Wastewater Lagoons

Operations and Maintenance Reference Manual

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Section 1 - Purpose of this Document

This manual serves as a guide for lagoon system owners and operators. It aims to provide an understanding of the different types of wastewater treatment lagoons, the fundamental processes involved, troubleshooting techniques, and strategies for maintaining a healthy wastewater lagoon.

Worldwide, sewage lagoons, also known as stabilization ponds, are shallow water bodies typically situated inland and not necessarily connected to larger water bodies. Lagoons are pond-like basins designed and created to treat wastewater through natural biological processes where bacteria, sunlight, and wind breakdown waste material, resulting in treated effluent to protect human and environmental health. Lagoon systems have been implemented in thousands of towns and cities to facilitate wastewater treatment. Lagoons are a straightforward and efficient method for treating wastewater due to their relatively low construction costs, minimal maintenance expenses, and the ability to achieve basic treatment requirements when operated correctly.

The lagoon system's simplicity can occasionally lead to inadequate oversight. Improper operation, insufficient maintenance, and neglect may result in odor issues and subpar effluent quality. Additionally, inadequately maintained lagoons can lead to significant contamination of groundwater or surface water.

Section 2 - Why Do We Treat Wastewater?

Wastewater treatment is essential for several reasons:

1. **Public Health**: Untreated wastewater contains harmful pathogens, chemicals, and waste that can lead to the spread of diseases. Treating wastewater helps prevent outbreaks of waterborne illnesses, such as cholera, dysentery, and typhoid fever.
2. **Environmental Protection**: Discharging untreated wastewater into rivers, lakes, or oceans can harm aquatic ecosystems. It can cause oxygen depletion, which suffocates fish and other aquatic life, and introduces toxins that disrupt the food chain. Wastewater treatment removes harmful substances and helps preserve natural water resources.
3. **Water Recycling and Reuse**: In areas facing water scarcity, treated wastewater can be reused for irrigation, industrial processes, and even potable water (after advanced treatment). This reduces the demand for freshwater and supports sustainable water management.
4. **Legal and Regulatory Requirements**: The Clean Water Act, passed in 1972, set standards for wastewater discharges into U.S. waters. Wastewater treatment plants are required to meet federal and state regulations to ensure the water discharged is clean and safe.
5. **Preventing Eutrophication**: Wastewater often contains excess nutrients, such as nitrogen and phosphorus, which can lead to nutrient pollution in water bodies. This can cause eutrophication, where algae blooms deplete oxygen in the water, leading to "dead zones" where aquatic life cannot survive. Wastewater treatment helps reduce nutrient loadings.

By treating wastewater, we not only protect public health and the environment, but also create opportunities for sustainable water use in the face of increasing demand.

Wastewater comes from various sources, each contributing to the total amount of water and types of contamination that must be treated before being released into the environment or reused. Each type of wastewater has different treatment needs and challenges, depending on its source and the contaminants it contains. Proper treatment is necessary to protect human health, the environment, and water quality.

The primary types of wastewater sources are:

Domestic Wastewater (Municipal or Residential)

- **Source**: This type of wastewater is generated from households, including water from toilets, sinks, showers, washing machines, and dishwashers.
- **Characteristics**: It typically contains organic matter (e.g., food waste, soap, oils), nutrients (e.g., nitrogen and phosphorus), pathogens, and household chemicals.

Industrial Wastewater

- **Source**: Generated by industrial activities, such as manufacturing, food processing, mining, or chemical production.
- **Characteristics**: Can vary greatly depending on the industry, but may contain heavy metals, solvents, chemicals, oils, fats, suspended solids, and other toxic substances. It often requires specialized treatment processes due to the diverse and potentially hazardous nature of the contaminants.

Section 3 - When Do We Use Lagoons to Treat Wastewater?

Lagoons are used in situations where they offer a cost-effective, low-maintenance solution for wastewater treatment, especially in rural or small communities. Here are some common scenarios where lagoons are used:

1. **Rural or Remote Areas**: Lagoons are often employed in areas where the population density is too low to justify the cost of more advanced treatment technologies, like activated sludge systems. They are ideal for smaller communities or isolated locations where infrastructure costs must be low.
2. **Low Population Density**: In places with low wastewater volume, lagoon systems can provide sufficient treatment capacity without the need for expensive or complex mechanical systems.
3. **Cost-Effective Solutions**: Lagoons are relatively inexpensive to construct and operate. Since they rely on natural biological processes and require little energy (compared to mechanical treatment systems), they are particularly useful in areas with limited budgets.
4. **Land Availability**: Lagoons require a large land area for construction. In areas with abundant space, lagoons can be a practical choice, especially in rural or agricultural regions where there is plenty of open land.
5. **Temperate Climate Areas**: Lagoons are more effective in temperate climates because the natural processes that break down wastewater, such as microbial activity, work faster in warmer temperatures. In cold climates, lagoon operations may need to be adapted, or they may be less effective due to slower biological processes.
6. **Secondary or Tertiary Treatment**: Lagoons are often used for secondary or tertiary treatment in the treatment train. In some cases, they follow primary treatment (which removes solids) and provide additional treatment through biological processes like aerobic or anaerobic digestion.
7. **Long Retention Times**: Lagoons work by allowing wastewater to flow through large, shallow basins over extended periods (often weeks or months), providing time for microorganisms to break down organic matter and reduce pollutants. This makes them suitable for areas where extended treatment times are acceptable.

In summary, lagoons are used for wastewater treatment primarily in rural or low-population areas, where land is available, and cost-effectiveness is a priority. They are a practical solution in situations where more complex treatment systems are not necessary or feasible. The Environmental Protection Agency (EPA) identified a total of 4,657 discharging lagoon systems in 2022, with 83% identified as publicly owned treatment works. Most of these lagoon systems (84%) serve small communities with less than 3,000 people.

Section 4 - Regulatory Requirements for Lagoon Systems

When using lagoon systems for wastewater treatment, several regulatory requirements come into play. These regulations ensure that lagoons are designed, operated, and maintained in a way that protects public health, the environment, and water quality. Below are the primary regulatory drivers and permit requirements typically associated with lagoon wastewater treatment in the United States:

1. Clean Water Act (CWA)

The **Clean Water Act** is the main federal law governing water pollution in the U.S. It aims to restore and maintain the integrity of the nation's waters by preventing point-source pollution (from direct discharges) and non-point-source pollution (from runoff). Lagoon systems discharging treated wastewater to surface waters (like rivers, lakes, or oceans) are required to have a **National Pollutant Discharge Elimination System (NPDES)** permit. This permit sets limits on the pollutants that can be discharged, such as biochemical oxygen demand (BOD), total suspended solids (TSS), nitrogen, phosphorus, and pathogens. The permit also includes monitoring, reporting, and compliance requirements for effluent quality, frequency of testing, and maintaining records of treatment operations.

2. State Regulations and Permits

States have the authority to enforce their own water quality standards, which must be at least as stringent as federal requirements. State agencies may impose additional requirements for lagoon systems to address specific local environmental concerns. Most states require a **state-specific wastewater discharge permit** in addition to the federal NPDES permit. These permits may set more stringent effluent limits based on the water quality standards of the receiving waters and local regulations. States may also have specific rules regarding lagoon design, operation, and maintenance to ensure compliance with water quality standards.

3. Design and Operation Standards

Lagoon systems must meet specific design criteria and operational standards to ensure they function properly. These standards are typically set by state and local environmental agencies or public health departments. Before construction, a detailed **permit application** must be submitted to the relevant regulatory agencies. This application often includes:

- A design plan that outlines the lagoon's size, layout, and treatment processes.
- Information on the lagoon's hydraulic capacity, retention time, and expected pollutant removal efficiency.
- A monitoring and maintenance plan to ensure ongoing compliance with treatment standards.

4. Effluent Limitations

Effluent limitations define the maximum allowable concentrations of specific pollutants in the wastewater discharged from the lagoon. Permits for lagoon systems typically include limits for common pollutants like:

- **Biochemical Oxygen Demand (BOD)**: A measure of the organic matter in the wastewater.
- **Total Suspended Solids (TSS)**: A measure of the particles suspended in the water.
- **Nutrients**: Nitrogen and phosphorus, which can cause eutrophication in receiving waters.
- **Fecal Coliform or E. coli**: Indicators of pathogens that can affect public health.
- **Chlorine Residual:** Even low levels of residual

chlorine can harm fish and other aquatic organisms in receiving streams.

- **pH levels** and **temperature** of the discharge may also be regulated to prevent harm to aquatic life.

These effluent limitations are based on the type of wastewater and the quality of the receiving water.

5. Discharge Monitoring and Reporting

To ensure compliance with effluent limitations and other permit conditions, wastewater treatment systems must regularly monitor and report the quality of their discharge. Lagoon operators must monitor the effluent at regular intervals, which can include:

- Sampling for various pollutants (e.g., BOD, TSS, pathogens, etc.).
- Reporting results to regulatory agencies, typically on a monthly or quarterly basis, depending on the permit.
- Regular inspections of the lagoon system to verify its operational efficiency.

6. Groundwater Protection and Leachate Management

Lagoons that are not properly designed or maintained could potentially leak pollutants into the surrounding soil or groundwater, causing contamination. Lagoon systems must be designed with sufficient protective measures to prevent contamination of groundwater, especially in areas with shallow groundwater tables. Some states may require lagoon systems to install liners (e.g., clay or synthetic liners) to prevent leaks. If the lagoon is located near a sensitive aquifer or drinking water source, additional safeguards or monitoring may be required such as monitoring wells.

7. Sludge Management and Disposal

Lagoons accumulate sludge (solid waste) over time, which must be managed and disposed of properly to prevent environmental contamination. Regulations, such as the **Resource Conservation and Recovery Act (RCRA)** and **40 CFR Part 503**, govern the testing classification of biosolids (Class A or Class B) and the beneficial reuse and disposal of sludge from wastewater treatment systems. Sludge quality (e.g., concentration of metals, pathogens, and organic matter) must be tested before disposal. Lagoon systems must comply with requirements for the storage, handling, and disposal of sludge. This can include land application, composting, or disposal in landfills.

