Troubleshooting Manual for Small, Facultative, Partial-Mix Aerated, and Complete-Mix Aerated Wastewater Lagoons

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Contents

Contributions and Acknowledgements

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Abbreviations

Table 1 presents the abbreviations used throughout the document.

Table 1. Acronyms and abbreviations.

Abbreviations	Full Phrase
BOD	biochemical oxygen demand
BOD_5	five-day biological oxygen demand
$CBOD_5$	five-day carbonaceous biochemical oxygen demand
CFR	Code of Federal Regulations
DO	dissolved oxygen
EPA	United States Environmental Protection Agency
I&I	infiltration and inflow
mg/L	milligrams per liter
NPDES	National Pollutant Discharge Elimination System
TSS	total suspended solids
WWTP	wastewater treatment plant

Introduction

To reduce the rate of significant noncompliance with National Pollutant Discharge Elimination System (NPDES) permits at lagoon facilities, improve water quality, and protect environmental and public health, the U.S. Environmental Protection Agency (EPA) has developed this troubleshooting manual. Specifically, this manual is designed to help operators at small wastewater treatment plant (WWTP) lagoons, also called wastewater stabilization ponds, identify causes of lagoon upset conditions and the corresponding troubleshooting steps.

This manual specifically focuses on small, facultative lagoons and partial-mix and complete-mix aerated lagoons serving communities under 1,000 people. Additionally, while this manual focuses on NPDES-permitted lagoons with controlled or continuous discharge, it is also relevant to non-discharging lagoons.

Note: For more details on these and other lagoon types, review EPA's Principles of Design and Operations of Wastewater Treatment Pond Systems for Plant Operators, Engineers, and Managers (EPA/600/R-11/088).

Manual Organization

This manual is organized into six sections as follows:

- **Section 1** provides an overview of the recommended approach to navigating this manual and managing lagoon changes, as well as information on financial resources.
- **Section 2** provides the steps operators should follow to identify possible lagoon upset conditions before proceeding to the troubleshooting tips outlined in this manual.
- **Section 3** describes troubleshooting procedures applicable to all lagoon types.
- **Section 4** describes troubleshooting procedures specific to facultative lagoons.
- **Section 5** describes troubleshooting procedures specific to partial-mix aerated lagoons.
- **Section 6** describes troubleshooting procedures specific to complete-mix aerated lagoons.

1. Manual Navigation, Impacts of Managing Change, and Financial Resources

This section gives a brief overview of the recommended approach to navigating this manual and managing lagoon changes, as well as information on financial resources.

1A. Recommended Manual Navigation

This manual includes a sample of operational problems or upsets experienced at small lagoon systems. The troubleshooting content included in this manual is broken into four sections:

- General lagoon troubleshooting tips.
- Troubleshooting tips for facultative lagoons.
- Troubleshooting tips for partial-mix aerated lagoons.
- Troubleshooting tips for complete-mix aerated lagoons.

Table 2, below, shows the upset conditions included in each troubleshooting section of the manual. Each upset condition section includes the following content: (1) description of upset condition, (2) common indicators, (3) impacts, and (4) troubleshooting tips.

When experiencing an upset condition, first review the applicable general upset conditions in Section 3. Then, review additional lagoon-specific tips in sections 4, 5, or 6. For example, if a facultative lagoon facility is experiencing short-circuiting, first review the short-circuiting tips in Section 3: General Lagoon Troubleshooting Tips. Then, review the additional short-circuiting content included in Section 4: Facultative Lagoon Troubleshooting Tips.

Table 2. Manual navigation.

Section 3: General Lagoon Troubleshooting Tips	Section 4: Facultative Lagoon Troubleshooting Tips	Section 5: Partial-Mix Aerated Lagoon Troubleshooting Tips	Section 6: Complete-Mix Aerated Lagoon Troubleshooting Tips
Short-Circuiting	Short-Circuiting	Short-Circuiting	Foaming
Sewage Sludge Accumulation	Organic Overload	Organic Overload	Algal Overgrowth
Hydraulic Overloading	Odors	Odors	Inadequate Nitrification for Facilities with Ammonia Permit Limits

Algal Overgrowth	Algal Overgrowth	Algal Overgrowth	
Erosion	Inadequate Nitrification for Facilities with Ammonia Permit Limits	Inadequate Nitrification for Facilities with Ammonia Permit Limits	
Overgrown Vegetation Other Than Algae (Lagoon Surface and Banks)			
Scum and Trash Accumulation			
Low Water Levels (Leakage)			
Disinfection and Dechlorination Issues			

1B. Managing Change

Anytime changes are made at a facility, it is critical that operators consider their potential impacts, including those resulting from implementing troubleshooting solutions outlined in this manual. Potential impacts include:

- **Permit requirements.** Changes to the lagoon (particularly physical changes) may require approval by a permitting or regulatory authority and/or may require design by a licensed professional engineer. Where possible, these considerations are noted within the manual. However, when in doubt, permitted facilities should contact their permitting or regulatory authority with any questions.
- **Unintended impacts.** Changes to lagoon design or standard operational procedures implemented as a result of troubleshooting may result in unintended impacts elsewhere in the lagoon. Permitted facilities should follow management of change protocols, including documenting changes to the lagoon operating conditions, procedures, or parameters and considering potential unintended impacts throughout the lagoon.

1C. Financial Resources

For lagoon troubleshooting solutions beyond a facility's budget, consider grant or loan programs offered through the federal government or other entities. At the time this manual was completed, federal programs to consider include but are not limited to:

- EPA's State Revolving Fund Program and Tribal Funding Sources.
- U.S. Department of Agriculture Rural Development Program Loan and Grant Programs.

- The U.S. Department of Housing and Urban Development Community Development Block Grant Program.

Additionally, the facility may consider:

- Contacting state or EPA permitting or regulatory authorities to learn more about wastewater infrastructure funding or financing resources.
- Referring to the Water Finance Clearinghouse to identify additional funding and financing resources available for wastewater infrastructure projects.
- Contacting a Rural, Small and Tribal Technical Assistance provider, local Environmental Finance Center, or requesting technical assistance through EPA's Water Technical Assistant Request Form.

2. Approach to Troubleshooting

If the lagoon facility is not meeting discharge requirements, first consider any feasible operational changes. The goal of these changes should be to improve retention times, solids removal, and lagoon hydraulics or flow patterns. After these operational changes, begin conducting troubleshooting activities outlined in this manual.

If permit violations continue, conduct observations, field measurements, and/or lab analysis throughout the lagoon. Operators should conduct observations, field measurements, and analysis at the influent and effluent of each pond or cell. If there is aeration, the midway point or both before and after any aeration should also be considered. Compare this information to older records. Then, given observations, measurements, or sampling results, proceed to the troubleshooting tips outlined in this manual for the system upset conditions experienced.

Note: Central to identifying when lagoons are experiencing system upset conditions is having established and recorded standard operating parameters. Baseline data allow facilities to more effectively identify upset conditions. They also help identify possible root causes or contributing factors. The troubleshooting techniques described in this manual assume the facility has baseline data to compare against data the operator has observed, measured in the field, or analytically tested.

If baseline data are not yet established:

- **Appendix A** provides a recommended inspection checklist for establishing standard operating parameters based on operator observations and field measurements.
- **Appendix B** provides an example sampling protocol for establishing standard operating parameters based on laboratory-tested lagoon parameters.

3. General Lagoon Troubleshooting Tips

3A.Short-Circuiting

Short-circuiting occurs when influent passes through the lagoon, from the inlet to the outlet, without circulating through treatment processes. Short-circuiting may lead to high biochemical oxygen demand (BOD) and soluble BOD, moderate total suspended solids (TSS), and high ammonia in the final cell. Short-circuiting can be most serious for lagoons with a single cell. Operators should evaluate all cells when evaluating the presence of short-circuiting conditions, as some may short-circuit while others may not.

Effluent that is warmer than the overall lagoon may indicate a short-circuit. To confirm this diagnosis, conduct a dye test or add small floating objects such as oranges or tennis balls at the influent pipe and observe the path they take. The objects may need to be added at the influent point to each cell if the transfer pipes between cells are screened or have turtle guards. Be mindful of any effect ambient wind may have on driving the objects. If the objects are floating along the dike wall, rather than completing a winding path, a cell may be short-circuiting. An additional way to identify potential short-circuiting is to compare actual detention time to design detention time. If actual detention time is less than design detention time, this could indicate the wastewater flow is taking a shorter path, and short-circuiting may be occurring.

Note: If the facility routinely experiences high-wind conditions, consider using a drogue or drifter device, as shown in Figure 1. These floating devices have an underwater “sail” to catch underwater currents when they exist. If an underwater current does exist, the operator will be able to observe the movement of the buoy attached to the device.

