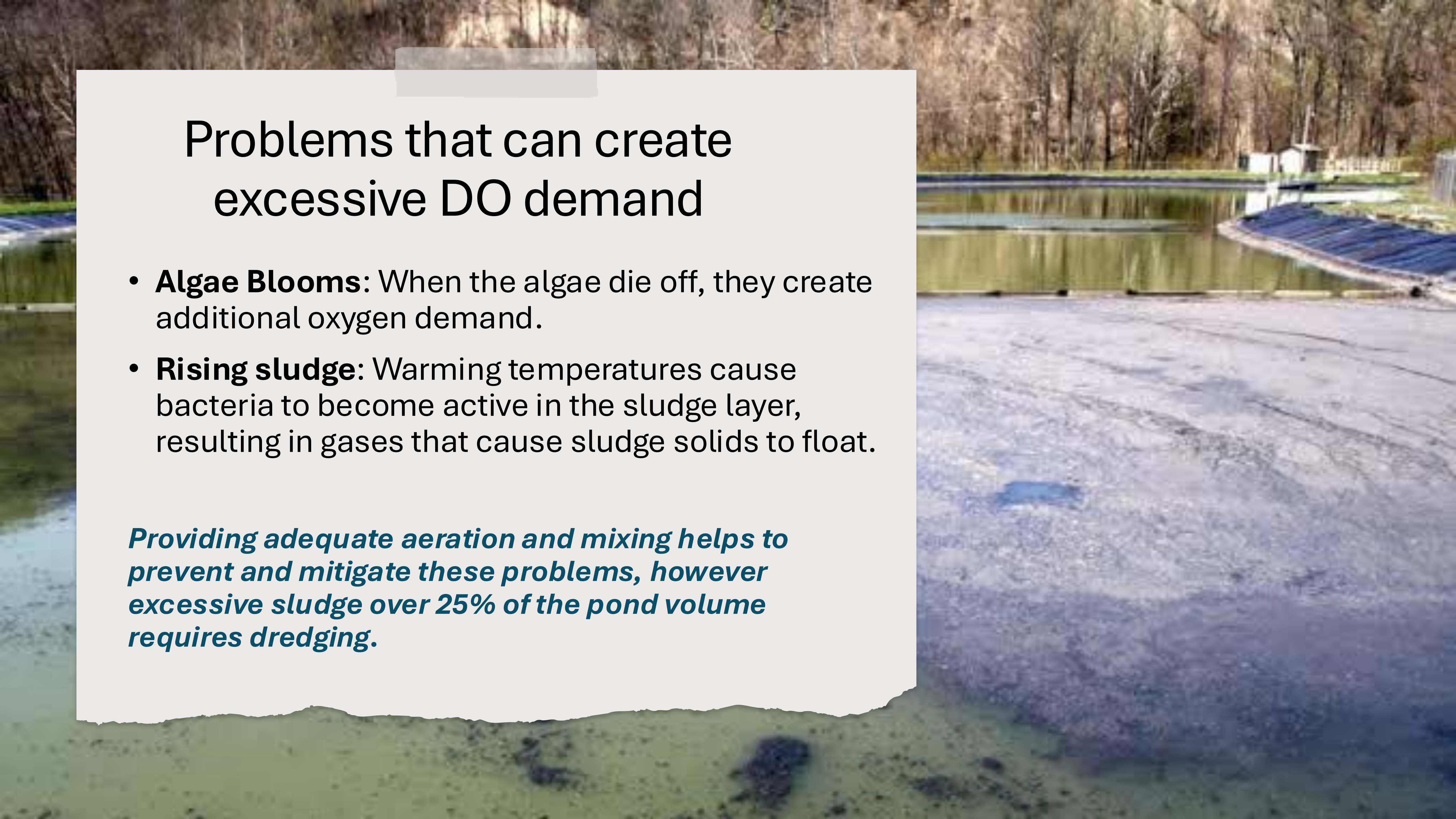
Using sensors and VFD

A diffused air blower motor can be controlled with a variable frequency drive that responds to a DO sensor.