40 CFR Part 503 Biosolids Testing for Land Application

A. Regulated Pollutants (Metals)

- Arsenic
- Cadmium
- Copper
- Lead
- Mercury
- Molybdenum
- Nickel
- Selenium
- Zinc

B. Pathogen Reduction Verification

- Fecal coliform density (MPN/g or CFU/g; geometric mean across multiple samples) or
- Salmonella for Class A biosolids, depending on treatment method)

C. Vector Attraction Reduction (VAR) Indicators *(process/performance-based; may include testing)*

- Volatile solids reduction (if used as a compliance option)
- Other approved VAR methods (per Part 503 options)

D. Agronomic / Nutrient Management Parameters *(commonly required by permits or best practice, not Part 503 itself)*

- pH
- Total solids and volatile solids
- Nitrogen (TKN, ammonia, nitrate, nitrite, organic N)
- Phosphorus
- Potassium

8. Public Health and Safety Regulations

Lagoon systems must be designed and operated in a way that minimizes public health risks. For example, lagoons that are open to the air could potentially emit unpleasant odors or harbor disease-causing pathogens. Regulations may require the use of barriers or other measures to prevent public access to lagoons and reduce exposure to potentially harmful bacteria and viruses. Periodic inspections and maintenance to ensure that the lagoon is functioning effectively and is not a health hazard may also be required.

9. Air Quality Regulations

In some cases, lagoon treatment processes may generate odors due to the decomposition of organic matter. Depending on local or state air quality regulations, treatment facilities may need to implement odor control measures to prevent air pollution. These measures can include installing covers over lagoons, biofilters, or other systems to manage odors.

10. Environmental Impact Assessments (EIA)

In certain cases, especially for large-scale lagoon systems or those located near sensitive environments, an **Environmental Impact Assessment (EIA)** may be required. This assessment evaluates the potential environmental consequences of the lagoon system, including effects on wildlife, water quality, and surrounding ecosystems.

Lagoons used for wastewater treatment must comply with a combination of federal, state, and local regulations. The **Clean Water Act** and **NPDES permits** are the key federal regulatory drivers, while states may impose additional specific requirements based on local environmental conditions. Permits typically cover effluent limitations, system design, monitoring and reporting, sludge management, groundwater protection, and more. Compliance with these regulations ensures that lagoon systems operate effectively and minimize environmental and public health risks.

Section 5 - Flows and Loads Seen by a Lagoon System

The typical **wastewater flows** and **loads** into a lagoon treatment system depend on various factors, including the type of wastewater being treated, the size and design of the lagoon, the population served, and the type of treatment process. Here's an overview of the key components:

1. Wastewater Flow

Wastewater flow refers to the volume of water entering the lagoon for treatment. This can vary based on the source (e.g. domestic, industrial, etc.) and the specific needs of the treatment system.

- **Daily Flow Rates**: Generally, wastewater flow is measured in **million gallons per day (MGD)** or **cubic meters per day (m^3/day)**. The flow rate depends on the size of the population served or the industrial operations generating the wastewater.
  - **Residential or Domestic**: For typical residential areas, average flow rates range from 50 to 100 gallons per person per day (gpcd), depending on water usage habits.
  - **Industrial or Commercial**: For industrial or commercial wastewater, the flow can vary widely based on the type of industry or business. Industrial wastewater might have a much higher flow rate due to processes like cooling, cleaning, or manufacturing.
- **Example Calculation for a Small Community**:
  - For a small community of 1,000 people with an average flow of 75 gallons per person per day:
    - Daily flow = 1,000 people × 75 gallons/day = 75,000 gallons/day (or ~0.075 MGD).
- **Peak Flow**: Wastewater flow can also peak during certain periods, such as during morning hours when people are using water for bathing, cooking, or cleaning. Lagoons should be designed to handle these peak flows, which may be 2-3 times higher than the average daily flow.

2. Wastewater Loads

Wastewater loads represent the number of pollutants in the wastewater and the concentrations of the pollutants that need to be treated. The main parameters for wastewater load include **Biochemical Oxygen Demand (BOD)**, **Total Suspended Solids (TSS)**, **nitrogen**, **phosphorus**, and **pathogens**.

- **Biochemical Oxygen Demand (BOD)**: BOD is a measure of organic matter in wastewater that is biologically degraded by microorganisms. It is an indicator of the strength of wastewater.
  - **Domestic wastewater** typically has a BOD load of 100–300 mg/L.
  - **Industrial wastewater** can have a much higher BOD load, depending on the type of industry (e.g., food processing, pulp, and paper).
- **Total Suspended Solids (TSS)**: TSS refers to solid particles in the wastewater that need to be removed by the treatment process.
  - Domestic wastewater typically has TSS concentrations ranging from 100–200 mg/L.
  - Industrial or agricultural wastewater may have higher TSS concentrations due to solids from industrial processes or runoff.
- **Nitrogen** and **Phosphorus**: These are nutrients commonly found in wastewater, especially from domestic sewage (e.g., urine and detergents) and agricultural runoff. Excess nitrogen and phosphorus can lead to eutrophication and water quality issues in receiving waters.

- Typical nitrogen concentrations in domestic wastewater range from 30–60 mg/L.
- Phosphorus levels can range from 5–10 mg/L in domestic wastewater.

- **Pathogens**: Pathogens (e.g., bacteria, viruses, protozoa) are also present in wastewater, especially untreated or partially treated sewage. The lagoon system needs to treat these to prevent waterborne diseases.

3. Typical Wastewater Loads for Lagoon Treatment Systems

For a **domestic wastewater** treatment system, here are typical values for influent wastewater loadings:

- **BOD**: 100–300 mg/L
- **TSS**: 100–200 mg/L
- **Total Nitrogen**: 20–50 mg/L
- **Total Phosphorus**: 5–10 mg/L

These concentrations can vary depending on the quality of the wastewater entering the lagoon, the level of pre-treatment (if any), and the type of population or facility being served.

4. Lagoon Treatment Capacities

Lagoons are designed based on the **organic loading** (BOD) and the required **retention time** to ensure adequate treatment. Here are some general guidelines for lagoon design:

- **Retention Time**: Lagoons generally operate with **long hydraulic retention times (HRT)**, often **20–60 days** or more, depending on the climate, the type of lagoon, and the quality of treatment required.
- **BOD Removal**: Lagoons typically remove 70–90% of BOD, with the level of treatment depending on factors such as the lagoon type (e.g., facultative, aerated, or anaerobic lagoons), retention time, and environmental conditions.

Typical Organic Loadings for Facultative Lagoons:

- A typical **facultative lagoon** system may have an organic loading of about **0.05–0.2 lbs. BOD per 1,000 gallons per day (lbs./1,000 gpd)** or **5–20 grams of BOD per cubic meter per day (g/m³/day)**.
- Larger systems or those designed for higher flow may have higher loadings.2

5. Impact of Temperature

- The effectiveness of lagoon treatment is heavily influenced by **temperature**. In temperate climates, microbial activity in the lagoon is faster, allowing for more efficient treatment. In colder climates, treatment may be slower, and lagoons may need to be larger or require additional aeration or other methods to enhance performance.

Example of Lagoon Design for a Small Community:

Let's take the example of a small community serving 1,000 people with an average flow of 75,000 gallons per day (0.075 MGD) and an average BOD of 200 mg/L.

- **Flow**: 75,000 gallons/day
- **BOD Load**: 200 mg/L
    - Convert to pounds: (75,000 gallons/day × 200 mg/L) ÷ remembering that water weighs 8.34 lbs/gallon = 1,800 pounds BOD/day.

A lagoon designed for this community would need to treat approximately 1,800 pounds of BOD per day, using appropriate design parameters to handle this load while ensuring compliance with discharge standards (e.g., BOD ≤ 30 mg/L in effluent).

Conclusion:

The wastewater flows and loads into a lagoon treatment system vary based on the type of wastewater, the size of the population or industrial operation, and the lagoon's design. Typically, lagoon systems are designed to handle **daily flow rates** of thousands to millions of gallons per day (MGD) and reduce **BOD**, **TSS**, and other pollutants to meet regulatory standards. The lagoon's **retention time**, which could range from **20 to 60 days**, plays a key role in treating the wastewater effectively, along with seasonal variations in temperature and other local conditions.

Section 6 - Types of Lagoon Systems

Wastewater treatment lagoons come in different types, each designed to meet specific treatment needs. The primary types are **facultative lagoons**, **anaerobic lagoons**, and **aerobic lagoons**. Each type operates under different conditions and has its own specific purpose in wastewater treatment.

1. Facultative Lagoons

- **Description**: Facultative lagoons are the most common type of lagoon used for wastewater treatment. They are typically large, shallow ponds designed to provide both aerobic (with oxygen) and anaerobic (without oxygen) treatment conditions. The term "facultative" refers to the ability of microorganisms in the lagoon to adapt to either oxygen-rich or oxygen-poor environments (Figure 1).
- **Purpose**:
  - o **BOD Removal**: Facultative lagoons primarily reduce the **wastewater's biochemical oxygen demand (BOD)**. The upper layers of the lagoon receive oxygen from the air, where aerobic microorganisms break down organic matter. Deeper layers, where oxygen is limited, support anaerobic processes, breaking down organic material in the absence of oxygen.
  - o **Nutrient Removal**: They can also help reduce nutrients like nitrogen and phosphorus to some extent, although their primary function is organic matter (BOD) reduction.
  - o **Pathogen Reduction**: Facultative lagoons provide a long hydraulic retention time (HRT), allowing time for the natural die-off or removal of pathogens (Figure 2).
- **Structure**: Facultative lagoons are typically designed with:
  - o **Shallow Upper Layer**: Where aerobic microorganisms work in the presence of sunlight and oxygen.
  - o **Deeper Anaerobic Layer**: Where anaerobic microorganisms break down organic matter in the absence of oxygen.
- **Application**: Facultative lagoons are used for municipal wastewater, agricultural wastewater, and small communities with low-to-medium strength wastewater.

Figure1. Facultative Lagoon. (Source: Water & Wastewater: Your Source for Water Clarity, 2024).