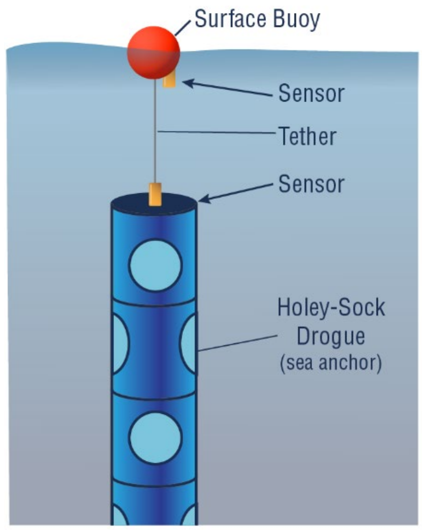

Figure 1. Drifter device.

Short-circuiting can be exacerbated by hydraulic overloading, such as from inflow and infiltration (I&I). If hydraulic overloading is suspected, see **Section 3C.**

Potential Solutions

The design and placement of influent and effluent structures is critical to avoiding short-circuiting and loss of solids. While the options presented below may be expensive, they have the highest probability of preventing short-circuiting in the future:

- If the lagoon inlet is located at the center, short-circuiting can occur. Facilities should redesign inlet and outlet structures to include manifolds and then relocate these structures as far apart from each other as possible to avoid short-circuiting. This redesign may require contacting a professional engineer to develop plans and getting approval from the appropriate permitting authority.
- If possible, add additional cells that are long and narrow. This addition will generally require hiring an engineer to design the retrofit, receiving approval from the permitting authority, and hiring a contractor to construct the retrofit.
- If practicable, consider making the bottom of each cell as flat as possible and round the corners to improve flow.

Additional solutions may be less costly than those in the previous list. However, these potential solutions may not solve the short-circuiting. The solutions include:

- Changing the lagoon from series operation to parallel operation (in multicell lagoons, where feasible).

- Cleaning out weeds or accumulated solids if they affect the flow patterns.
- In some cases, relocating mixers or aerators in a cell may improve flow distribution.

For more information, see **Section 4A** for facultative lagoons and **Section 5A** for partial-mix aerated lagoons.

3B. Sewage Sludge Accumulation

Excess sewage sludge means less volume is available to store wastewater and therefore reduces retention time, which can result in poor treatment. Common indicators of sewage sludge accumulation include high BOD, low-to-moderate TSS, low dissolved oxygen (DO), and high ammonia in the final cell.

Source: EPA.

Image 1. Sludge accumulation at a transfer structure.

To diagnose sewage sludge accumulation, check for buildup at the inlet and outlet points, tanks, ultraviolet channels, pipes, or anywhere sewage sludge may accumulate. As an example, Image 1 shows sludge accumulating at a transfer structure. Next, measure sewage sludge depth in the lagoon using a core sampler, sonar, or sewage sludge interface detector at 24 to 36 sample points throughout each cell, depending on the number of cells in the system. After collecting measurements, calculate the average sewage sludge depth to estimate overall sewage sludge accumulation. If the sewage sludge depth is at or above 25 percent of the lagoon operating depth, the lagoon requires de-sludging.

Example: A facultative lagoon with a typical operating depth of 60 inches (5 feet) should be de-sludged when the average sewage sludge depth meets or exceeds 15 inches (i.e., 25 percent of 60 inches).

Potential Solutions

A short-term solution to sewage sludge accumulation is to use a vacuum truck or trash pump to remove accumulated sewage sludge from conveyance structures. Depending on available equipment, an operator may also consider fitting a power takeoff pump on a tractor or commercial vehicle to pump out sewage sludge. Other tools an operator may consider include chain drags, nets, or rakes.

If sludge accumulation is causing problems (e.g., high soluble BOD), increase aeration as a temporary solution and plan to remove sludge from the bottom of the lagoon in accordance with local regulations.

Options for sewage sludge waste management include:

- Land application as fertilizer or soil conditioner, meeting the requirements of 40 Code of Federal Regulations (CFR) Part 503.
    - **Note:** This management method is typically part of the facility discharge permit. However, the facility may need to obtain an additional permit depending on the specific sewage sludge reuse scenario.
- Surface disposal, meeting the requirements of 40 CFR Part 503.
- A landfill, meeting the requirements of 40 CFR Part 258.
- Incineration, meeting the requirements of 40 CFR Part 503.

3C. Hydraulic Overloading

Hydraulic overloading occurs when increased flow (e.g., from population growth) or I&I exceed lagoon design flow capacity. Hydraulic overloading shortens water retention time and degrades performance.

As depicted in Figure 2 below, inflow is water that enters a sewer system through a specific path, such as manhole covers, roof leaders, cellar drains, yard drains, area drains, drains from wet areas, cross-connections between storm sewers and sanitary sewers, catch basins, or cooling towers. Infiltration is water that can seep into the collection system through broken sewage pipes or faulty joints.

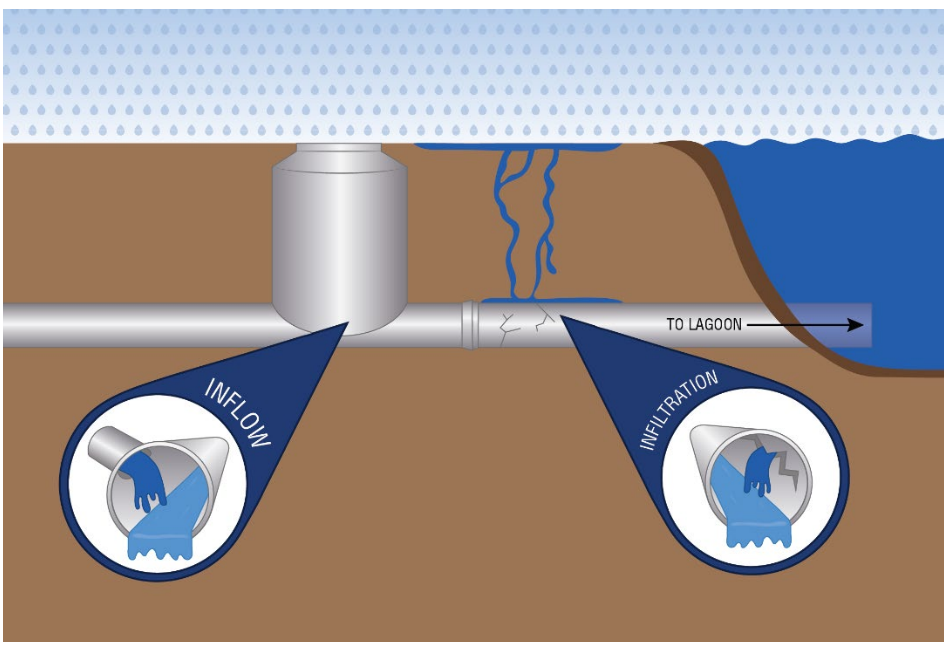

Figure 2. Infiltration and inflow.

Note: Hydraulic overloading can also be caused by sewage sludge accumulation, which can reduce available lagoon volume. If the overloading may be due to sewage sludge accumulation, refer to **Section 3B.**

If water levels in the lagoon exceed the design depth (e.g., reduced freeboard) for an extended period, or the lagoon is frequently overloaded during rainfall events, the lagoon may be experiencing hydraulic overloading.

Comparing the actual (i.e., measured) detention time with the lagoon's designed detention time can help confirm hydraulic overloading due to increased flow or I&I. **If the measured detention time is less than the designed detention time, the lagoon is hydraulically overloaded.**

Note: To calculate the actual detention time, measure the influent rate using a flow meter and divide this value by the total lagoon volume. Then, compare this measured detention time against the lagoon's designed detention time.

Potential Solutions

If resources allow, consider contacting a technical assistance provider or a professional engineer to perform an I&I study.

If I&I studies are not accessible, facilities may monitor for common indicators of an I&I problem such as significant spikes in inflow during a wet weather event, high groundwater conditions, or lift stations that run for a longer period after a rain event. Additionally, systems may consider utilizing a 2014 EPA Guide for Estimating Infiltration and Inflow for additional means of identifying I&I.

If inflow is discovered, cap or seal the open access points contributing to inflow. Repair manholes by grouting and/or repairing the frames and covers.

If sources of infiltration are discovered, consider repairing damaged pipes that are contributing to infiltration through trenchless rehabilitation or an open-cut replacement, as appropriate.

Note: Become familiar with the sewer use ordinance that gives municipalities legal standing to prohibit illegal sources of I&I.

If correcting I&I does not resolve the hydraulic overloading, consider constructing an additional lagoon cell. Resolving hydraulic overloading via construction may be necessary to meet effluent limits.

3D. Algal Overgrowth

Algal overgrowth, such as that depicted in Image 2, is prevalent in regions with a high number of sunny days during the year. Overgrowth occurs predominantly in the spring and summer. Long detention times, shallow pond depths, abundant nutrients, warm water, and sunshine promote algal growth. Algal overgrowth increases water pH, consumes oxygen (deficits are measurable at night when photosynthesis is absent), and can lead to high TSS levels. Ammonia increases in toxicity when pH is elevated, meaning the same amount of ammonia is more toxic. This condition may cause fish kills in the water body receiving lagoon discharge.

