United States Environmental Protection Agency

Office of Wastewater Management

EPA 832-F-26-010, September 2026 (Updated)
EPA 832-F-02-014, September 2002 (Original)

Wastewater Technology Fact Sheet
Facultative Lagoons

DESCRIPTION

Wastewater lagoons, sometimes called wastewater stabilization ponds, are earthen ponds that break down wastewater using natural biological processes. The three main types of wastewater lagoon, based on oxygen concentration, are facultative, anaerobic, and aerated.[1] About one publicly owned treatment works (POTW) in four is a lagoon system, and at least one-third are facultative lagoons (U.S. EPA, 2022). Facultative lagoon wastewater treatment systems have been in widespread use in the United States for over 100 years and are the focus of this fact sheet. They are used to treat raw, screened, or primary settled municipal wastewater and are more common in rural and/or small communities where land costs are not a limiting factor.

These earthen lagoons are usually 4 to 8 feet, or 1.2 to 2.4 meters, in depth. They are not mechanically mixed or aerated and are composed of three strata or layers (see Figure 1) (U.S. EPA, 2011). The layer of water near the surface contains dissolved oxygen due to atmospheric reaeration and algal photosynthesis, a condition that supports aerobic and facultative[2] organisms. The intermediate anoxic layer, known as the facultative zone, ranges from aerobic near the top to anaerobic at the bottom. The bottom layer of the lagoon includes sludge deposits and supports anaerobic organisms. These layers may remain stratified for long periods due to temperature-induced water density variations. Inversion (also known as turnover) typically occurs in the spring and fall when temperatures and densities in the layers equalize and the lagoon mixes, similar to seasonal turnover or mixing of lakes and reservoirs. These events can create turbidity and produce odors.

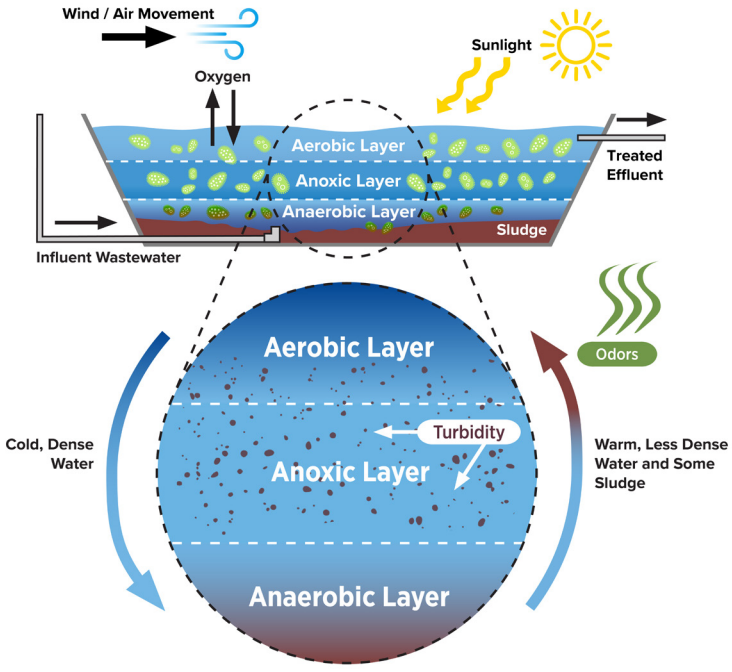


Figure 1. Depiction of facultative lagoon treatment process, strata, and the lagoon inversion process.



Example of facultative lagoon wastewater treatment system.

A facultative lagoon's primary pollutant removal mechanisms include algal uptake; sludge deposition; retention of heavy metals, potassium, and other pollutants by bottom organic matter and clay; nitrification; denitrification; and loss of ammonia as a gas to the atmosphere (volatilization). The presence of algae in the aerobic and facultative zones is essential to the successful performance of facultative lagoons. In sunlight, the algal cells use carbon dioxide from the water and release oxygen produced from photosynthesis. On warm, sunny days, the oxygen concentration in the surface water can exceed saturation levels. In addition, as the algae consume carbon dioxide in sunlight, the pH of water near the surface can exceed 10, creating conditions favorable for ammonia removal via volatilization. This photosynthetic activity occurs on a diurnal basis, causing both oxygen and pH levels to shift from a maximum in daylight hours to a minimum at night.