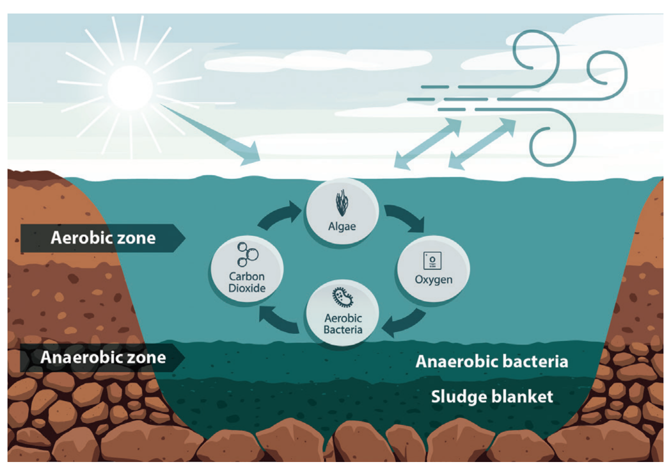

Figure 2. Facultative Lagoon Interactions

2. Anaerobic Lagoons

- **Description**: Anaerobic lagoons are designed to treat wastewater in an environment where little to no oxygen is present. These lagoons rely on **anaerobic bacteria** to decompose organic material. Anaerobic bacteria break down organic matter into simpler compounds without the presence of oxygen, producing gases like methane (Figure 3).
- **Purpose**:
  - o **Organic Matter Degradation**: Anaerobic lagoons are particularly effective at treating wastewater with high organic content, such as animal manure, food processing waste, or high-strength industrial wastewater. The process of anaerobic digestion breaks down complex organic matter into simpler forms, with minimal energy requirements.
  - o **Sludge Stabilization**: Anaerobic lagoons are also useful for stabilizing and reducing the volume of **sludge** generated during wastewater treatment. This process reduces the buildup of sludge in the lagoon and can produce methane gas, which can sometimes be captured for energy production (Figure 4).
  - o **Low Energy Requirement**: Anaerobic lagoons are energy-efficient because they do not require aeration, making them cost-effective for treating high-strength organic waste, like manure from agricultural operations.

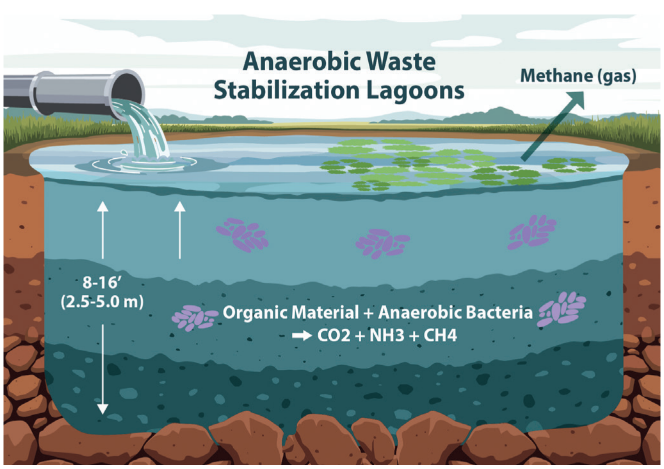

Figure 3. Anaerobic Waste Stabilization Lagoons

- **Structure**: Anaerobic lagoons are typically deeper than facultative lagoons, as the anaerobic zone needs to be larger to support microbial activity without oxygen.
- **Application**: Anaerobic lagoons are most commonly used for agricultural waste (e.g., animal manure), food processing wastewater, and other high-strength organic wastes. They are especially useful in rural or agricultural areas where waste volume is large, and the focus is on sludge reduction.

3. Aerobic Lagoons

- **Description**: Aerobic lagoons are designed to operate in the presence of oxygen. These lagoons are typically smaller and shallower than facultative or anaerobic lagoons and rely on **aerobic microorganisms** that require oxygen to break down organic pollutants. Aerobic conditions are achieved by introducing oxygen into the water through natural diffusion or mechanical aerators. (Figure 5)
- **Purpose**:
  - o **High-Rate Organic Matter Degradation**: Aerobic lagoons are designed to treat wastewater with moderate organic loading. The aerobic process efficiently reduces **BOD** and **TSS** (total suspended solids),

Figure 4. Midwest Assistance Program (ND) Operation and Troubleshooting of Lagoons [PowerPoint Presentation]

Figure 5. Aerated Lagoon. Figure 2. Midwest Assistance Program. (2021). Intro into Wastewater and Lagoon O&M. [PowerPoint Presentation]

making them suitable for wastewater with moderate strength.

  - **Faster Treatment**: Aerobic lagoons can provide quicker treatment compared to facultative or anaerobic lagoons because aerobic bacteria work faster in the presence of oxygen.
  - **Efficient Nutrient Removal**: Aerobic processes can be more effective at removing nitrogen and phosphorus compared to anaerobic systems, especially if the system is designed with nutrient removal in mind (Figure 6).

- **Structure**: Aerobic lagoons may include **aeration devices** such as mechanical aerators or diffused air systems that introduce oxygen into the water, supporting the growth of aerobic bacteria. The lagoon is generally shallower and smaller than a facultative lagoon.

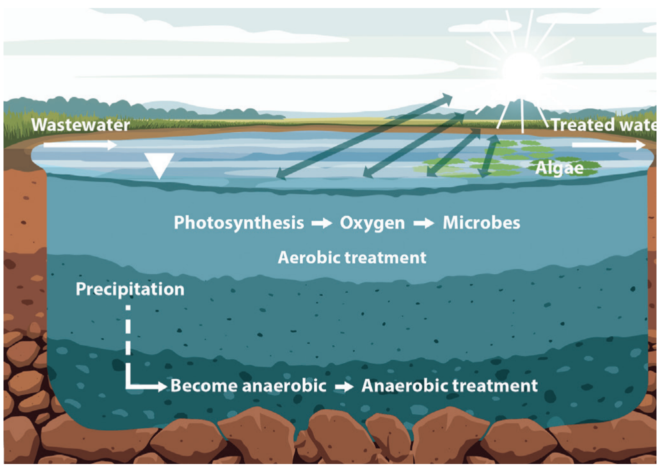

Figure 6. Aerobic Lagoon Process

- **Application**: Aerobic lagoons are often used in applications where higher levels of treatment are needed in a shorter amount of time. They are suitable for municipal and industrial wastewater with moderate strength, and for systems where rapid organic matter degradation and nutrient removal are priorities.

Key Differences and Purpose Summary

Each type of lagoon has its specific applications depending on the nature of the wastewater and treatment goals (Table1):

- **Facultative lagoons** are ideal for general use, treating a wide range of wastewater types, balancing aerobic and anaerobic processes.
- **Anaerobic lagoons** are well-suited for high-strength organic waste with low oxygen demand, especially in agricultural or industrial settings.
- **Aerobic lagoons** are efficient in environments requiring rapid treatment of moderate-strength wastewater, especially where nutrient removal is a concern.

Choosing the right lagoon type depends on factors such as the type and strength of the wastewater, treatment goals, and available resources.

Table 1: Key Differences and Purpose

	Purpose	Typical Use	Main Treatment Process
Facultative Lagoon	Reduces BOD, stabilizes sludge, provides pathogen reduction	Municipal wastewater, agricultural runoff, small communities	Both aerobic and anaerobic processes in different layers
Anaerobic Lagoon	Degrades high-strength organic matter, stabilizes sludge, produces methane	Agricultural waste (manure), high-strength industrial wastewater	Anaerobic bacteria decompose organic matter in the absence of oxygen
Aerobic Lagoon	Treats moderate-strength wastewater, efficient BOD removal, potential nutrient removal	Municipal wastewater with moderate strength, industrial effluents	Aerobic bacteria break down organic matter in the presence of oxygen

Section 7 - Components of Lagoons

Wastewater treatment lagoon systems involve a series of processes and components that work together to treat and remove pollutants from wastewater. Lagoon systems use natural biological, chemical, and physical processes to break down organic matter, remove nutrients, and reduce pathogens. Here's a breakdown of the **main components** and **processes** involved in wastewater treatment lagoon systems:

1. Components of a Lagoon Treatment System

A) Lagoon Basin

- **Description**: The lagoon itself is the basin or pond where wastewater is held for treatment. These lagoons can be designed in different shapes (e.g. rectangular, circular, or natural contours) and depths, depending on the type of treatment required (Figure 7).
- **Function**: It provides the space for wastewater to be stored and treated by natural processes. The size of the lagoon is determined by factors such as the wastewater flow, treatment goals, and climate conditions.

B) Inlet and Outlet Structures

- **Inlet Structure**: This is where the influent wastewater enters the lagoon. It typically includes a distribution system that ensures even flow across the lagoon's surface.
- **Outlet Structure**: The treated effluent exits the lagoon through the outlet structure. This may include a **weir, pipe, or siphon system** designed to maintain proper water levels and facilitate the discharge of treated water.

C) Aeration Equipment (for Aerobic Lagoons)

- **Description**: Aeration devices are used in aerobic lagoons to introduce oxygen into the water, supporting the growth of aerobic microorganisms that break down organic matter.
- **Types of Aerators**: These may include **mechanical aerators** (surface aerators) or **diffused aeration systems**, which distribute air bubbles throughout the lagoon (Figure 8).
- **Function**: Oxygen is supplied to the lagoon to enhance the degradation of organic pollutants by aerobic bacteria, speeding up the treatment process.

D) Sludge Collection and Disposal Systems

- **Description**: Over time, wastewater treatment lagoons accumulate sludge (settled solids), which must be removed periodically.
- **Components**: Sludge collection systems may include **sluice gates**, **pumps**, or **mechanical dredgers** to remove sludge from the bottom of the lagoon.

Figure 7. Lagoon Basins. Copyright © 2001-2020 Black Warrior Riverkeeper Inc. *https://blackwarriorriver.org/sewage/*

Figure 8. Diffused Aeration. *http://northcowichan.bc.ca*

- **Function**: The collected sludge is typically either dried in the lagoon or removed for disposal or further treatment (e.g., land application or composting).

E) Fencing and Barriers

- **Description**: Lagoons may be enclosed by fences or barriers to prevent public access, particularly in wastewater systems containing untreated or partially treated wastewater.

- **Function**: These structures help to ensure public safety and minimize the risk of exposure to potentially harmful pathogens in wastewater.

2. Processes in Wastewater Treatment Lagoon Systems

A) Physical Processes

- **Sedimentation**: In all types of lagoons (anaerobic, facultative, and aerobic), solid particles in the wastewater settle to the bottom over time due to gravity. This is known as **primary treatment** and helps remove suspended solids (TSS).

- **Filtration**: Some systems may rely on the natural filtering action of the lagoon's bottom and vegetation along the edges to remove additional particles from the wastewater.

B) Biological Processes

- **Aerobic Digestion**: In **aerobic lagoons**, microorganisms (bacteria) use oxygen to decompose organic matter in the wastewater. Aerobic bacteria convert organic compounds into carbon dioxide (CO_2), water (H_2O), and biomass. This process significantly reduces **BOD (biochemical oxygen demand)** and **TSS (total suspended solids)**.