Source: EPA.

Image 2. Yellow-colored algae growth.

Algal overgrowth may increase effluent BOD under certain conditions. Effluent from some types of lagoons contains algae and may require additional treatment or "polishing" to meet discharge permit requirements.

Algae consume carbon dioxide in sunlight, which raises pH levels. Consequently, high effluent pH (greater than 9.0) can be a sign of algal overgrowth. Operators can also determine algal overgrowth by examining effluent microscopically and observing elevated algae content.

Potential Solutions

To suppress algae growth and reduce solids in effluent discharges:

- Add water-soluble dye that blocks sunlight.
- Add a floating cover, such as floating ballast balls or a swimming pool cover. Installing a lagoon cover may require assistance from an engineer.
    - **Note:** The pool cover should not cover the entire lagoon.
- Add mechanical aeration and mixing to a lagoon to help control algae overgrowth. Mechanical aeration can cause turbulent surface water to block sunlight penetration. Recirculating wastewater in the final cell may help stifle algae growth before an algae bloom sets in, but this should be done carefully so as not to adversely impact settling where needed. If the lagoon is not currently discharging, mixing the lagoon for a month prior to discharge can be effective to address algae overgrowth.
- For a multicell aerated lagoon system, consider removing an individual cell from operation to reduce the overall hydraulic retention time and prevent or address an algal overgrowth condition. However, make sure the reduction in retention time does not negatively affect treatment.

- If considerable sewage sludge accumulation exists, de-sludge the lagoon.
- If permitted to discharge, discharge effluent that is below the surface at variable depths to reduce surface algae entering the effluent. Take care not to discharge effluent from too far below the surface, or sewage sludge may inadvertently be drawn out with the effluent.
- For multicell lagoon systems, consider operating cells in series (e.g., effluent flows through each cell in succession), provided that operating in series does not affect overall lagoon operations.
- If available, and in coordination with the relevant regulatory authority, use a small final lagoon that has a one-day to two-day hydraulic detention time.

For additional algal overgrowth troubleshooting solutions, refer to **Section 4D** for facultative lagoons, **Section 5D** for partial-mix aerated lagoons, and **Section 6B** for complete-mix aerated lagoons.

3E. Erosion

Erosion can be a common problem for lagoon systems, specifically for the interior slopes, where erosion can reduce the structural effectiveness of banks and dikes constructed to contain process water. Disintegration of the soils and materials that compose the interior slopes is primarily caused by lagoon wave action and surface runoff. Wave action mechanisms occur at the interface of lagoon water and the surrounding interior slopes, while surface runoff occurs when particles detach from and transport off the slopes.

Other factors that can contribute to erosion include burrowing animals and deteriorated or inappropriately constructed erosion control features (e.g., protection systems at pipe locations, riprap, geotextile fabric, liners, topsoil with established growth).

Operators should first determine the primary erosion mechanism and review the lagoon system design, but the primary objective of erosion control should be to protect the interior slopes.

Potential Solutions

Source: EPA.

Image 3. Riprap dike construction.

- Install riprap, such as the riprap depicted in Image 3, or a concrete liner along banks to prevent erosion. If riprap is not available, gunite (also known as shotcrete or sprayed concrete) may be an option. Be sure the liner, or sprayed concrete, extends from the lagoon banks to 3 feet below the surface of the water. This depth will help deter muskrats and protect against erosion from strong wave action. Contact the appropriate regulatory authority to discuss any regulatory requirements prior to lining dikes.
- Consider adding fast-growing grass cover with a shallow and dense root system. Avoid long-rooted plants that can cause leakage or damage to other structural elements.
- Control burrowing animals such as muskrats with the following methods:
  - Maintain fencing around the lagoon to discourage rodents.
  - Remove food supply such as cattails and burr reed. See **Section 3F** for more information.
  - Raise and lower the water level by 6 to 8 inches over several weeks, which upsets the muskrats' environment and makes them vulnerable to predators.
  - If the problem persists, check with the local regulatory authorities for approved methods of removing burrowing animals.

3F. Overgrown Vegetation Other Than Algae (Lagoon Surface and Banks)

Excessive weed growth on **lagoon banks,** such as that in Image 4, can harbor insects, attract vermin and snakes, and trap grease and organics. Weeds can also interfere with wind movement, provide habitat for burrowing animals, cause odors, create breeding conditions for mosquitoes, cause short-circuiting problems, and allow scum to collect in the lagoon.

Source: EPA.

Image 4. Partially cleared, overgrown vegetation.

On the **lagoon surface,** duckweed and other vegetation stop sunlight penetration and prevent wind movement, thus reducing oxygen in the lagoon. Root penetration through the bottom of the dike can cause leaks in the lagoon seal. Woody vegetation, such as trees and shrubs, should never grow on lagoon dikes.

Note: Unless duckweed is specifically introduced to create shade and control algal growth, skim the surface regularly and do not allow it or other vegetation to accumulate. Otherwise, duckweed can cause sewage sludge accumulation, low DO, and odors.

Potential Solutions

Implement control measures when vegetation becomes excessive.

For lagoon banks:

- Mow grass periodically and control weed growth along the edges of lagoon cells, including pulling new growth of cattails and bulrushes.
- Cut and remove trees, shrubs, and dead vegetation on dikes and at the edges of lagoon cells.
- As a last resort, if the lagoon or dikes have excessive vegetation that can only be remedied by herbicides, contact a licensed herbicide applicator to apply herbicide according to the label restrictions. Failure to do so may result in harm to the beneficial biological activity in the lagoon and failure to meet permit limits.

For the lagoon surface:

- Use a boat to push and collect vegetation in the corner of a lagoon cell, or take advantage of a windy day, then remove the collected vegetation with a rake or a vacuum truck.

3G. Scum and Trash Accumulation

Both scum and trash accumulation can be problematic for lagoons, preventing sunlight penetration and wind movement, as well as reducing DO concentration. These conditions can lead to odors and provide a habitat for insects.

Note: A small amount of scum may not be cause for concern. However, scum covering a significant portion of a lagoon cell will require intervention.

Potential Solutions

Inspect the lagoon surface and the inlet and outlet structures for scum buildup on a weekly basis. Clean the structures regularly to remove floating debris, caked scum, or trash.

To remove excessive scum and trash:

- Use rakes, a portable pump that can create a water jet, or motorboats to break up scum formations. Scum usually sinks once it is broken up. If scum remains, skim and properly dispose of the removed scum. Facilities should coordinate with state regulatory agencies regarding potential options and related regulatory requirements for handling scum, including potential recycling opportunities.
- If the influent regularly contains excessive fats, oils, and greases, review local sewer use ordinances and implement a fats, oils, and greases program that requires installing grease interceptors at commercial (e.g., a restaurant) and industrial facilities.
- Add pretreatment (e.g., skimming, floating booms, sorbent pads) to prevent scum buildup in the future.
- If trash accumulates in the primary treatment cell, consider modifying the influent structure to screen it out. This process may require approval from the permitting authority; consider applicable design standards in making modifications.
- Add a channel in the headworks at an appropriate flow velocity (between 15–30 centimeters per second) to settle sand and grit particles before they enter the lagoon and contribute to scum and trash buildup. Always properly dispose of built-up grit.
- Study wind directions and locate transfer outlets to prevent dead pockets where scum tends to accumulate. Retrofits may need approval from the permitting authority and should be designed by a professional engineer.

3H. Low Water Levels (Leakage)

Lagoons can leak due to excessive vegetation, erosion caused by burrowing animals, or leaks in the lagoon lining, seals, or control structures. Leakage can cause low water levels, increased vegetation, and potential groundwater infiltration or permit violations.

Note: Some states have requirements for lagoons that include maximum seepage, leakage tolerance, and/or leak detection.

If leakage is suspected, consider conducting water balance testing by determining the difference between recorded inflows (i.e., sewage and rainfall) and outflows (i.e., seepage, discharge, irrigation, and evaporation). In arid and semi-arid parts of the country, evaporation will exceed rainfall, so be sure to factor evaporation in the "outflow" calculation. If outflows exceed inflows, further investigation may be required to determine potential sources of leakage.

Note: For resources on water balance testing, refer to the Oregon Department of Environmental Quality's Guidelines for Estimating Leakage from Existing Sewage Lagoons or, if possible, contact a technical service provider to assist with testing.

Potential Solutions

To address leakage, inspect control structures and lagoon lining for breaches and repair as necessary. Many states have protocols for inspecting and repairing leaking lagoons. Check with the state government for inspection or repair protocols if support is needed.

If leakage is due to erosion or burrowing animals, refer to **Section 3E** and **Section 3F,** respectively, for additional troubleshooting information.