For information on aerated (or aerobic) lagoons, where oxygen is supplied to the system through surface aerators or a diffused aeration system, see EPA's wastewater technology fact sheet on aerated, partial mix lagoons: https://www.epa.gov/system/files/documents/2026-08/aerated-lagoons-wastewater-tech-fact-sheet.pdf.

[1] Find additional resources and information on lagoon wastewater treatment systems at https://www.epa.gov/lagoons.

[2] Facultative organisms can function in the presence or absence of oxygen.

Aerobic and facultative bacteria use the oxygen produced by algae and surface reaeration to break down organic material in the upper layer of water, reducing biochemical oxygen demand (BOD). Anaerobic fermentation is the dominant activity in the bottom layer of the lagoon. In cold climates, oxygenation and fermentation reaction rates are significantly reduced during the winter and early spring, and effluent quality may be reduced to the equivalent of primary effluent when ice cover persists on the water surface. As a result, some northern U.S. states and provinces in Canada prohibit discharge from facultative lagoons during the winter.

Common Operational Modifications

An operational method common in facultative lagoons in some states is the "controlled discharge" mode, where wastewater is discharged in controlled amounts one to two times a year. The lagoon discharge is restricted during the winter in cold climates (when the cold suppresses treatment) and/or during peak algal growth periods in the summer (to minimize discharges of total suspended solids, or TSS, to the receiving water). In this approach, the final secondary cell(s) are isolated by valving off the transfer piping from the preceding primary cell(s) prior to discharge. During the isolation period, cell contents are analyzed based on discharge permit requirements, as are conditions of the receiving stream. State agencies may require notification and/or approvals before controlled discharge begins. When approval is received, discharge begins from the final cell(s) while the upstream cell(s) stay isolated. Discharge continues until wastewater only remains in the primary cell(s). Then, the content of the primary cell(s) flows to the now-drawn-down final secondary cells. Discharges may need to continue to achieve an overall depth of 2 feet to ensure sludge remains in the cell and is not discharged to the outfall. For a step-by-step lagoon discharge operation, refer to the manual *Stabilization Pond Systems: Operations, Maintenance, Management* (Erickson et al., 2013).



Microalgae are essential to the successful performance of facultative lagoons. *Image source: iStock.*

A non-discharge or total containment lagoon is one type of facultative wastewater lagoon used in certain regions where evaporation rate exceeds precipitation and influent rate on an annual basis. This type of lagoon has also been used as part of land treatment of wastewater. In this approach, total containment lagoons provide a preliminary treatment component, helping settle out solids and break down organics before land application. These lagoons can provide storage when land application cannot occur due to soil conditions (e.g., too cold, too wet) or during crop harvest seasons.

Another variation of controlled discharge facultative lagoon is hydrograph-controlled release (HCR) lagoon. HCR lagoons were developed in the southern United States to correlate peak stream flows with lagoon discharge (Crites & Tchobanoglous, 1998). The content of the final cell(s) is retained and discharged to receiving waters when stream flow and the stream's assimilative capacity meet specific criteria. The possibility of obtaining a flow-regulated discharge permit should be discussed with the lagoon's National Pollutant Discharge Elimination System (NPDES) discharge permitting authority before an HCR lagoon is considered, as some state agencies may not allow such permits. Due to the additional complexity of monitoring and discharge, HCR should only be considered in states that provide additional guidance in their standards.

Common Physical Modifications

Common lagoon modifications include adding baffles, curtains, or other engineered barriers to divide lagoons into multiple cells, which can improve hydraulic conditions and distribute the flow more evenly across a lagoon cell. Another option uses floating shade covers to restrict the penetration of light and thus limit algae growth, improving the final effluent quality.[3] Physical modifications can include artificial dividers, like mesh curtains, that split a large single cell into smaller separate cells, or baffles to reduce short-circuiting and increase hydraulic retention time by creating a serpentine flow pattern across the lagoon. Creation of an additional smaller cell before the point of discharge can provide final effluent clarification or an opportunity for tertiary treatment. For these or other physical modifications, state agencies may require notification and/or permission before installation.