- **Anaerobic Digestion**: In **anaerobic lagoons**, organic matter is broken down by **anaerobic bacteria**, which operate in the absence of oxygen. These bacteria convert organic material into simpler compounds, such as methane (CH_4), carbon dioxide, and other byproducts. This process is slower but is effective in reducing organic solids, particularly in high-strength wastewater such as animal manure.

- **Facultative Digestion**: **Facultative lagoons** combine both aerobic and anaerobic processes. The upper layer of the lagoon is aerobic (supports oxygen-loving bacteria), while the deeper layers are anaerobic (support bacteria that thrive without oxygen). In the aerobic layer, microorganisms break down organic matter using oxygen, while in the anaerobic layer, microorganisms degrade solids in the absence of oxygen.

- **Nutrient Removal**: Facultative and aerobic lagoons can help remove nitrogen and phosphorus, although this is often limited. Nitrogen is removed through processes like **nitrification** (conversion of ammonia to nitrates) and **denitrification** (conversion of nitrates to nitrogen gas), while phosphorus can be absorbed by algae and microorganisms or precipitate out of solution.

C) Chemical Processes

- **Algae Growth and Photosynthesis**: In facultative lagoons, the upper layers may support the growth of algae. These algae, through photosynthesis, produce oxygen during the day, which helps aerobic bacteria break down organic matter. Algae can also help absorb nutrients like nitrogen and phosphorus, although excessive algae growth can lead to problems such as nutrient imbalances or odors (Figure 9).

- **pH Adjustment**: Lagoon systems may naturally stabilize the pH of wastewater through chemical processes. However, in some cases, lime or other chemicals may be added to adjust the pH

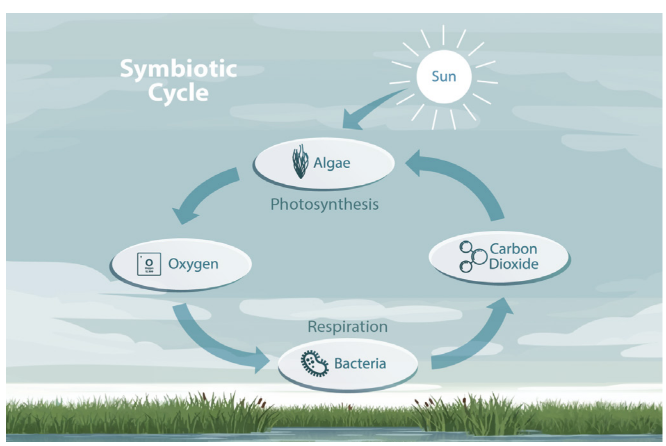

Figure 9. Chemical Processes: Photosynthesis and Respiration.

SECTION 7 - COMPONENTS OF LAGOONS

to optimize treatment conditions (for example, enhancing nitrification or controlling odors).

D) Pathogen Removal

- **Natural Die-off**: Pathogens in wastewater are typically reduced over time due to natural processes in the lagoon. Exposure to sunlight (UV light), high temperatures, and predation by other microorganisms can reduce pathogen concentrations.
- **Disinfection**: In some cases, lagoons may require additional disinfection steps, such as chlorination or ultraviolet (UV) light, to further reduce pathogens before the treated effluent is discharged or reused.

E) Sludge Stabilization and Reduction

- **Sludge Storage and Removal**: Sludge must be removed periodically to maintain the lagoon's efficiency. Some lagoons accumulate sludge at the bottom, and it is removed by dredging or pumping. The sludge may be treated further, land-applied, or disposed of in landfills.

Table 2 (page 20) compares the differences in **operation and maintenance** between **facultative**, **aerobic**, and **anaerobic** lagoons:

Summary:

- **Facultative lagoons** are cost-effective and provide natural treatment, but they may have slower performance in colder weather and can be less effective in nutrient removal.
- **Aerobic lagoons** require constant energy for aeration but are efficient at removing organic matter and nutrients, offering better effluent quality.
- **Anaerobic lagoons** are the most energy-efficient in terms of aeration but may have issues with nutrient removal and require careful sludge management.

Each lagoon type has its advantages and challenges, and the selection of a lagoon type typically depends on factors like influent characteristics, climate, and regulatory requirements.

3. Overall Treatment Process Flow in a Lagoon System

1. **Influent enters the lagoon** through the inlet, which distributes the wastewater evenly across the lagoon.
2. **Sedimentation**: Suspended solids settle out of the wastewater in the lower layers of the lagoon, especially in anaerobic or facultative lagoons.
3. **Biological Treatment**:
   - In **aerobic lagoons**, aerobic bacteria use oxygen to degrade organic matter in the wastewater (Figure 10).
   - It is the breakdown of organic contaminants by microorganism when oxygen is present
   - Organic contaminants are rapidly degraded under aerobic conditions by aerobic bacteria called aerobes.
   - In **anaerobic lagoons**, anaerobic bacteria decompose organic materials in the absence of oxygen (Figure 11).

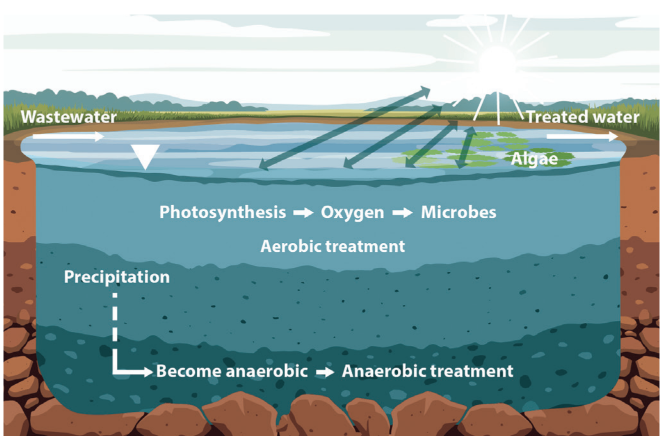

Figure 10. Aerobic Treatment Process

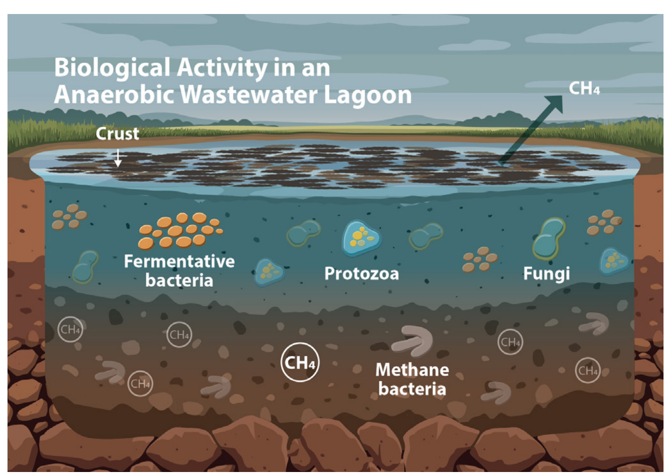

Figure 11. Biological Activity in an Anaerobic Wastewater Lagoon

- In **facultative lagoons**, both aerobic and anaerobic processes take place in different layers, depending on the availability of oxygen (Figure 12).

4. **Algae Growth and Photosynthesis**: In facultative lagoons, algae grow and provide oxygen to the upper layers through photosynthesis, supporting aerobic bacterial processes.

5. **Nutrient and Pathogen Removal**: Nutrients like nitrogen and phosphorus are removed through biological uptake or chemical processes, while pathogens are naturally reduced over time.

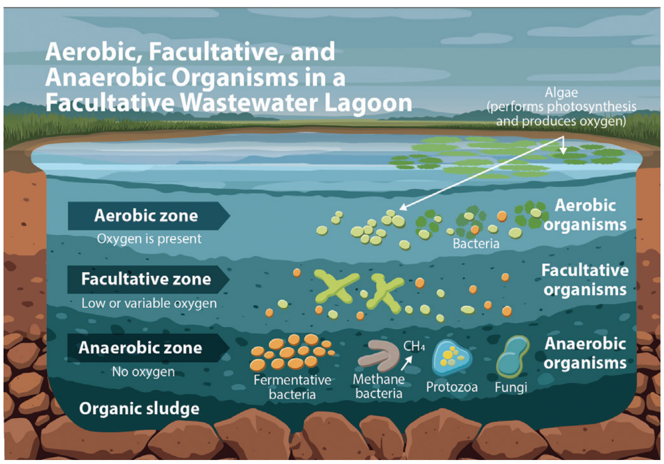

Figure 12. Aerobic, Facultative, and Anaerobic Organisms in a Facultative Wastewater Lagoon.

6. **Sludge Accumulation and Stabilization**: Sludge settles at the bottom of the lagoon and is gradually broken down by microorganisms, reducing its volume and potential odor.

7. **Effluent Discharge**: The treated wastewater (effluent) is discharged from the lagoon, either to a receiving body of water, for further treatment, or for reuse, depending on treatment levels and regulatory requirements.

8. **Sludge Management**: Periodic removal and disposal of accumulated sludge are necessary to maintain system performance.

Conclusion:

Wastewater treatment lagoon systems use a combination of **physical**, **biological**, and **chemical processes** to treat wastewater. The **main components** include the **lagoon basin**, **aeration equipment** (for aerobic lagoons), inlet and outlet structures, and **sludge management systems**. The key processes in lagoon treatment are **sedimentation**, **biodegradation** (aerobic, anaerobic, or facultative), **algae growth**, **nutrient removal**, and **sludge stabilization**. These systems are typically designed to reduce organic matter (BOD), suspended solids (TSS), pathogens, and nutrients (like nitrogen and phosphorus) while maintaining an efficient and cost-effective treatment process.