3I. Disinfection and Dechlorination Issues

The last steps in treating wastewater can include disinfection[1] to kill pathogenic organisms and dechlorination to remove chlorine residuals generated from chlorine disinfection before effluent is discharged.

Improper or incomplete disinfection and dechlorination can result in excess coliform. Coliform can form for several reasons, including poor chlorine contact chamber design or an increase in chlorine-demanding substances such as hydrogen sulfide, dead algae, organic matter, or waterfowl contamination.

Note: When using chlorine to disinfect, chlorination must be followed by dechlorination prior to effluent discharge. This step protects fish and other aquatic life in receiving waters from the toxic nature of chlorine, even at low levels. Additionally, dechlorination dosing and retention times should follow state requirements.

[1] The most common disinfection methods are chlorination (with gas or liquid) or exposure to ultraviolet light.

Potential Solutions

To address the potential causes improper or incomplete disinfection and dechlorination, begin by inspecting the chlorine contact chamber for buildup of solids. If buildup is present, remove the buildup with available tools.

Next, test the chlorine residual to determine whether to increase the chlorine feed rate. A chlorine residual test, also called a Cl- test, determines the amount of chlorine present after disinfection. Grab samples must be tested immediately and cannot be held for analysis.

Note: To help prevent inaccurate chlorine residual readings, ensure the sample is not exposed to sunlight or agitation, and that the sample collection bottle is clean. These issues can cause an inaccurate (generally low) reading.

Note: Maintaining sufficient chlorine residual in accordance with NPDES permit requirements is important for complying with coliform requirements in the facility's NPDES permit. However, NPDES permits can also include limits on chlorine residuals in effluent. To avoid permit violations, take chlorine residual samples to determine when the residual is low enough to discharge, per the facility's NPDES permit.

If using a tablet feeder in a small lagoon for chlorine disinfectant, be aware that if the tablets are used up and fully dissolved, no chlorine will be available to disinfect the effluent. Likewise, if the dechlorinator runs out of dechlorination tablets, then the effluent may contain harmful concentrations of chlorine in the effluent. At times, the chlorine and dechlorination tablets can become trapped in the dispensing tube and therefore do not fall down into the flow entering the contact tank. When this happens, it is possible no chlorination or dechlorination will occur, which would likely result in a permit violation for chlorination. The tablets must be properly inserted into the tubes so that when one tablet dissolves, the next tablet falls into the correct place.

4. Facultative Lagoon Troubleshooting Tips

A facultative lagoon, also known as a photosynthetic pond, is not mechanically mixed or aerated. As depicted in Figure 3 below, facultative lagoons have an aerobic layer, followed by an anoxic or facultative layer, and then an anaerobic layer beneath. The aerobic layer at the top is caused by atmospheric reaeration and algal photosynthesis, which supports aerobic and facultative bacteria.

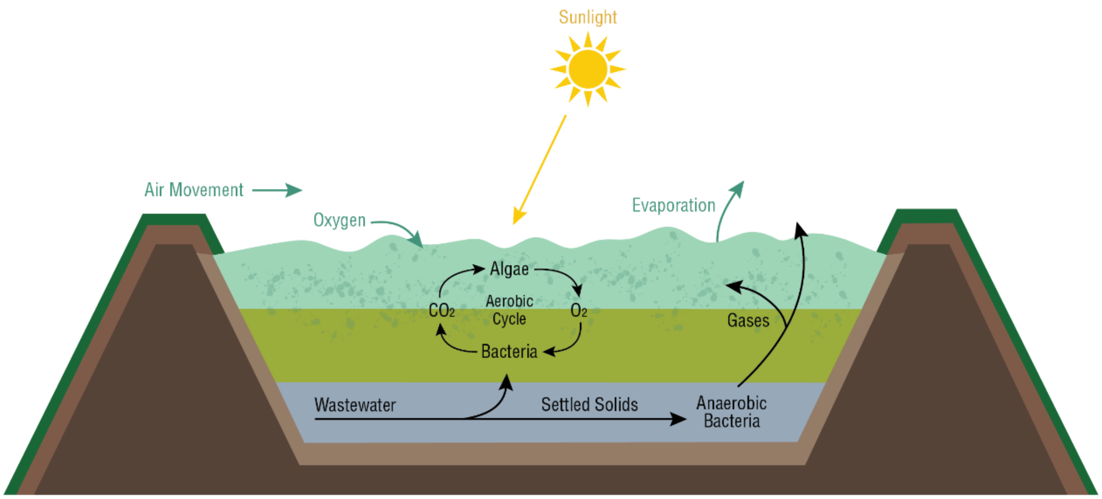

Figure 3. Facultative lagoon.

Some unique features of facultative lagoons include:

- Most facultative lagoons operate without primary treatment.
- Facultative lagoons may be unable to discharge during the winter due to ice and low oxygenation and fermentation, which can slow and impede treatment.
- Facultative lagoon layers may invert in the spring and fall when temperature fluctuations make the surface water layer more dense than lower layers. When the heavier water sinks, it creates instability, turbidity, and odors.

4A.Short-Circuiting

Short-circuiting occurs when influent passes from the inlet to the outlet of the lagoon without circulating through treatment processes. Short-circuiting is more likely during the winter months when temperature stratification is more likely. Temperature stratification can cause short-circuiting when the influent water temperature is much higher than the lagoon temperature and flows over the lower layers without mixing.

Short-circuiting may lead to high BOD and soluble BOD, moderate TSS, and high ammonia in the final cell. Short-circuiting can be most serious for lagoons with a single cell. Operators should evaluate all cells when evaluating the presence of short-circuiting conditions, as some may short-circuit while others may not.

Effluent that is warmer than the overall lagoon may be an indicator of a short-circuit. To confirm this diagnosis, conduct a dye test or add small floating objects such as oranges or tennis balls at the influent pipe and observe the path they take. The objects may need to be added at the influent point to each cell if the transfer pipes between cells are screened or have turtle guards. Be mindful of any effect ambient wind may have on driving the objects. If the objects are floating along the dike wall, rather than completing a winding path, a cell may be short-circuiting. An additional way to identify potential short-circuiting is to compare actual detention time to design detention time. If actual detention time is less than design detention time, this could indicate the wastewater flow is taking a shorter path, and short-circuiting may be occurring.

Note: If the facility routinely experiences high-wind conditions, consider using a drogue or drifter device, as shown in Figure 1. These floating devices have an underwater "sail" to catch underwater currents when they exist. If an underwater current does exist, the operator will be able to observe the movement of a buoy attached to the device.

Short-circuiting can be exacerbated by hydraulic overloading, such as from I&I. If hydraulic overloading is suspected, see **Section 3C.**

Potential Solutions

In addition to the potential solutions listed within **Section 3A,** consider these additional potential solutions, specific to facultative lagoons:

- Add baffles, curtains, or other engineered barriers along the width of the cell to redirect flow and enhance turbulence and mixing.
- Install a manifold at the cell inlet to distribute the hydraulic load more evenly across the cell.

4B. Organic Overload

Organic overloading occurs when a lagoon is receiving more organic material than it was designed to receive. In small rural communities, food processing entities such as small animal slaughtering and dairy operations can contribute to a significant organic load. Additional causes can include expanding the service area without increasing the capacity of the lagoon, as well as poor lagoon design.

The layer of water near the surface of a facultative lagoon generally contains sufficient DO from atmospheric aeration and photosynthetic oxygenation to support the growth of aerobic and facultative bacteria that oxidize and stabilize wastewater organics. However, when a lagoon is organically overloaded, DO levels drop as organic material consumes more oxygen to meet an increase in BOD.

When DO levels drop, pH falls, ammonia levels increase, effluent has high BOD, and odors may be present. Color changes, such as the lagoon water in Image 5, may also indicate overloading. For example, facultative lagoons are commonly emerald green but may change to gray, brown, black, pink, or red when experiencing organic overloading.

Source: Jessica Duggan, EPA Region 8.

Image 5. Brownish-red lagoon water.

As a starting point to monitor DO levels, measure DO at the effluent discharge point of each lagoon cell. If a DO meter and boat are available, measure oxygen in the upper photic zone at different locations throughout the lagoon system to get a better idea of the lagoon's condition. Generally, the average DO content in the upper photic zones should be approximately 2.0 milligrams per liter (mg/L), with 1 mg/L or below (or a pH level below 6.5) indicating conditions requiring intervention.

Note: Levels of DO vary throughout the day and night. For this reason, it is best to establish baseline measurements for different periods throughout the day and night.

Potential Solutions

There are multiple ways to address organic overloading, including reducing organic matter in the influent or making adjustments to the lagoon that can support increased DO concentration and thus handle an increased organic load.