BENEFITS AND CHALLENGES

Some benefits and challenges related to facultative lagoons are listed below and discussed further in the following sections.

Benefits

- These systems are easy to operate and maintain.
- Their capital cost is low.
- Designed to operate with gravity flow, they have minimal power requirements.
- They remove pathogens and settleable solids effectively.

[3] Floating shade covers should only be employed in final cells where exceedance of effluent TSS limits is a concern due to algal productivity.

Challenges

- These systems need a large footprint/area.
- Desludging is an infrequent, significant rehabilitation effort which requires dedicated pre-planning and financing.
- They face difficulty in controlling effluent ammonia and phosphorus levels.
- Excessive algal growth can elevate effluent TSS.
- Reduced rates of biological activity impact performance during cold weather.
- These systems are more susceptible to nuisance odor production, especially during fall and spring turnover.
- They can provide a habitat for mosquitoes and similar insect vectors if vegetation in the lagoon and along the berms is not controlled.
- Burrowing animals may be a problem.
- Residing waterfowl can elevate *E. coli* in effluent.



A facultative lagoon designed with multiple cells in series.

DESIGN CRITERIA

Facultative lagoons appear simple but require specialized design considerations. A typical system has a liner (clay or nonpermeable membrane) to control seepage to groundwater, inlet and outlet structures that are sized for correct flows and positioned to prevent short-circuiting, hydraulic controls, floating dividers, and baffles. Many facultative lagoons are large, single-cell systems[4] with the inlet constructed near the center of the cell. This configuration can result in short-circuiting and ineffective use of the design volume of the system. A multiple-cell system with at least three cells in series is recommended, with appropriate inlet and outlet structures sized for correct flows and positioned to prevent short-circuiting and maximize effectiveness of the design volume. Most states have design criteria that specify the areal organic loading (measured in pounds/acre/day or kilograms/hectare/day) and/or the hydraulic retention time. Typical organic loading values range from 13 to 71 pounds/acre/day (15 to 80 kilograms/hectare/day). Typical hydraulic retention times range from 20 to 180 days, depending on the location, but may exceed 200 days in cold climates.

Empirical and rational models exist for the design of facultative lagoons (e.g., first-order plug flow, first-order complete mix). An important consideration in selecting a design model is that its basis is understood, proper parameters are selected, and the hydraulic retention and sludge retention characteristics of the system are known. These considerations are critical because short-circuiting in a poorly designed cell can result in actual retention times of 50 percent or less than the design specification.

Non-discharge lagoons account for evaporation as the primary method of dewatering; as such, a non-discharge system needs considerably more surface area in its design than a system with lagoons that discharge. Non-discharge lagoons are also limited to areas with a dry climate that reduce additional water inputs from precipitation.

PERFORMANCE

Facultative lagoons, like all wastewater treatment systems, need to meet the requirements in their NPDES permits when they discharge. Under the NPDES regulations, POTWs are subject to the technology-based effluent limitations established under 40 CFR 133 (secondary treatment regulations), as well as any additional limitations, such as water-quality-based effluent limitations (WQBELs), determined necessary to achieve water quality standards. The secondary treatment regulations provide the minimum treatment standards for all POTWs, including effluent limitations for BOD, TSS, and pH (see the appendix). For facilities eligible under 40 CFR 133.101(g), including those with biological treatment technologies such as waste stabilization ponds, EPA promulgated alternative standards in 40 CFR 133.105, called “treatment equivalent to secondary treatment" standards, which can allow for higher concentrations of BOD and TSS in the effluent provided that the conditions outlined in 133.101(g) are met. Additionally, 40 CFR 133.103(c) allows the NPDES permitting authority to adjust the maximum allowable suspended solids concentration for waste stabilization ponds if the appropriate criteria are met. EPA has published approved alternate, state-specific TSS requirements in 49 FR 37005, September 20, 1984 (these requirements are summarized in Exhibit 5-4 in the *NPDES Permit Writers' Manual*; see U.S. EPA, 2010). While the need for WQBELs is largely dependent on the receiving waterbody and the effluent, common WQBELs in NPDES permits for POTWs include bacteria and nutrients.