Table 2: Operation and maintenance between facultative, aerobic, and anaerobic lagoons

Aspect	Facultative Lagoon	Aerobic Lagoon	Anaerobic Lagoon
Oxygen Requirement	Mixed aerobic and anaerobic zones. Oxygen is produced by algae in the upper layers (aerobic), while deeper layers are anaerobic.	Requires continuous aeration to maintain aerobic conditions.	Operates under anaerobic conditions with little to no oxygen.
Aeration	Natural aeration by algae photo-synthesis in the upper layers. May require supplemental aeration in deeper layers or during colder months.	Requires mechanical or diffused aeration to maintain oxygen levels throughout the lagoon.	No aeration required, relies on natural anaerobic conditions for treatment.
Sludge Accumulation	Moderate accumulation of sludge in the bottom, requiring periodic dredging.	Moderate to high accumulation, depending on flow rate and reten-tion time. Needs regular sludge removal.	Significant sludge buildup, usu-ally requires periodic dredging for sludge removal.
Treatment Process	Organic matter is decomposed in the upper aerobic layer by algae and microorganisms, while anaer-obic conditions in deeper layers break down organic matter.	Organic matter is broken down by aerobic bacteria that require oxygen.	Organic matter is decomposed by anaerobic bacteria, pro-ducing methane gas as a by product.
Temperature Sensitivity	Sensitive to temperature changes, particularly in colder climates where microbial and algal activity slows down.	Performance is sensitive to temperature; cold weather can reduce microbial activity.	Less sensitive to temperature but slow down during colder periods; reduced methane production.
Effluent Quality	Typically meets BOD and TSS standards, but nutrient removal (es-pecially nitrogen and phosphorus) may be less effective.	Generally, produces better effluent quality with lower BOD, TSS, and better pathogen removal.	Effluent may have higher BOD and TSS, but effective at reducing organic material. Higher nitrogen levels can be a concern.
Energy Requirements	Low energy requirement due to natural aeration (though supple-mental aeration may be needed).	High energy requirement for aeration.	Very low energy requirement since no aeration is needed.
Odor Issues	Potential for odors, especially in anaerobic deeper layers. Algae growth and sludge decomposition may contribute to odors.	Odor issues may occur if aeration is insufficient or if sludge manage-ment is inadequate.	Significant odor potential due to anaerobic conditions, espe-cially if sludge is not properly managed.
Nutrient Removal	Some nitrogen and phosphorus re-moval, especially in aerobic layers, but may not be as effective as aerobic lagoons.	More effective at removing ni-trogen and phosphorus through aerobic processes but still may require additional measures.	Less effective in nutrient remov-al, especially nitrogen; often needs additional treatment for nutrient reduction.
Maintenance Frequency	Moderate maintenance; requires periodic inspection of algae levels, sludge buildup, and inlet/outlet structures.	Regular maintenance of aerators, monitoring of dissolved oxygen levels, and sludge management.	Low maintenance for aeration but requires periodic sludge management and monitoring of methane production.
Discharge Standards	Generally, meets BOD and TSS standards, but may struggle with nutrient (nitrogen/phosphorus) removal and pathogen control.	More effective at meeting effluent standards for BOD, TSS, and pathogens. Can achieve better compliance with regulations.	May fail to meet effluent quality standards for BOD, TSS, and pathogens, requiring post-treat-ment or additional disinfection.
Cost	Low operational cost due to natural aeration; periodic dredging and sludge management.	Higher operational cost due to energy consumption for aeration.	Very low operational cost with little energy requirement, but higher maintenance costs for sludge management.

Section 8 - Key Considerations for Operating and Maintaining a Lagoon System

Operating and managing wastewater treatment lagoon systems require careful attention to various factors to ensure the system functions effectively, meets regulatory standards, and minimizes environmental impact. Here are the **key considerations** for the **operation and management** of wastewater treatment lagoon systems:

1. Lagoon Design and Sizing

- **Capacity and Size**: Ensure the lagoon is appropriately sized to handle the expected **flow rates** and **pollutant loads**. A lagoon that is too small may not provide adequate treatment, while one that is too large could lead to operational inefficiencies.
- **Retention Time**: The lagoon's hydraulic retention time (HRT) must be long enough to allow adequate treatment. The typical retention time ranges from **20 to 60 days**, depending on the lagoon type and the wastewater strength.
- **Lagoon Depth**: The depth of the lagoon is crucial in determining the balance between aerobic and anaerobic zones, especially in facultative lagoons. The **shallow upper layers** support aerobic activity, while deeper layers support anaerobic processes.

2. Influent Flow and Loading Control

- **Flow Variations**: Wastewater flow can fluctuate due to seasonal changes, peak flows, or industrial cycles. Lagoons should be designed to handle peak flow conditions, and operational strategies should account for variations in flow.
- **Pollutant Load Monitoring**: Regularly monitor influent water quality (BOD, TSS, nitrogen, phosphorus, and other parameters) to ensure that the lagoon is handling the expected load. Sudden increases in pollutant levels can overwhelm the lagoon's capacity.
- **Flow Distribution**: Proper distribution of influent across the lagoon ensures even treatment. An ineffective inlet system can lead to short-circuiting or uneven treatment, resulting in untreated wastewater being discharged.

3. Temperature and Climate Factors

- **Impact of Temperature**: Temperature plays a critical role in microbial activity. **Warmer climates** tend to accelerate treatment processes due to faster microbial activity. In colder climates, microbial activity slows down, requiring longer retention times or possibly supplemental aeration or heating.
- **Climate-Dependent Adjustments**: Seasonal changes can impact lagoon performance, particularly with **algae growth** (which is critical in facultative lagoons). Cold temperatures can reduce algae growth and oxygen production, slowing down the treatment process. During winter months, it may be necessary to adjust the depth, add aeration or additional treatment steps.
- **Freeze Protection**: In colder regions, lagoon systems may be at risk of freezing. Proper design and operational practices are needed to prevent ice formation, which could impair the lagoon's function.

4. Aeration Management (for Aerobic and Facultative Lagoons)

- **Oxygenation in Aerobic Lagoons**: Proper aeration is crucial to maintain aerobic conditions for microbial breakdown of organic matter. **Aerators** (mechanical or diffused air systems) should be maintained and adjusted to ensure they provide sufficient oxygen throughout the lagoon.

- **Algae Management in Facultative Lagoons**: Algae are crucial in facultative lagoons for maintaining aerobic conditions in the upper layer. However, excessive algae growth can lead to problems such as **odor** (due to anaerobic conditions in deeper layers) and **high nutrient concentrations**. Algae blooms should be monitored and controlled if necessary.

5. Sludge Management

- **Sludge Accumulation**: Sludge builds up over time at the bottom of the lagoon. Regular **monitoring** and **dredging** of accumulated sludge are necessary to maintain effective treatment capacity. Without proper sludge removal, the lagoon's treatment efficiency can degrade.
- **Sludge Stabilization**: Sludge needs to be stabilized to prevent odors and pathogens. Anaerobic lagoons naturally stabilize sludge, but facultative and aerobic lagoons may require more frequent sludge management.
- **Sludge Disposal or Reuse**: After stabilization, sludge can be land-applied, composted, or sent for further processing (e.g., dewatering, landfilling). Proper disposal or reuse methods should be in place to avoid environmental issues.

6. Nutrient Removal

- **Nitrogen Removal**: **Nitrification** and **denitrification** processes occur naturally in lagoons but may require management to optimize nitrogen removal. Facultative lagoons typically perform better at removing nitrogen, especially under aerobic conditions in the upper layers.
- **Phosphorus Removal**: While lagoons can absorb phosphorus, they are generally less effective at removing it than nitrogen. In cases where phosphorus removal is a concern, additional measures (e.g., chemical precipitation) may be needed.
- **Monitoring Nutrient Levels**: Regular testing for nitrogen, phosphorus, and other nutrients is necessary to ensure that lagoon performance is adequate, especially if the effluent is discharged into sensitive receiving waters.

7. Effluent Quality Monitoring and Compliance

- **Effluent Quality Standards**: Wastewater treatment lagoons must meet local, state, and federal effluent standards for parameters like BOD, TSS, fecal coliform, and nutrients (nitrogen, phosphorus). Regular monitoring is essential to ensure compliance with regulatory discharge limits.
- **Sampling and Analysis**: Routine sampling of lagoon effluent for parameters such as BOD, TSS, ammonia, nitrates, pH, and pathogens helps ensure the system is functioning correctly and that the treated water meets discharge requirements.
- **Flow Monitoring**: Monitoring the volume of effluent discharged from the lagoon helps ensure it matches the system's design and permits.

8. Odor Control

- **Algae and Sludge Management**: Odor issues are common in wastewater treatment lagoons, especially if there is an imbalance between aerobic and anaerobic conditions. Excessive algae growth, inadequate aeration, or improper sludge management can result in the production of odors such as **hydrogen sulfide**.
- **Operational Adjustments**: Managing the balance between the aerobic and anaerobic zones, controlling algae blooms, and timely sludge removal can help minimize odors. Regular aeration or chemical treatments may also be necessary.
- **Buffer Zones**: For lagoons located near residential or recreational areas, establishing a buffer zone of vegetation around the lagoon can help mitigate odor by acting as a physical barrier.

9. Health and Safety Considerations

- **Public Health Risks**: Lagoons often contain pathogens, especially in untreated or partially treated wastewater. Ensuring that safety barriers (e.g., fencing) are in place around the lagoon is essential to prevent accidental exposure to hazardous conditions.
- **Worker Safety**: Workers involved in the operation and maintenance of lagoons should be trained to handle chemicals, manage sludge, and operate equipment safely. Proper personal protective equipment (PPE) should be provided, particularly when dealing with sludge or high-risk tasks.
- **Security**: For facilities dealing with industrial or high-strength waste, proper security measures should be implemented to prevent unauthorized access to the lagoon and ensure the safety of workers and the surrounding community.

10. Regulatory Compliance and Documentation

- **Permit Compliance**: Lagoon systems are typically subject to environmental regulations and permitting requirements. Operators must ensure that the system operates within the bounds of its **National Pollutant Discharge Elimination System (NPDES)** permit or similar state-issued permits.
- **Record Keeping**: Accurate records of **maintenance activities**, **effluent quality monitoring**, **sludge management**, and **flow data** must be kept for regulatory reporting purposes. These records also help in identifying trends or issues in lagoon performance.
- **Routine Inspections**: Regular inspections of lagoon conditions, equipment, and operational logs are required to identify potential issues, such as excessive sludge buildup or inadequate treatment capacity.

11. Public and Environmental Impact

- **Discharge to Receiving Waters**: The effluent from the lagoon, once treated, is usually discharged into a **river**, **stream**, or **lake**. Operators must ensure that the lagoon's effluent meets water quality standards to prevent negative impacts on the receiving water body and the surrounding environment.
- **Ecological Considerations**: Lagoons may also have ecological value, serving as habitats for birds or other wildlife. Operators should consider the environmental impact of the lagoon system on local ecosystems and avoid actions that might harm these environments.

Operating and managing wastewater treatment lagoon systems require careful planning and attention to detail. Key considerations include proper lagoon design and sizing, managing influent flow and pollutant loading, temperature and climate factors, aeration management (for aerobic and facultative lagoons), effective sludge management, nutrient removal, regulatory compliance, and ensuring public health and safety. Regular monitoring and operational adjustments are necessary to ensure the lagoon continues to provide efficient, effective, and compliant wastewater treatment while minimizing its environmental impact.