Other solutions include:

- If the lagoon receives industrial or commercial wastewater, consider asking these facilities to improve housekeeping procedures (e.g., reduce spills, clean up raw feed materials near floor drains, install grease traps). Alternatively, the lagoon WWTP can consider implementing pretreatment programs.[2]

[2] The National Pretreatment Program is a Clean Water Act regulatory program designed to control pollution emitted from indirect dischargers, which are often commercial or industrial users that send their waste to a direct

- Remove weeds such as duckweed if they cover more than 40 percent of the lagoon. Removing excess weeds on the surface of the lagoon can increase DO content.
- If there is evidence of excess sewage sludge accumulation that is causing organic overloading beyond lagoon design, de-sludge the affected cells to increase DO (see **Section 3B**).
- If the lagoon is operated in series (e.g., flow goes through each cell in successions), consider converting to operating in parallel (e.g., more than one cell that is receiving wastewater at the same stage of treatment). See Figure 4 for examples of both methods. Splitting influent flow between two cells reduces the effective load. However, the lagoon design and actual hydraulic loading may make this impossible since a single cell does not provide sufficient treatment in many cases. Consult the permitting authority and a professional engineer when considering changing the cell structure.

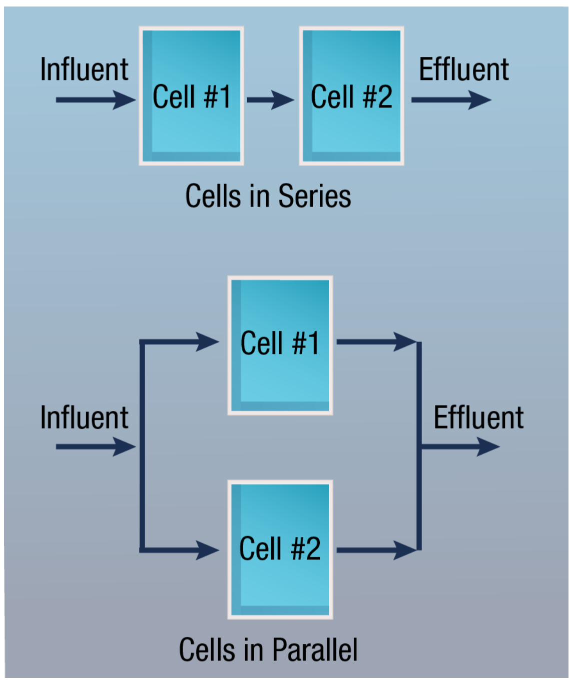

Figure 4. Parallel and series cell operations.

discharger (i.e., NPDES permitholder) like a WWTP. It is always good operational practice to require industries to institute pollution prevention practices in their facilities to minimize impacts on a lagoon system. This practice becomes imperative if a lagoon is consistently experiencing organic overloading, pass-through, or interference. The operator may need to require industrial users in their community to pretreat their waste before sending it to the lagoon. Learn more about the National Pretreatment Program.

4C. Odors

Aerobic treatment processes in the upper layer of facultative lagoons generally control odors produced by the lower anaerobic layers. However, during seasonal inversion, odorous compounds are released into the air and may become a public nuisance. These odors are typically temporary.

Odors can also be caused by low DO. When DO is low, the contents might be septic. In most cases, wastewater odors result from anaerobic or septic conditions with no DO available for microbial respiration. As a result, sulfate-reducing bacteria utilize the sulfate for respiration and produce malodorous hydrogen sulfide, which has low solubility in the wastewater and is characterized by a strong rotten egg odor released to the atmosphere. Other odorous organic compounds such as mercaptans and amines may also be present and released.

Odors and low DO could also be caused by short-circuiting, as well as poor wind action in facultative ponds due to trees, resulting in anaerobic conditions and low pH in certain areas.

Note: If multiple cells exist, use a DO probe to identify which cell is causing the odor.

If algal overgrowth is the suspected cause of the odor, see **Section 4D.**

Potential Solutions

- Reduce organic overload if possible (see **Section 4B** for details).
- If a multicell lagoon is operated in series and there is organic overload, consider converting to operating in parallel by splitting influent flow between the first two cells, thereby reducing the loading rate on the first cell. The lagoon design and actual hydraulic loading may make operating in parallel impossible since a single cell might not provide sufficient treatment in many cases. Consult the permitting authority and a professional engineer when considering changing the cell structure.
- Mitigate odor with sodium nitrate to increase DO.

4D. Algal Overgrowth

Algae in the aerobic and facultative zones is essential to the proper functioning of a facultative treatment lagoon. It produces oxygen necessary for aerobic bacteria, which break down the organic waste compounds in sewage. However, excessive algae growth can lead to high TSS and BOD concentration in the effluent and contribute to turbidity.

Overgrowth typically occurs in the spring and summer during extended exposure to higher temperatures and sunlight. Algae consume carbon dioxide during sunlight, which raises pH levels. Consequently, high effluent pH (greater than 9.0) can be a sign of algal overgrowth. The presence of algal overgrowth may also be determined by examining effluent microscopically and observing elevated algae content.

Effluent from some types of lagoons may require additional treatment or "polishing" to meet discharge permit requirements.

Potential Solutions

In addition to the potential solutions listed within **Section 3D,** consider these additional potential solutions, specific to facultative lagoons:

- If permitted, discharge effluent that is below the surface at variable depths to reduce the amount of surface algae that enters the effluent. However, take care not to draw effluent from too low in the lagoon or sewage sludge may be drawn inadvertently.
- Consider blocking sunlight with a cover in areas with algae areas or on the last settling cell in a multicell lagoon, which will prevent new algae growth and cause existing algae to die off and settle to the bottom. As a last option, consider using chemical additives in accordance with EPA registry instructions provided they do not negatively impact effluent quality.
- If the algal overgrowth is caused by excessive hydraulic retention time in a multicell lagoon, consider temporarily removing an individual cell from operation, if possible, to reduce the overall hydraulic retention time and prevent algal overgrowth conditions.

4E. Inadequate Nitrification for Facilities with Ammonia Permit Limits

Nitrification is a biological process involving a group of aerobic organisms referred to as nitrifiers that oxidize ammonia to nitrite and then to nitrate. This process occurs under aerobic conditions, sufficient alkalinity, a favorable temperature, and other conditions such as a sufficient detention time for the nitrifiers, suspension of nitrifiers for contact with ammonia and nitrite, and an adequate DO concentration (typically maintained at a minimum of 2 mg/L). Alkalinity levels above 60 mg/L of calcium carbonate are required to maintain nitrification and depend on pH and concentrations of ammonium nitrogen. Nitrifiers are slow growers and more sensitive to environmental factors than compounds that remove BOD. As such, for facilities that rely on nitrification to meet discharge permit limits for ammonia, maintaining such favorable conditions is important. Otherwise, effluent ammonia concentration can exceed permit limits.

Providing enough oxygen to meet both the BOD and ammonia removal demand is important for nitrification. Depending on lagoon design and the ammonia effluent limit, this may involve lagoon modifications requiring the services of a consultant and approval of the permitting authority.

Nitrification generally occurs over a wastewater temperature range of 4–45 °C (39–113 °F), with 35–42 °C (95–108 °F) being the optimum range. Many facultative lagoons in colder climates are not capable of implementing sufficient operational upgrades and are required to store wastewater and not discharge during winter periods.

Potential Solutions

Identify what may be causing partial or low nitrification (e.g., poor ammonia removal), then consider one of the following potential solutions depending on the cause:

- Check for increases in BOD and ammonia loading to the lagoon and consider whether options are available to reduce the loadings to the lagoon. In some cases, running lagoons in parallel instead of in series may be a temporary option until the loadings are reduced, provided adequate retention time is available. Such changes may need approval from the permitting authority.
- If there is considerable sewage sludge accumulation, de-sludge the affected cell (see **Section 3B**).
- Increase the DO content mechanically by removing anything blocking atmospheric reaeration and algal photosynthesis in sunlight. This process may include removing excessive duckweed, matted algae, or sewage sludge that is blocking the surface.
- Supplement alkalinity by adding lime, using the facility's standard operating procedures specific to the lagoon design and dimensions.
- If short-circuiting is suspected, consider adding baffles to better control flow and improve hydraulic retention time.
- If necessary, consider conducting an engineering study of feasible options for upgrading the lagoon facility for consistent ammonia removal.

5. Partial-Mix Aerated Lagoon Troubleshooting Tips

Source: EPA.

Image 6. Wind-driven aerators on a lagoon.

In aerated lagoons, such as the one depicted in Image 6, oxygen is supplied primarily through mechanical (i.e. surface) or diffused aeration, rather than by algal photosynthesis. Partial-mix aerated lagoons provide enough aeration to meet the oxygen requirements of the system and provide partial mixing of the lagoon.

Some partial-mix aerated lagoons were originally facultative and eventually needed aerators to meet discharge requirements. Aerated lagoons can usually discharge throughout the winter, while an ice-covered facultative lagoon may not be able to do so. Overall, aerated lagoons need less land area than facultative lagoons and can provide a more consistent level of treatment.