- This method can increase efficiency while ensuring adequate DO.
- When the sensor indicates lagoon DO is high, the VFD can run the blower at a lower speed for less airflow or even shut it down.
- When DO is low, the blower ramps up to a higher speed and delivers more airflow



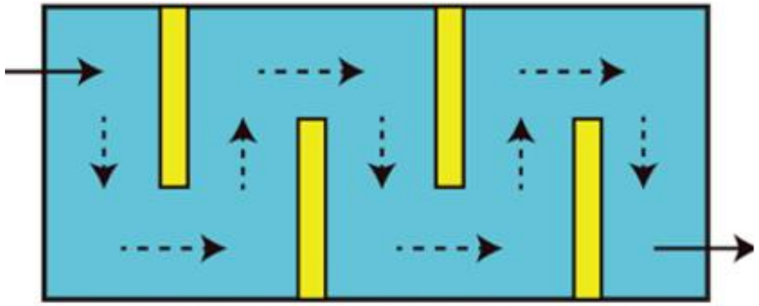
DO levels over 3 mg/L indicate that energy is being wasted, while DO under 1 mg/L is under-aeration that can lead to anaerobic conditions and ineffective treatment.

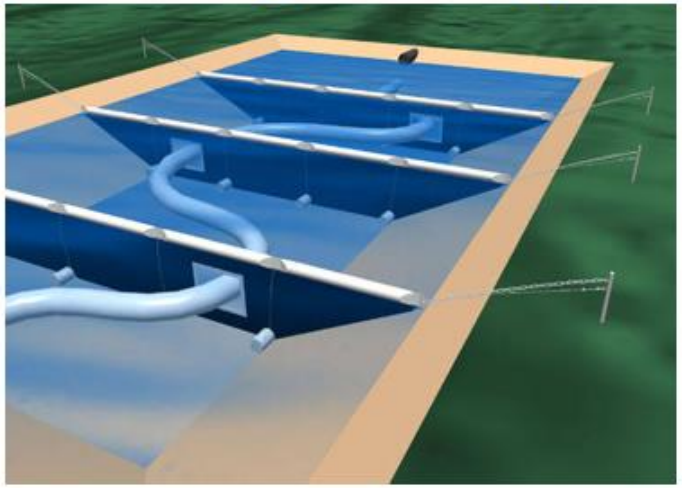


Problems that can create excessive DO demand

- **Algae Blooms**: When the algae die off, they create additional oxygen demand.
- **Rising sludge**: Warming temperatures cause bacteria to become active in the sludge layer, resulting in gases that cause sludge solids to float.

Providing adequate aeration and mixing helps to prevent and mitigate these problems, however excessive sludge over 25% of the pond volume requires dredging.





Installing curtain baffles

Adding baffles to lagoon cells improves the circulation of dissolved oxygen

1. Prevents short-circuiting and dead-zones
2. Ensures that BOD, microorganisms, and oxygen come into contact
3. Increases treatment efficiency

DO Targets and Monitoring

Using a DO probe, test oxygen levels at several locations around the lagoon

- Regions with low DO (below 1.0 mg/L) can indicate short circuiting or lack of aeration. Over 3.0 mg/L indicates over-aeration.

Check DO levels at different depths:

- **1-2 feet below the surface** (*the surface could provide a false high DO if influenced by algae*)
- **Mid-depth, 4 - 6 feet**. (*this is where aeration should be working at its best*)
- **1 foot above sludge layer** (this checks how well DO is being mixed)

What we covered today

The importance of aeration for achieving BOD and Ammonia removal treatment goals

- Tips for monitoring and optimizing DO in wastewater lagoons
- Characteristics of surface aerators and diffused air systems
- The basics of sizing aeration systems

We are now open for questions

Please share in the chat, something you appreciated learning about today.

Where to learn more:

Lagoon Wastewater Treatment Systems EPA Website:
https://www.epa.gov/lagoons

First Stop Toolbox for Lagoon Systems:
https://www3.epa.gov/npdes/lagoontoolbox/index.html

Troubleshooting Manual for Small, Facultative, Partial-Mix Aerated, and Complete-Mix Aerated Wastewater Lagoons:
https://www.epa.gov/system/files/documents/2024-02/lagoon-troubleshooting-manual.pdf

Principles of Design and Operations of Wastewater Treatment Pond Systems for Plant Operators, Engineers, and Managers:
https://www.epa.gov/sites/default/files/2014-09/documents/lagoon-pond-treatment-2011.pdf

Thank you for attending