Table 3 (page 24) compares the differences in operation and maintenance between facultative, aerobic, and anaerobic lagoons.

Summary:

- **Facultative lagoons** are cost-effective and provide natural treatment, but they may have slower performance in colder weather and can be less effective in nutrient removal.
- **Aerobic lagoons** require constant energy for aeration but are efficient at removing organic matter and nutrients, offering better effluent quality.
- **Anaerobic lagoons** are the most energy-efficient in terms of aeration but may have issues with nutrient removal and require careful sludge management.

Each lagoon type has its advantages and challenges, and the selection of a lagoon type typically depends on factors like influent characteristics, climate, and regulatory requirements.

Table 3: Operation and maintenance between facultative, aerobic, and anaerobic lagoons

Aspect	Facultative Lagoon	Aerobic Lagoon	Anaerobic Lagoon
Oxygen Requirement	Mixed aerobic and anaerobic zones. Oxygen is produced by algae in the upper layers (aerobic), while deeper layers are anaerobic.	Requires continuous aeration to maintain aerobic conditions.	Operates under anaerobic conditions with little to no oxygen.
Aeration	Natural aeration by algae photosynthesis in the upper layers. May require supplemental aeration in deeper layers or during colder months.	Requires mechanical or diffused aeration to maintain oxygen levels throughout the lagoon.	No aeration required, relies on natural anaerobic conditions for treatment.
Sludge Accumulation	Moderate accumulation of sludge in the bottom, requiring periodic dredging.	Moderate to high accumulation, depending on flow rate and retention time. Needs regular sludge removal.	Significant sludge buildup usually requires periodic dredging for sludge removal.
Treatment Process	Organic matter is decomposed in the upper aerobic layer by algae and microorganisms, while anaerobic conditions in deeper layers break down organic matter.	Organic matter is broken down by aerobic bacteria that require oxygen.	Organic matter is decomposed by anaerobic bacteria, producing methane gas as a byproduct.
Temperature Sensitivity	Sensitive to temperature changes, particularly in colder climates where microbial and algal activity slows down.	Performance is sensitive to temperature; cold weather can reduce microbial activity.	Less sensitive to temperature but slow down during colder periods; reduced methane production.
Effluent Quality	Typically meets BOD and TSS standards, but nutrient removal (especially nitrogen and phosphorus) may be less effective.	Generally produces better effluent quality with lower BOD, TSS, and better pathogen removal.	Effluent may have higher BOD and TSS, but effective at reducing organic material. Higher nitrogen levels can be a concern.
Energy Requirements	Low energy requirement due to natural aeration (though supplemental aeration may be needed).	High energy requirement for aeration.	Very low energy requirement since no aeration is needed.
Odor Issues	Potential for odors, especially in anaerobic deeper layers. Algae growth and sludge decomposition may contribute to odors.	Odor issues may occur if aeration is insufficient or if sludge management is inadequate.	Significant odor potential due to anaerobic conditions, especially if sludge is not properly managed.
Nutrient Removal	Some nitrogen and phosphorus removal, especially in aerobic layers, but may not be as effective as aerobic lagoons.	More effective at removing nitrogen and phosphorus through aerobic processes but still may require additional measures.	Less effective in nutrient removal, especially nitrogen; often needs additional treatment for nutrient reduction.
Maintenance Frequency	Moderate maintenance; requires periodic inspection of algae levels, sludge buildup, and inlet/outlet structures.	Regular maintenance of aerators, monitoring of dissolved oxygen levels, and sludge management.	Low maintenance for aeration but requires periodic sludge management and monitoring of methane production.
Discharge Standards	Generally, meets BOD and TSS standards, but may struggle with nutrient (nitrogen/phosphorus) removal and pathogen control.	More effective at meeting effluent standards for BOD, TSS, and pathogens. Can achieve better compliance with regulations.	May fail to meet effluent quality standards for BOD, TSS, and pathogens, requiring post-treatment or additional disinfection.
Cost	Low operational cost due to natural aeration; periodic dredging and sludge management.	Higher operational cost due to energy consumption for aeration.	Very low operational cost with little energy requirement, but higher maintenance costs for sludge management.

Section 9 - Common Issues Operating and Maintaining a Lagoon System

Operating and maintaining a wastewater treatment lagoon system can be challenging due to various factors related to environmental conditions, operational variables, and system design. Below are some common issues that may arise when managing and operating wastewater treatment lagoon systems:

1. Sludge Accumulation

- **Problem**: Sludge builds up at the bottom of the lagoon over time as solids settle. If not properly managed, excessive sludge accumulation can reduce the lagoon's treatment capacity, leading to inefficient treatment and potential overflow (Figure 13).
- **Causes and Negative Impacts on the Treatment Process**:
    - o **Short Circuiting:** Wastewater may flow unevenly, bypassing parts of the lagoon reducing contact time within the lagoon.
    - o **Higher Risk of Algae Blooms:** Nutrients released from sludge can fuel excessive algae growth.
    - o **Increased Risk of Odors:** Thick sludge layers can create anaerobic zones near the surface water of the lagoon. This can lead to the production of hydrogen sulfide and other foul-smelling gases, especially problematic in warm weather or stagnant conditions.
    - o **Blockage and Hydraulic Issues:** Sludge can clog inlets, outlets, and baffles.

Figure 13. Figure 13. Sludge Accumulation. Photo Courtesy of Mark Cubbon. RCAC

The more sludge that accumulates over the lagoon's design, the more likely you will be troubleshooting problems and the higher the cost to remove the sludge will be.

- **Troubleshooting**:
    - o **Optimize Aeration:** Encourage aerobic decomposition, if applicable.
    - o **Reduce Organic and Inorganic Loading:** Limit inflow and infiltration (I & I) and industrial discharges, if possible.
    - o **Sludge Monitoring Program:** Perform sludge surveys at least yearly and track sludge depth trends to predict when dredging will be needed.
    - o **Sludge Management Plan:** Conduct regularly scheduled meetings with management to develop a budget for sludge removal.
    - o **Sludge Removal:** The most effective long-term solution for excessive sludge accumulation. This is done mechanically using dredges and pumps, or manually in smaller lagoons. The sludge removed (biosolids) can be land-applied, composted, dried, or taken to a landfill (must meet any applicable regulations).

2. Algae Overgrowth (Excessive Algae)

- **Problem:** In facultative lagoons, algae grow in the upper aerobic layers through photosynthesis, providing oxygen for microbial activity. High levels of nitrogen and phosphorus in the influent can lead to excessive algae growth and additional problems (Figure 14).

- **Causes and Negative Impacts on the Treatment Process**:
  - **Increased Organic Matter**: Large amounts of algae can increase the organic load when they die and decompose.
  - **Odor Problems**: Excessive algae can also cause odor issues as they break down anaerobically in deeper layers.
  - **Imbalance in Treatment**: Overgrowth of algae can disrupt the delicate balance of aerobic and anaerobic zones, leading to less effective treatment.
  - **Algae in the Effluent**: May lead to permit violations.
- **Troubleshooting**:
  - **Optimize Aeration:** This improves circulation, reduces stagnant zones, and limits algae growth. It can also boost dissolved oxygen levels within the lagoon, supporting healthy bacteria and limiting algae-favorable conditions.
  - **Mechanical Removal:** Skim floating algae mats with nets, screens, or mechanical equipment to provide short-term relief.
  - **Nutrient Management:** Reduce nitrogen and phosphorus entering the lagoon by identifying and controlling industrial discharges, stormwater runoff, or I & I.
  - **Consider Pre-Treatment:** Applicable to high-strength wastewater sources.
  - **Reduce Organic and Inorganic loading:** Limit I & I and industrial discharges, if possible.
  - **Algaecide Application:** Use approved algaecides (such as copper sulfate) in controlled doses. Overuse can harm beneficial bacteria and aquatic life. Always follow environmental regulations and product instructions.

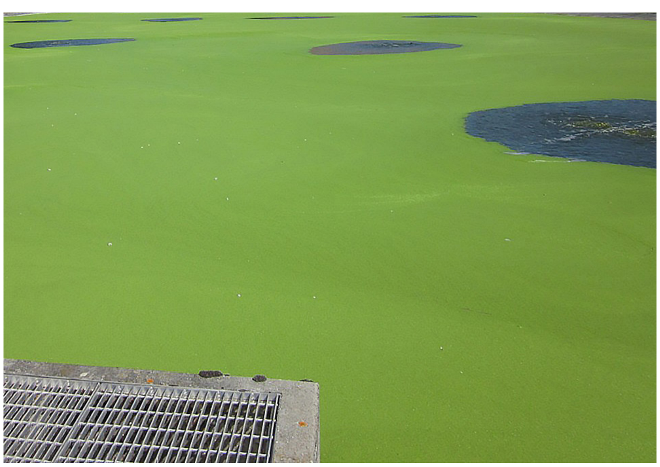

Figure 14. Algae Growth. Great Lakes Community Action Partnership. (n.d.). Headworks, Disinfection, and Understanding Lagoon Operations. [PowerPoint Slide]

3. Odor Issues

- **Problem:** Odors can occur when organic matter breaks down anaerobically or when sludge accumulates without proper stabilization. Odors are particularly problematic in anaerobic and facultative lagoons. Odor complaints from nearby communities can lead to regulatory pressure and increased scrutiny of the lagoon system.
- **Causes and Negative impacts on the Treatment Process**:
  - **Anaerobic Conditions**: When there is insufficient oxygen, the lagoon produces gases like **hydrogen sulfide**, which has a strong, unpleasant odor.
  - **Algae and Sludge**: Decomposing algae and sludge in deeper, anaerobic zones can contribute to odor.
- **Troubleshooting**:
  - **Control Measures**: Odor control methods, such as **aeration**, **covering lagoons**, or adding **lime** or other chemicals, may be required to mitigate odors.

4. Inefficient Treatment Due to Inadequate Aeration

- **Problem**: In aerobic lagoons or facultative lagoons with an aerobic component, inadequate aeration can lead to insufficient oxygen levels for microbial activity, resulting in poor treatment efficiency.