A common modification to aerated lagoons is using plastic curtains with floats anchored to the bottom of the dike to divide existing lagoons into multiple cells and/or serve as baffles to improve hydraulic conditions. Another modification is to install a row of submerged diffusers—suspended from flexible, floating booms—that cause the wastewater to move in a cyclical pattern.

5A.Short-Circuiting

Short-circuiting occurs when influent passes through the lagoon, from the inlet to outlet, without properly circulating through treatment processes. Short-circuiting is more likely during the winter months when temperature stratification is more likely. Temperature stratification can cause short-circuiting when the influent water temperature is much higher than the lagoon temperature and flows over the lower layers without mixing. Additionally, in partial-mix aerated lagoons, if aerators are cycled on and off, short-circuiting is more likely to occur when aerators are cycled off.[3] It's recommended to aerate lagoons at night when there is no sunlight to support algae growth.

[3] During the day, when light allows for photosynthesis by algae, aerators can be cycled off. If aerators are left on during the day, the lagoon may be "off-gassing" essential oxygen.

Short-circuiting may lead to high BOD and soluble BOD, moderate TSS, and high ammonia in the final cell. Short-circuiting can be most serious for lagoons with a single cell. Operators should evaluate all cells when evaluating the presence of short-circuiting conditions, as some may short-circuit while others may not.

Effluent that is warmer than the overall lagoon may be an indicator of a short-circuit. To confirm this diagnosis, conduct a dye test or add small floating objects such as oranges or tennis balls at the influent pipe and observe the path they take. The objects may need to be added at the influent point to each cell if the transfer pipes between cells are screened or have turtle guards. Be mindful of any effect ambient wind may have on driving the objects. If the objects are floating along the dike wall, rather than completing a winding path, a cell may be short-circuiting. An additional way to identify potential short-circuiting is to compare actual detention time to design detention time. If actual detention time is less than design detention time, this could indicate the wastewater flow is taking a shorter path, and short-circuiting may be occurring.

Note: If the facility routinely experiences high-wind conditions, consider using a drogue or drifter device, as shown in Figure 1. These floating devices have an underwater “sail” to catch underwater currents when they exist. If an underwater current does exist, the operator will be able to observe the movement of a buoy attached to the device.

Short-circuiting can be exacerbated by hydraulic overloading, such as from I&I. If hydraulic overloading is suspected, see **Section 3C.**

Potential Solutions

In addition to the potential solutions listed in **Section 3A,** consider these additional potential solutions, specific to aerated lagoons:

- Relocate aerators to promote a flow path that moves through the lagoon rather than adhering to the dike wall. Baffles and manifolds can be added to break up the flow path.
- Add directional aerators or mixers.
- If the lagoon has appropriate pumping and piping equipment, recirculate effluent using portable pumps to encourage mixing.

5B. Organic Overload

Organic overloading occurs when the lagoon is receiving more organic material than it was designed to receive. In small rural communities, food processing entities such as small animal slaughtering and dairy operations can contribute to a significant organic load. Additional causes can include expanding the service area without increasing the capacity of the lagoon, as well as poor lagoon design.

The layer of water near the surface of a facultative lagoon generally contains sufficient DO from atmospheric aeration and photosynthetic oxygenation to support the growth of aerobic and facultative bacteria that oxidize and stabilize wastewater organics. However, when a lagoon is organically overloaded, DO levels drop as more oxygen is consumed by organic material to meet an increase in BOD.

When DO levels drop, pH falls, ammonia levels increase, effluent has high BOD, and odors may be present. Color changes may also indicate overloading. For example, facultative lagoons are commonly emerald green but may change to gray, brown, black, pink, or red when experiencing organic overloading.

As a starting point to monitor DO levels, measure DO at the effluent discharge point of each lagoon cell. If a DO meter and boat are available, measure oxygen in the upper photic zone at different locations throughout the lagoon system to get a better idea of the lagoon's condition. Generally, the average DO content in the upper photic zones should be approximately 2.0 mg/L, with 1 mg/L or below (or a pH level below 6.5) indicating conditions requiring intervention.

Note: Levels of DO vary throughout the day and night. For this reason, it is best to establish baseline measurements for different periods throughout the day and night.

Potential Solutions

There are multiple ways to address organic overloading by either reducing organic matter in the influent or making adjustments to the lagoon that can support increased DO concentration and thus handle an increased organic load. For instance:

- If the lagoon receives industrial or commercial wastewater, consider asking these facilities to improve housekeeping procedures (e.g., reduce spills, clean up raw feed materials near floor drains, install grease traps). Alternatively, the lagoon WWTP can consider implementing pretreatment programs.[4]

[4] The National Pretreatment Program is a Clean Water Act regulatory program designed to control pollution emitted from indirect dischargers, which are often commercial or industrial users that send their waste to a direct discharger (i.e., NPDES permitholder) like a WWTP. It is always good operational practice to require industries to institute pollution prevention practices in their facilities to minimize impacts on a lagoon system. This practice becomes imperative if a lagoon is consistently experiencing organic overloading, pass-through, or interference. The operator may need to require industrial users in their community to pretreat their waste before sending it to the lagoon. Learn more about the National Pretreatment Program.

- Increase aerator running time with a goal of maintaining at least 2 mg/L DO in all treatment cells. If the DO is fluctuating, use a timer to control the aeration system to allow operation during high-load periods, keeping DO at 2 mg/L or more at all times.
- If increasing the aerator running time does not provide enough oxygen, add supplemental aeration such as surface aerators, diffusors, and/or daily operation of a motorboat. Such changes may need approval from the permitting authority and should be designed by a professional engineer.
- Check for clogged diffusers:
    - If clogging is minor, increase airflow output or turn off the affected section of the diffuser and increase diffusion in the section that is not blocked, which will compensate for the reduced airflow in the blocked section of the diffuser.
        - **Note:** Increasing the amount of air going through each diffuser beyond design specifications should be done carefully and only temporarily as it can increase the backpressure at the blower, potentially causing problems depending on the severity of the clogging. Additionally, increasing airflow can increase power and electricity costs.
    - As a cleaning option for minor clogs, introduce oxygen, ozone, or other gases through the air lines.
        - **Note:** Introducing gases through the air lines should be done with care and following safety instructions. If none of these procedures work, the last option would be to draw the lagoon cell down to repair or replace diffusers.
    - If clogging is major, or if the options above do not solve the clog, draw down the lagoon to clean, repair, or replace the diffusers.
- Remove weeds such as duckweed if they cover more than 40 percent of the lagoon. Removing excess weeds covering the surface of the lagoon can result in increased DO content.
- If there is evidence of excess sewage sludge accumulation that is causing organic overloading beyond lagoon design, de-sludge the affected cells to increase DO (see **Section 3B**).
- If the lagoon is operated in series (e.g., flow goes through each cell in successions), consider converting to operating in parallel (e.g., more than one cell receives wastewater at the same stage of treatment). See Figure 4 for examples of both methods. By splitting influent flow between two cells, the effective load reduces. The lagoon design and actual hydraulic loading may make this step impossible since a single

cell might not provide sufficient treatment in many cases. Consult the permitting authority and a professional engineer when considering changing the cell structure.

- Add more mixing to the final cell in the lagoon system to discourage algae growth and improve effluent TSS.
- If the lagoon has appropriate pumping and piping equipment, recirculate effluent to the headworks using portable pumps to provide more oxygen.

5C. Odors

Aerated lagoons can generate lagoon odors when DO levels in the lagoon are not sufficient to meet the demand of the organic load in the wastewater. Excessive buildup of sewage sludge on the bottom of aerated lagoons can cause noxious odors as well. Algal overgrowth, duckweed, seasonal inversion, and excess weed growth on lagoon banks can trap grease and organics, also causing odors.

If multiple cells exist, use a DO probe to identify the cell causing the odor. When DO is low, the contents might be septic, causing odors. In most cases, wastewater odors result from anaerobic or septic conditions with no DO available for microbial respiration. As a result, sulfate-reducing bacteria utilize the sulfate for respiration and produce malodorous hydrogen sulfide, which has low solubility in the wastewater and is characterized by a strong rotten egg odor released to the atmosphere. Other odorous organic compounds such as mercaptans and amines may also be present and released.

If algal overgrowth is the suspected cause of the odor, see **Section 5D.**

Potential Solutions

- Reduce organic overload, if possible (see **Section 5B** for details).

- Remove excess weeds, such as those shown in Image 7. Physically remove any excess weeds by pulling or mowing. As a last resort, consider contracting a licensed herbicide applicator. Take caution as herbicide application can harm the beneficial biological activity in the lagoon and result in a failure to meet permit limits.
- In colder months, lower the water level so that ice freezes around the weed stem, killing the weeds.

Source: EPA.

Image 7. Excess weed growth.