Overall, facultative lagoon systems are simple to operate but provide limited removal performance in colder months, particularly for ammonia nitrogen. Five-day biochemical oxygen demand (BOD_5) removal can range up to 85 percent, and effluent BOD_5 of 30 milligrams per liter (mg/L) or less can

[4] Single-cell lagoons are no longer permitted by current design standards and are gradually being replaced by multiple-cell systems (Great Lakes–Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers, 2014).

usually be achieved in a properly designed lagoon. However, effluent TSS may range from 30 mg/L to more than 150 mg/L, depending on the algal concentrations during warmer months and design of discharge structures.

In addition to technology-based effluent limitations, many lagoon systems will also have permit limitations based on Water Quality Standards and designated uses (see U.S. EPA, 2024a). For example, many lagoons have additional limits for pathogens, ammonia (see U.S. EPA, 2025), and other nutrients during the summer months due to contact recreation in the receiving water body (see U.S. EPA, 2024b), the increased utilization of nutrients for phytoplankton growth, and risk of eutrophication in the receiving waters. Removal of ammonia nitrogen can be inconsistent and vary seasonally depending on temperature, pH, and retention time in the system but can at times be as high as 90 percent in warm weather (U.S. EPA, 2011). However, the high removal rate cannot be sustained over the winter season. Phosphorus removal by precipitation can occur simultaneously if the daily high pH (alkaline) conditions in the lagoon are maintained; phosphorus removal as high as 50 percent can be achieved under ideal conditions (Surampalli et al., 1995). Systems can effectively remove pathogens and coliforms, depending on temperature and retention time.

In cold climates, low temperatures and ice formation will limit process efficiency during the winter and early spring. Odors may be a problem in the spring and fall during periods of turnover, excessive algal blooms, and unfavorable weather conditions.

OPERATION AND MAINTENANCE

Most facultative lagoons operate by gravity flow. This means they are not maintenance intensive and their power costs are minimal, because pumps and other electrically operated devices may not be required. However, effective long-term performance of a facultative lagoon requires continual maintenance, including sludge buildup monitoring and sludge removal, vegetation maintenance, and general performance monitoring to find early warning signs of issues.

It is important to monitor for sewage sludge buildup, especially around inlet and outlet points, tanks, effluent channel for lagoons using ultraviolet disinfection, and pipes. High BOD and TSS, low dissolved oxygen, or high ammonia in the final cell of a multiple-cell system are signs that there may be excess sludge. A core sampler, sonar, or sewage sludge interface detector can be used to take measurements. Desludging is needed when sludge depth is at or above 25 percent of the lagoon operating depth.

Vegetation management is another ongoing maintenance need. While algae in the aerobic and facultative zones are essential to facultative lagoon performance, excess growth, common in the spring and summer, can result in high effluent TSS and BOD and necessitate extra polishing prior to discharge. Duckweed and other vegetation on the lagoon's surface can be detrimental to system function. Additionally, vegetative growth on the lagoon banks should be managed to discourage insects and other pests like burrowing animals. Excessive bank vegetation can also reduce air movement across the lagoon surface, thus reducing oxygen transfer, and should be maintained below 12 inches. Any earthen structures used as impoundments must be periodically inspected for rodent damage. If left unchecked, rodent damage can cause severe weakening of lagoon embankments.



Municipal wastewater staff measure sludge depth as part of routine maintenance.

Facultative lagoons can experience periods of inadequate performance due to short-circuiting, organic overload, excessive odors, algae overgrowth, inadequate nitrification, and other factors (U.S. EPA, 2024c). EPA has developed a lagoon toolbox and a troubleshooting manual with useful tips and information on addressing operational problems.[5]

COSTS

Construction costs scale significantly based on intended treatment flow, mass loadings, and site-specific water quality requirements of the receiving water the lagoon discharges to. Other variables include cost of the land, excavation, grading, groundwater table depth (e.g., distance between lagoon bottom and top of perched groundwater table), berm construction, flood protection, inlet and outlet structures, and lining for the lagoon. There may be additional costs for disinfection, including chemical costs for chlorination/dechlorination or electrical costs for ultraviolet lights, to ensure adequate disinfection of effluent to protect recreational uses in the receiving water.