- **Causes and Negative Impacts to the Treatment Process**:
  - o **Aerator Failure**: Mechanical aerators or diffused aeration systems may fail due to mechanical issues, clogging, or electrical failures.
  - o **Energy Costs**: Maintaining adequate aeration can be costly, especially in larger lagoons or regions with colder climates that reduce the efficiency of aeration systems.
  - o **Oxygen Deficiency**: Low dissolved oxygen levels can lead to **poor BOD removal** and potential buildup of harmful substances like ammonia.
- **Troubleshooting**:
  - o **Mechanical Removal:** Remove duckweed, matted algae, or sludge that is blocking the surface.
  - o **BOD Load Reduction:** Add an influent screen or run lagoons in parallel instead of in series.
  - o **Sludge Removal:** This is done mechanically using dredges and pumps, or manually in smaller lagoons.
  - o **Vegetation Removal:** Cut down any trees or plant materials that are interfering with the wind action on the lagoon.
  - o **Optimize Aeration and Mixing:** This improves circulation, reduces stagnant zones, and limits algae growth.
  - o **Preventative Maintenance:** Perform maintenance on equipment to the manufacturer's recommendations.

5. Nutrient Imbalances

- **Problem**: Lagoons, particularly facultative ones, can experience nutrient imbalances, especially in regions with high nitrogen and phosphorus levels in the influent.
- **Causes and Negative Impacts on the Treatment process**:
  - o **Eutrophication**: Excessive nutrients, particularly nitrogen and phosphorus, can promote excessive algae growth, which in turn affects lagoon performance and leads to increased organic load and odor issues.
  - o **Inefficient Nitrogen Removal**: If the lagoon is not properly managed, **nitrification** (conversion of ammonia to nitrate) and **denitrification** (conversion of nitrate to nitrogen gas) may be less effective, leading to elevated nitrogen levels in the effluent.
- **Troubleshooting**:
  - o **Control of Nutrients**: Managing nutrient levels through operational adjustments (e.g., reducing influent nutrient loads, optimizing aeration, and controlling algae) is often required but can be complex.

6. Short Circuiting and Uneven Flow Distribution

- **Problem:** Inadequate flow distribution can result in short circuiting, where wastewater flows through the lagoon too quickly, bypassing treatment zones, or flows unevenly through the lagoon (Figure 15).
- **Cause and Negative Impacts on the Treatment Process**:
  - o **Improper Inlet Design:** An inlet system that doesn't evenly distribute the influent can cause uneven treatment across the lagoon.
  - o **Flow Overloading:** High influent flow rates or surges can overwhelm the lagoon's capacity to treat wastewater, leading to untreated or under-treated effluent.

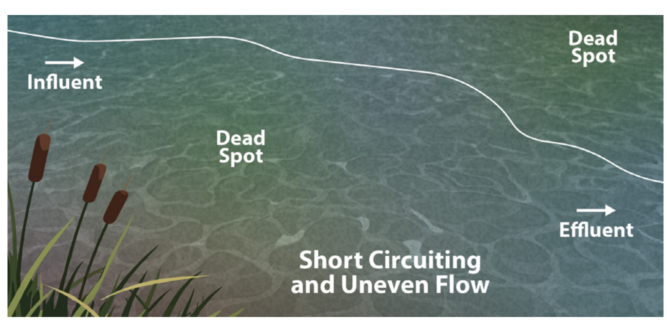

Figure 15. Lagoon Short Circuit Design

- **Discharge Quality:** Short-circuiting can result in poor removal of pollutants such as BOD, TSS, and nutrients, leading to effluent quality that doesn't meet discharge standards.

- **Troubleshooting**:
  - **Visual Observation:** Watch how water enters and exits the lagoon looking for visible currents or channels where water quickly flows toward the outlet.
  - **Structure Confirmation:** Check the placement and condition of inlets, outlets, baffles, and islands. Damaged or poorly positioned structures often contribute to short-circuiting.
  - **Scheduled Dye Testing:** Introduce a non-toxic dye at the inlet and monitor its movement. If the dye reaches the outlet quickly, short circuiting may occur.
  - **Sludge Removal:** Buildup of sludge can change flow patterns and worsen short-circuiting.
  - **Install or Repair Baffles:** Baffles, curtains, or walls help direct flow through the lagoon, increasing retention time. Floating baffles are often used and can be retrofitted into existing lagoons.
  - **Adjust Inlet and Outlet Positions:** Reposition or modify inlets and outlets to ensure proper flow patterns.
  - **System Design:** Ensuring proper lagoon design with appropriate inlet distribution systems and baffle structures to prevent short-circuiting is critical. It is also possible to add a method of recirculation to the lagoon, as applicable.

7. Poor Sludge Stabilization and High Sludge Volume

- **Problem**: Inadequate stabilization of sludge in anaerobic or facultative lagoons can lead to an **increased volume** of sludge and poor treatment performance.

- **Cause and Negative Impacts on the Treatment Process**:
  - **Sludge Stabilization**: In anaerobic lagoons, it can take a long time for the sludge to stabilize, and **methane production** may not be sufficient to reduce volume. This can lead to higher sludge volumes and potential for operational inefficiencies.
  - **Methane Production**: In anaerobic systems, methane can be produced, which is often a valuable byproduct. However, if not properly managed, methane can accumulate and pose safety risks, as well as contribute to greenhouse gas emissions.
  - **Odor from Sludge**: Sludge that is not adequately stabilized can emit strong odors, particularly in anaerobic lagoons.

- **Troubleshooting**:
  - **Mixing:** Ensure proper mixing within the lagoon to facilitate the movement of sludge and nutrients, which is crucial for anerobic digestion.
  - **Optimize Conditions:** Maintain optimal Hydraulic Retention Time, (HRT) and Solids Retention Time (SRT) to maximize volatile solids reduction.

8. Seasonal Variability in Performance

- **Problem**: The performance of wastewater treatment lagoons can be significantly influenced by **seasonal changes**, especially temperature.

- **Cause and Negative Impacts on the treatment Process**:
  - **Colder Temperatures**: In colder weather, microbial activity in both aerobic and facultative lagoons slows down, which can reduce treatment efficiency, especially for BOD removal.

- **Reduced Algae Activity**: In colder climates, algae growth in facultative lagoons may decrease, leading to a reduction in oxygen levels in the upper layers and potentially causing anaerobic conditions and increased odors.
- **Winterization**: Lagoons in colder regions may require additional infrastructure or operational changes to prevent freezing, such as **aeration** to keep the water moving and prevent ice formation, increasing water levels in the pond, or **insulating lagoon covers**.

- **Troubleshooting**:
    - **Protect equipment:** Be sure surfaces around the lagoon are clear of road gravel, which can damage the lagoon liner with the freeze-thaw cycle. Cover or store unnecessary equipment.
    - **Check and Maintain Outdoor Equipment:** If you have any motors sitting outside all winter long, including blowers or surface aerators, change the oil and check any belts for wear and tear. By properly maintaining these motors now you can reduce the risk that they will fail during the cold winter months when it will be harder to access them.
    - **Increase DO to Reduce BOD and Sludge Buildup:** Microbial populations require dissolved oxygen to digest BOD and keep it from building up as sludge. Provide sufficient oxygenation by adding aeration.
    - **Prevent Short-Circuiting and Spring Lagoon Turnover:** Thorough mixing of the entire water column will ward off thermal stratification. Without thermoclines, warmer influents will incorporate into the overall mix and not flow out untreated. In addition, with homogeneous water temperature and environment, no spring lagoon turnover can occur.

Section 10 - Common Issues Managing and Recordkeeping

1. Regulatory Compliance and Monitoring

- **Problem**: Ensuring that the lagoon consistently meets **regulatory discharge limits** for parameters such as BOD, TSS, ammonia, and pathogens can be challenging.
- **Challenges**:
  - **Monitoring Costs**: Continuous monitoring of lagoon effluent quality is required to ensure compliance with regulatory standards, which can be resource intensive.
  - **Permit Violations**: Non-compliance with effluent discharge standards, such as exceeding BOD or nutrient levels, can result in penalties, fines, or corrective actions.
  - **Effluent Quality Variability**: Variations in influent characteristics, temperature, or operational issues can cause fluctuations in effluent quality, complicating compliance.

2. Cost and Resource Constraints

- **Problem**: Operating and maintaining a lagoon system can be expensive due to the need for equipment maintenance, sludge management, and energy costs for aeration.
- **Challenges**:
  - **Maintenance Costs**: Regular maintenance of aeration equipment, inlet/outlet structures, and monitoring systems is necessary for optimal performance.
  - **Energy Consumption**: Aeration systems can be energy intensive. In larger systems or regions with cold temperatures, the cost of maintaining proper aeration can become a significant operating expense.
  - **Resource Allocation**: Smaller municipalities or agricultural operations may face challenges in securing sufficient funding or resources for necessary maintenance and upgrades.

3. Pathogen Removal Efficiency

- **Problem**: Wastewater treatment lagoons can be effective at reducing pathogens, but their efficiency in **pathogen removal** can vary depending on factors like temperature, retention time, and lagoon type.
- **Challenges**:
  - **Temperature Sensitivity**: Low temperatures can slow down the pathogen die-off process.
  - **Retention Time**: Lagoons with insufficient retention time may not achieve the necessary level of pathogen reduction to meet regulatory standards.
  - **Supplemental Disinfection**: Some lagoons may require additional disinfection steps (e.g., chlorination, UV treatment) to achieve sufficient pathogen removal, especially for effluent reuse or discharge to sensitive receiving waters.

Operating and maintaining a wastewater treatment lagoon system comes with a variety of challenges, including sludge accumulation, algae overgrowth, odor management, aeration issues, nutrient imbalances, and regulatory compliance. Effective management involves regular monitoring, appropriate system design, and proactive problem-solving to address these issues. Addressing these common problems requires a combination of proper lagoon sizing, efficient sludge and aeration management, seasonal adjustments, and ensuring compliance with environmental standards to maintain the lagoon's long-term operational efficiency.

Section 11 - Sampling and Monitoring

Sampling and monitoring are essential for ensuring that a wastewater treatment lagoon system is operating effectively and complying with regulatory standards. The requirements can vary depending on local regulations, lagoon type (facultative, aerobic, anaerobic), and the specific characteristics of the wastewater being treated. Below is a general overview of **typical sampling and monitoring requirements** for wastewater treatment lagoon systems.