- If a multicell lagoon is operated in series and organic overload occurs, consider converting to operating in parallel: split influent flow between the first two cells, thereby reducing the loading rate on the first cell. The lagoon design and actual hydraulic loading may make this impossible since a single cell does not provide sufficient treatment in many cases. Consult the permitting authority and a professional engineer when considering changing the cell structure.
- Increase aerator running time with a goal of at least 2.0 mg/L DO in all treatment cells. If increasing the aerator running time does not provide enough oxygen to reduce odors, add supplemental aeration such as surface aerators, diffusors, and/or daily operation of a motorboat.
- If possible, recirculate effluent from the odorous cell to the head of the plant.

5D. Algal Overgrowth

Overgrowth typically occurs in the spring and summer during extended exposure to higher temperatures and sunlight.

Because partial-mix aerated lagoons receive oxygen through mechanical or diffused aeration, algal photosynthesis is not important to the survival of aerobic bacteria. Surface agitation through mixing or aeration simulates wind movement, helping remove stagnant areas of water that are prime for algae growth. Aeration also prevents algae growth within the water column because it evens out temperature differences and prevents algae from getting direct sunlight. However, when mixing or aeration is inadequate, algal overgrowth can occur, causing high BOD and TSS in the final cell.

Operators can determine the presence of algal overgrowth by examining effluent microscopically and observing elevated algae content. Effluent from some types of lagoons may require additional treatment or "polishing" to meet discharge permit requirements.

Potential Solutions

In addition to the potential solutions listed within **Section 3D,** consider these additional potential solutions, specific to facultative lagoons:

- Increase aerator running time at night when photosynthetic activity is reduced.
- Where DO is reduced, increase mixing and aerator running time at all times. Increased DO may help remove or reduce BOD, meeting BOD limits and, where applicable, ammonia nitrogen permit limits.
- Investigate causes of reduced DO, including poor light penetration, low detention time, high BOD loading, or toxic industrial wastes, and address as appropriate.

5E. Inadequate Nitrification for Facilities with Ammonia Permit Limits

Nitrification is a biological process involving a group of aerobic organisms referred to as nitrifiers that oxidize ammonia to nitrite and then to nitrate. This process occurs under aerobic conditions, sufficient alkalinity, a favorable temperature, and other conditions such as a sufficient detention time for the nitrifiers, suspension of nitrifiers for contact with ammonia and nitrite, and an adequate DO concentration, usually maintained at a minimum of 2 mg/L. Alkalinity levels above 60 mg/L of calcium carbonate are required to maintain nitrification and depend on pH and concentrations of ammonium nitrogen. Nitrifiers grow slowly and are more sensitive to environmental factors than compounds that remove BOD. As such, maintaining such favorable conditions are important for facilities that rely on nitrification to meet discharge permit limits for ammonia. Otherwise, effluent ammonia concentration can exceed permit limits.

Providing enough oxygen to meet both the BOD and ammonia removal demand is important for nitrification. Depending on lagoon design and the ammonia effluent limit, this may involve increasing lagoon volume and aeration capacity to support nitrification, particularly for heavily loaded systems.

Nitrification generally occurs over a wastewater temperature range of 4–45 °C (39–113 °F) with 35–42 °C (95–108 °F) being the optimum range. Aerated lagoons in colder climates may experience inhibited nitrification. Increasing detention time and maintaining a higher concentration of nitrifiers can compensate for colder temperatures. Other options include adding sedimentation to clarifiers with solids recycle and add-on processes to support nitrification in cold weather.

Facilities that decide to implement modifications may require the services of a consultant and approval from the permitting authority.

Potential Solutions

Identify what may be causing poor ammonia removal, then consider one of the following potential solutions depending on the cause:

- Check for increases in BOD and ammonia loading to the lagoon and consider whether options are available to reduce the loadings to the lagoon. In some cases, running lagoons in parallel instead of in series may be a temporary option until the loadings are reduced, provided adequate retention time is available. Such changes may need approval from the permitting authority.
- If there is considerable sewage sludge accumulation, de-sludge the affected cell (see **Section 3B**).
- Increase the DO content mechanically by removing anything blocking atmospheric reaeration and algal photosynthesis in sunlight. This process may include removing excessive duckweed, matted algae, or sewage sludge that is blocking the surface.
- Supplement alkalinity by adding lime, using the facility's standard operating procedures specific to the lagoon design and dimensions.
- If short-circuiting is suspected, consider adding baffles to better control flow and improve hydraulic retention time.
- If necessary, consider conducting an engineering study of feasible options for upgrading the lagoon facility for consistent ammonia removal.

6. Complete-Mix Aerated Lagoon Troubleshooting Tips

Complete-mix aerated lagoons rely on mechanical aeration for three things. The first is to introduce enough oxygen to significantly biodegrade five-day biological oxygen demand (BOD_5). The second is to oxidize ammonia where required by permit. The third is to provide additional mixing to suspend all solids to enhance biodegradation.

Complete-mix aerated lagoons maintain DO throughout their entire depth. These lagoons are appropriate for treatment in warm, sunny climates. They are typically shallow, between 1–6 feet in depth, to allow sunlight to penetrate throughout the water column. To boost DO concentration and keep all solids in suspension, aerobic lagoons use mechanical aeration.

6A.Foaming

Accumulated foam and scum in aerobic lagoons can produce unwanted odors, clog equipment, and degrade the quality of the effluent. Foam and scum have been observed in the presence of non-degradable surfactants and with specific filamentous microorganisms in the process water. This condition contributes to a mechanism that floats significant amounts of solids to the surface, producing putrid brown foam and scum. Buildup of filamentous microorganisms makes particles more hydrophobic, making it easier for those particles to then cling to air bubbles, resulting in foam and scum at the surface.

Oil and grease in the wastewater, low food-to-microorganism ratio, and high TSS levels have been correlated with the presence of foam and scum. To prevent harmful effects of foaming and scum, monitor conditions as frequently as possible, remove any buildup identified, and address the issue with the following approaches in mind.

Potential Solutions

- Use rakes, a portable pump that can create a water jet, or motorboats to break up scum formations. Scum usually sinks once it is broken up. If scum remains, skim and properly dispose of materials removed. Facilities should coordinate with state regulatory agencies regarding potential options and related regulatory requirements for handling scum, including potential recycling opportunities.
    - If the influent regularly contains excessive fats, oils, and greases, review sewer use ordinances and implement a fats, oils, and greases program that requires installing grease interceptors at commercial (e.g., restaurants) and industrial facilities.
- Add pretreatment to prevent scum buildup in the future, such as skimming, floating booms, or sorbent pads.

- If trash accumulates in the primary treatment cell, consider modifying the influent structure to screen it out. This process may require approval from the permitting authority; consider applicable design standards in making modifications.
- Study wind directions and locate transfer outlets to prevent dead pockets where scum will tend to accumulate. Retrofits may need approval from the permitting authority and should be designed by a professional engineer.

6B. Algal Overgrowth

Overgrowth typically occurs in the spring and summer during extended exposure to higher temperatures and sunlight.

Because complete-mix aerated lagoons receive oxygen through mechanical or diffused aeration, algal photosynthesis is not important to the survival of aerobic bacteria. Surface agitation through mixing or aeration simulates wind movement, helping remove stagnant areas of water that are prime for algae growth. Aeration also prevents algae growth within the water column because it evens out temperature differences and prevents algae from getting direct sunlight. However, when mixing or aeration is inadequate, algal overgrowth can occur, causing high BOD and TSS in the final cell.

Aerobic lagoons are particularly susceptible to excessive algae growth due to warmer climates year round. These conditions can lead to high TSS and BOD concentration in the final cell, which contribute to higher levels of turbidity.

The presence of algal overgrowth may also be determined by examining effluent microscopically and observing elevated algae content. Effluent from some types of lagoons may require additional treatment or "polishing" to meet discharge permit requirements.

Potential Solutions

In addition to the potential solutions listed within **Section 3D,** consider these additional potential solutions, specific to complex-mix aerated lagoons:

- Divide the lagoon basin into a series of two or three cells using curtain walls to limit algal growth, provided retention times do not increase.
- In some cases, increasing aeration power intensities can provide shading by improving suspension of solids to reduce algal growth. Additional mixing by aeration will also remove significant quantities of carbon dioxide from the system during the night hours, ensuring carbon dioxide becomes growth-limiting to algae earlier in the day.

- **Note:** Operators should only increase aeration times if needed and within certain limits to prevent flocculation problems and unnecessary additional power consumption.

- Consider installing covers to prevent light from entering the lagoon water column, helping to limit algae growth. Commercially available floating polyester fabrics have been used to shade aerated lagoons. They should not cover the entire lagoon surface. Leave sufficient room if the lagoon uses mechanical surface aerators.
- Increase aerator running time at night when photosynthetic activity is reduced.
- Where there is reduced DO, increase mixing and aerator running time at all times. Increased DO may help remove or reduce BOD, meeting BOD permit limits and, where applicable, ammonia nitrogen permit limits.
- Investigate causes of reduced DO, including poor light penetration, low detention time, high BOD loading, or toxic industrial wastes, and address as appropriate.