Communities must budget in advance for operations, maintenance, and periodic upkeep like sludge removal, as well as for unexpected repairs. Proactive maintenance can help ensure high performance and prevent system failures, which can often only be fixed through expensive projects.

[5] These and other relevant resources are available at https://www.epa.gov/lagoons.

REFERENCES

Crites, R., & Tchobanoglous, G. (1998). *Small and decentralized wastewater management systems*. McGraw-Hill.

Erickson, G., Curtin, K., & Duerre, S. (2013). *Stabilization pond systems: Operations, maintenance, management*. Minnesota Pollution Control Agency. https://www.pca.state.mn.us/sites/default/files/wq-wwtp8-22.pdf

Great Lakes–Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers. (2014). *Recommended standards for wastewater facilities*. Health Research, Inc. https://www.health.state.mn.us/communities/environment/water/docs/tenstates/tenstatestan2014.pdf

Surampalli, R. Y., Banerji, S. K., Pycha, C. J., & Lopez, E. R. (1995). Phosphorus removal in ponds. *Water Science and Technology*, 31(12), 331–339.

U.S. EPA. (2025). *Aquatic life criteria—ammonia*. https://www.epa.gov/wqc/aquatic-life-criteria-ammonia

U.S. EPA. (2024a). *Permit limits—TBELs and WQBELs*. https://www.epa.gov/npdes/permit-limits-tbels-and-wqbels

U.S. EPA. (2024b). *Recreational water quality criteria and methods*. https://www.epa.gov/wqc/recreational-water-quality-criteria-and-methods

U.S. EPA. (2024c). *Troubleshooting manual for small, facultative, partial-mix aerated, and complete-mix aerated wastewater lagoons* (EPA-305-B-23-001). https://www.epa.gov/system/files/documents/2024-02/lagoon-troubleshooting-manual.pdf

U.S. EPA. (2022). *The universe of lagoons* (EPA-823-R-22-001). https://www.epa.gov/system/files/documents/2022-06/universe-lagoons-report-2022.pdf

U.S. EPA. (2011). *Principles of design and operations of wastewater treatment pond systems for plant operators, engineers, and managers* (EPA/600/R-11/088). https://www.epa.gov/sites/default/files/2014-09/documents/lagoon-pond-treatment-2011.pdf

U.S. EPA. (2010). *NPDES permit writers' manual* (EPA-833-K-10-001). https://www.epa.gov/sites/default/files/2015-09/documents/pwm_2010.pdf

The mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Environmental Protection Agency.

APPENDIX

Lagoon Secondary Treatment Standards

EPA establishes secondary treatment standards in 40 CFR 133 applicable to POTWs. These technology-based standards set the minimum requirements for municipal wastewater treatment plants. All POTWs need to meet monthly and weekly limitations of 30 mg/L and 45 mg/L, respectively, for five-day biochemical oxygen demand (BOD_5) and TSS, as well as percent removal requirements. However, 40 CFR 133.105 allows for special considerations for facilities that meet the criteria under 133.101(g), including lagoon systems (referred to as waste stabilization ponds in the regulations). The regulations at 40 CFR 133.105 establish alternative minimum treatment standards attainable by eligible facilities, referred to as "equivalent to secondary treatment" standards. The minimum levels of effluent quality attainable by secondary treatment and "treatment equivalent to secondary treatment" described in the regulations are listed in the table below.

	Secondary Treatment Standards			Equivalent to Secondary Treatment Standards		
Parameter	**30-Day Average**	**7-Day Average**	**30-Day Percent Removal**	**30-Day Average**	**7-Day Average**	**30-Day Percent Removal**
BOD_5	≤ 30 mg/L	≤ 45 mg/L	≥ 85%	≤ 45 mg/L	≤ 65 mg/L	≥ 65%
TSS	≤ 30 mg/L	≤ 45 mg/L	≥ 85%	≤ 45 mg/L	≤ 65 mg/L	≥ 65%
pH	6.0 to 9.0			6.0 to 9.0		