1. Influent Sampling and Monitoring

- **Flow Rate**:
  - **Monitoring**: Continuous or daily flow measurements to track influent volume and ensure the lagoon can handle the flow. This is often done using flow meters.
  - **Frequency**: Typically, daily or as per permit conditions.
- **Key Parameters**:
  - **BOD (Biochemical Oxygen Demand)**: Indicates the organic matter in the influent. Helps assess the lagoon's loading capacity and treatment performance.
  - **TSS (Total Suspended Solids)**: Measures the solid particles in the wastewater.
  - **Ammonia (NH_3)**: Important for understanding nitrogen levels and for managing aeration needs.
  - **pH**: Ensures the wastewater is within a pH range conducive to microbial activity.
  - **Nutrients (Nitrogen, Phosphorus)**: Monitoring nitrogen and phosphorus is crucial for nutrient management, especially to prevent eutrophication in receiving water bodies.
  - **Temperature**: Affects microbial activity, especially in cold climates, which can slow down treatment processes.
  - **Fecal Coliform or Pathogen Levels**: Key for determining the quality of effluent, especially for discharge to public waters or reuse.
- **Frequency**: Typically, influent sampling is done weekly or as required by permits, but certain parameters like pH or temperature may be monitored more frequently.

2. Effluent Sampling and Monitoring

- **Flow Rate**:
  - **Monitoring**: Similar to influent, effluent flow should be measured continuously or periodically to verify the lagoon's treatment capacity.
  - **Frequency**: Daily or per permit requirements.
- **Key Parameters**:
  - **BOD**: Effluent BOD is a key indicator of treatment performance and system effectiveness.
  - **TSS**: Effluent TSS is important for meeting discharge standards.
  - **pH**: The pH of the effluent should meet regulatory discharge limits.
  - **Ammonia (NH_3)**: Effluent ammonia is monitored to ensure nitrogen removal, especially in aerobic lagoons.
  - **Nitrate (NO_3)**: For systems designed to remove nitrogen, effluent nitrate levels are important.
  - **Total Phosphorus**: To assess phosphorus removal efficiency.

- **Fecal Coliform or E. Coli**: Regulatory standards for pathogen removal must be met in effluent, especially for recreational or potable reuse waters.
- **Chlorine Residual**: If chlorine disinfection is used in the lagoon system, residual chlorine levels need to be measured to ensure effective disinfection.

- **Frequency**: Effluent sampling is generally required on a **daily to weekly** basis, depending on the system and discharge permit.

3. Sludge Monitoring

- **Sludge Depth**:
  - **Monitoring**: The accumulation of sludge should be measured regularly to ensure that the lagoon is not overloaded. Sludge probes or manual methods can be used to determine the depth of sludge.
  - **Frequency**: Monthly or quarterly, depending on the lagoon size and operational characteristics.
- **Sludge Volume and Composition**:
  - **Monitoring**: Sludge characteristics, such as its composition and methane production (for anaerobic lagoons), should be measured regularly. This helps to determine when dredging or further treatment of sludge is needed.
  - **Frequency**: Periodically, typically quarterly or annually, depending on the lagoon's operational conditions.
- **Sludge Age**:
  - **Monitoring**: Tracking the age of sludge helps assess whether it is adequately stabilized.
  - **Frequency**: Annually or as required.

4. Algae and Oxygen Levels (for Facultative Lagoons)

- **Algae Growth**:
  - **Monitoring**: Algae growth is crucial for facultative lagoons as it supports aerobic processes. Monitoring algae blooms is important to avoid overgrowth that can cause odors or system imbalance.
  - **Frequency**: Weekly or monthly, depending on the lagoon and weather conditions.
- **Dissolved Oxygen (DO)**:
  - **Monitoring**: In aerobic and facultative lagoons, DO levels must be monitored to ensure adequate oxygen for microbial activity, especially in the upper layers.
  - **Frequency**: Weekly or as needed in aerobic lagoons; may be less frequent in facultative lagoons unless aeration is used.

5. Temperature Monitoring

- **Temperature**:
  - **Monitoring**: Temperature impacts microbial activity and the overall treatment process. It's important to monitor the lagoon's temperature to adjust operations (e.g., aeration, retention time) accordingly.
  - **Frequency**: Daily or weekly, especially in seasonal climates where temperature variation is significant.

6. Methane and Gas Monitoring (or Anaerobic Lagoons)

- **Methane Production**:
  - **Monitoring**: Anaerobic lagoons produce methane as a byproduct. Monitoring methane levels helps determine the rate of sludge stabilization and ensures there is no dangerous gas buildup.
  - **Frequency**: Monthly or as part of regular sludge management checks.
- **Gas Emissions**:
  - **Monitoring**: It may be important to monitor other gases, such as hydrogen sulfide, which can lead to odor problems and safety concerns.
  - **Frequency**: Monthly or based on operational needs and safety protocols.

7. Operational and Maintenance Monitoring

- **Aeration System Performance**:
  - o **Monitoring**: For aerobic lagoons, monitoring the aeration system's performance (e.g., power consumption, dissolved oxygen levels, aerator function) is essential to ensure proper treatment.
  - o **Frequency**: Daily checks or automated monitoring for aerators.
- **Inlet and Outlet Structures**:
  - o **Monitoring**: Regularly inspection inlet and outlet structures to ensure proper flow distribution and prevent short circuiting. Also, monitor for clogging or damage.
  - o **Frequency**: Monthly inspections or as needed.

8. Regular Inspections

- **Lagoon Condition**:
  - o **Monitoring**: Visually inspect the lagoon for signs of erosion, excessive algae growth, short-circuiting, or other structural issues.
  - o **Frequency**: Monthly or quarterly.
- **Fence and Safety**:
  - o **Monitoring**: Ensure that safety barriers (such as fencing) are intact and that the lagoon does not pose a safety risk to the public.
  - o **Frequency**: Monthly or after significant weather events.

9. Compliance and Reporting

- **Regulatory Compliance**:
  - o **Monitoring**: Sampling and testing must meet local, state, and federal requirements for discharge quality, pathogen levels, and nutrient content.
  - o **Frequency**: Regular reporting, often **monthly** or **quarterly**, to environmental agencies for compliance with permit conditions.
- **Reporting**: Results from influent and effluent sampling, sludge management, and aeration data must be documented and submitted to the relevant authorities.
  - o **Frequency**: Monthly, quarterly, or annually, depending on local regulations and permit requirements.

Table 4 (page 34) is a general guide, and specific sampling and monitoring requirements can vary depending on **permit conditions**, the **type of lagoon**, **wastewater characteristics**, and local **regulations**.

Explanation of Sampling Types:

- **Grab Sampling**: A single sample is collected at one specific point in time. It is typically used for **parameters like BOD, TSS, ammonia, fecal coliform, pH**, and **temperature**, where conditions are reasonably stable or instantaneous measurements are important.
- **Composite Sampling**: A mixture of multiple samples is collected over a period of time (such as during the day or over a shift). This type of sampling is commonly used for **flow-based parameters** like **influent and effluent flow**, or when more representative samples are required for **parameters like BOD or nutrients** that may vary over time.
- **Continuous Sampling**: Data is continuously recorded (such as for **flow rate** or **dissolved oxygen**). This provides real-time data and is especially important in monitoring system performance or aeration efficiency.
- **Manual/Probe Sampling**: For parameters such as **sludge depth**, a manual measurement (using probes or specialized equipment) is often required.
- **Visual/Visual Inspection**: For **algae growth**, visual monitoring or physical observation of the lagoon's surface is used to assess algae bloom and health.

Table 4: Potential Sampling / Monitoring Requirements

Parameter	Influent	Effluent	Sludge	Algae/ Oxygen (Facultative)	Methane/ Emissions (Anaerobic)	Sampling Type	Frequency
Flow Rate	Yes (Daily/ Continuous)	Yes (Daily/ Continuous)	N/A	N/A	N/A	Continuous	Daily/ Continuous
BOD	Yes (Weekly)	Yes (Weekly)	N/A	N/A	N/A	Grab	Weekly
TSS	Yes (Weekly)	Yes (Weekly)	N/A	N/A	N/A	Grab	Weekly
Ammonia	Yes (Weekly)	Yes (Weekly)	N/A	N/A	N/A	Grab	Weekly
Nutrients (N, P)	Yes (Weekly)	Yes (Weekly)	N/A	N/A	N/A	Grab	Weekly
Fecal Colform/ E. Coli	Yes (Weekly)	Yes (Weekly)	N/A	N/A	N/A	Grab	Weekly
pH	Yes (Daily)	Yes (Daily)	N/A	Yes (Weekly)	N/A	Grab	Daily/Weekly
Tempera-ture	Yes (Daily/ Weekly)	Yes (Daily/ Weekly)	N/A	Yes (Weekly)	Yes (Monthly)	Grab	Daily/Weekly
Sludge Depth	N/A	N/A	Yes (Month-ly)	N/A	N/A	Manual/Probe	Monthly
Algae Growth	N/A	N/A	N/A	Yes (Weekly/ Monthly)	N/A	Visual/Visual	Weekly/ Monthly
Dissolved Oxygen	N/A	N/A	N/A	Yes (Weekly)	N/A	Grab/ Continuous	Weekly
Methane/ Other Gases	N/A	N/A	N/A	N/A	Yes (Monthly)	Grab	Monthly

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Appendix A

Daily Log Sheet

Lagoon

Day/Date

Time

Operator

1. Water surface in pond
   a. Is the freeboard within 24 inches from top of berm/pond? (check freeboard requirements on permit)
   b. Was liquid/wastewater added?
      a. Date
      b. Time
      c. Flow (gallons)
      d. Rainwater (yes, no)
   c. Is ice present? No__________ Yes___________
2. Water surface in lagoon
   a. Is liquid level within buoy?
   b. Was level sensor lowered? Yes,___________ No___________
3. Check Equipment
   a. Fence ____
   b. Wooden instrument box____
   c. Solar panel ____
   d. Battery ____
   e. Weatherproof enclosure ____
   f. Rain gauge____
   g. Air temperature sensor ____
   h. Water temperature sensor ____

4. Operational adjustments ____

Example Maintenance Checklist

Operation and Maintenance	Frequency						
	Daily	Weekly	Monthly	Quarterly	Semi-Annual	Yearly	As Needed
Any buildup of scum on pond surface and discharge outlet boxes		x					
Signs of burrowing animals	x						
Anaerobic conditions: noted by odor and black color, floating sludge. large number of gas bubbles	x						
Water-grown weeds	x						
Evidence of berm erosion	x						
Berm leakage	x						
Fence damage	x						
Ice buildup in winter						x	x
Evidence of short-circuiting	x						
Pretreatment							
Clean inlet and screens, and properly dispose of trash.	x						
Check inlet flow meter and float well	x						
If discharge is once or twice per year, the discharge permit may require other as following:							
Odor		x					
Aquatic plant of pond		x					
Pond depth		x					
Berm condition		x					
Ice cover		x					