6C. Inadequate Nitrification for Facilities with Ammonia Permit Limits

Nitrification is a biological process involving a group of aerobic organisms referred to as nitrifiers that oxidize ammonia to nitrite and then to nitrate. This process occurs under aerobic conditions, sufficient alkalinity, a favorable temperature, and other conditions such as a sufficient detention time for the nitrifiers, suspension of nitrifiers for contact with ammonia and nitrite, and an adequate DO concentration, usually maintained at a minimum of 2 mg/L. Alkalinity levels above 60 mg/L of calcium carbonate are required to maintain nitrification and depend on pH and concentrations of ammonium nitrogen. Nitrifiers grow slowly and are more sensitive to environmental factors than compounds that remove BOD. As such, maintaining such favorable conditions are important for facilities that rely on nitrification to meet discharge permit limits for ammonia. Otherwise, effluent ammonia concentration can exceed permit limits.

Many aerobic organisms remove organic material and reduce BOD in wastewater. The competition for oxygen restricts the growth potential of slow-growing nitrifiers. However, when the organic material and BOD is significantly reduced, this competition is also reduced, which allows the nitrification (i.e., ammonia removal) process to occur more efficiently. Providing enough oxygen to meet both the BOD and ammonia removal demand is important. Depending on lagoon design and the ammonia effluent limit, providing oxygen may involve increasing lagoon volume and aeration capacity to support nitrification.

Nitrification generally occurs over a wastewater temperature range of 4–45 °C (39–113 °F) with 35–42 °C (95–108 °F) being the optimum range. Aerated lagoons in colder climates may experience inhibited nitrification. Increasing detention time and maintaining a higher concentration of nitrifiers can compensate for colder temperatures. Alternative options include adding sedimentation to clarifiers with solids recycle and add-on processes to support nitrification in cold weather.

Facilities that decide to implement modifications may require the services of a consultant and approval from the permitting authority.

Potential Solutions

Identify what may be causing poor ammonia removal, then consider one of the following potential solutions depending on the cause:

- Check for increases in BOD and ammonia loading to the lagoon and consider whether options are available to reduce such loadings. In some cases, running lagoons in parallel instead of in series may be a temporary option until the loadings reduce, provided adequate retention time is available. Such changes may need approval from the permitting authority.
- If there is considerable sewage sludge accumulation, de-sludge the affected cell (see **Section 3B**).
- Increase the DO concentration mechanically to improve aeration.
- Supplement alkalinity by adding lime. The amount of lime added will be based on a standard operating procedure specific to the lagoon design and dimensions.
- If short-circuiting is suspected, consider adding baffles to better control flow and improve hydraulic retention time.
- If necessary, consider conducting an engineering study of feasible options for upgrading the lagoon facility for consistent ammonia removal.

Appendix A. Establishing Standard Operating Parameters for Operator Observations and Field Measurements

This section provides recommended operator visual inspections and lagoon field measurements for establishing standard operating parameters.

In order to effectively identify and troubleshoot lagoon upset conditions, it is important to have standard operating parameters to allow for baseline comparisons. This section provides recommended inspection checklists that facilities can use to help establish standard operating parameters.

Note 1: Because all lagoons are unique, the checklists below should be considered a minimum list of operational checks. Review equipment manuals for additional parameters that require routine inspection and the frequency of those inspections. Use those parameters and associated inspection frequencies to establish a routine inspection and monitoring program.

Note 2: Lagoon operating conditions may vary seasonally, or even daily, as ambient temperatures change throughout the day and throughput varies. Establish and record standard operating parameters for varying conditions.

Note 3: Consider compiling sample results in a spreadsheet to use in assessing baseline conditions, parameter variability, trends, and upsets.

Visual Inspections

Recommended frequency: On a weekly basis (at minimum, unless otherwise specified)

- ☐ Lagoon Area Visual Checks (*Inspect Daily)*:
    - ☐ Weed and grass control.
    - ☐ Dike vegetation.
    - ☐ Evidence of dike erosion and instability.
    - ☐ Fencing (see Image 8 for an example of poorly maintained fencing).
    - ☐ Signs of burrowing animals.
    - ☐ Condition of outbuildings.

Source: Mike Beck, Eastern Research Group, Inc.

Image 6. A poorly maintained fence.

- ☐ Lagoon System Visual Checks:
    - ☐ Floating material in each lagoon cell, such as grease, sewage sludge, trash, floating vegetation, or mats of algae.
    - ☐ Changes in cell color.
    - ☐ Septic odors, which indicates the presence of hydrogen sulfide and absence of oxygen.
    - ☐ Unusually high solids or turbidity and/or floating material.
    - ☐ Water level and freeboard height (i.e., the distance between the water surface of the lagoon and the top of the dike).
    - ☐ Evidence of sewage sludge buildup at effluent points or conveyance structures.
- ☐ Influent and/or Effluent Flows:
    - ☐ Higher-than-normal influent and effluent flows (if applicable) that could indicate infiltration and inflow (I&I) problems.
    - ☐ Lower-than-normal flow or rising water levels that could indicate a blockage.
- ☐ Critical Equipment Operation Checks:
    - ☐ Operating status of pump stations.

Lagoon Field Measurements

Recommended frequency: Annually (at minimum)

Note 1: If possible, use a boat to take measurements at various points throughout each cell for better data quality. If a boat is unavailable, sample influent and effluent from each cell for all parameters below.

Note 2: To ensure data quality, it is a good practice to develop profiles for sewage sludge depth, DO, and pH by measuring each parameter at 1-foot increments from the surface of the cell to the bottom of the lagoon.

Recommended field measurements:

- pH, using a pH probe.
- DO, using a portable meter.
  - **Note 1:** If a DO meter is not available, conduct a visual assessment. Low DO indicators include the presence of red streaks from stressed *Daphnia magna*, the common water flea, or gray to black water due to anaerobic conditions.
  - **Note 2:** If measuring DO with a meter, perform the test at various times of the day, including the morning, close to sunrise, and in the afternoon, (between 2:00 and 3:00 p.m.), to capture the low and high DO concentrations for the day.
- Temperature, using a temperature probe.
- Sludge depth, using a core sampler or similar.
  - **Note:** Aerators should be turned off when taking core sewage sludge samples.
- Alkalinity, using a test kit.

Additional Sources of Obtaining and Establishing Baseline Operating Parameters

In addition to visual observations and operator-performed analytical tests, equipment manuals or associated documentation can also help establish baseline operation conditions.

Consider reviewing the following documents, if available:

- Past inspection reports.
- If the lagoon meets state design standards, as-built construction plans.
- NPDES permit requirements.
- Discharge monitoring reports and plant performance records.
- Operation and maintenance records and standard operating procedures.

- Noncompliance correspondence.
- WWTP design specifications.
- Recommendations from the facility’s past assessments or reports from technical assistance providers.

Appendix B. Establishing Standard Operating Parameters Using Laboratory Analysis

In order to effectively identify and troubleshoot lagoon upset conditions, it is important to establish standard operating parameters to allow for baseline comparisons. This section gives a recommended sampling approach to establish standard operating parameters using laboratory testing.

Note 1: Because all lagoons are unique, the sampling approach shown below should be considered a minimum. Review equipment manuals for parameters that require sampling and testing. Also review equipment manuals for sampling frequency. Use those parameters and associated sampling frequencies to establish a routine sampling program.

Note 2: Lagoon operating conditions may vary seasonally, or even daily, due to ambient temperature and flow rate changes throughout the day and year. Establish and record standard operating parameters for varying conditions.

Note 3: Consider compiling sample results in a spreadsheet to use in assessing baseline conditions, parameter variability, trends, and upsets.

Table 3, below, is an example of a lagoon WWTP sampling approach that can be used monthly or quarterly to identify deviations from standard operating parameters. The sampling and analysis approach presented here is based on a three-cell lagoon configuration. The approach will be different depending on site-specific conditions.

Table 3. Recommended sample analysis parameters.

Sample Site	Ammonia	TSS	Alkalinity	pH	BOD_5	Soluble BOD_5	$CBOD_5$	Temperature	DO
Influent	✓	✓	✓	✓	✓	✓			
Cell #1 effluent	✓		✓	✓	✓	✓	✓	✓	✓
Cell #2 effluent	✓		✓	✓	✓	✓	✓	✓	✓
Cell #3 effluent	✓		✓	✓	✓	✓	✓	✓	✓
Final effluent	✓	✓	✓	✓	✓	✓	✓	✓	✓

If resources are limited, operators may focus on certain parameters that are causing compliance problems. The goal is to consistently collect analytical results that will help make process control decisions.

Ideally, a comprehensive analysis of lagoon WWTP performance would include five years of historical data. However, with limited data, start examining trends beginning in the second year of data collection. Consider contacting a technical assistance provider to perform a statistical analysis to find correlations and likely causes of noncompliance. Once enough analytical data have been collected, use these data to identify possible causes of compliance problems and corresponding solutions.

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