United States Environmental Protection Agency

Office of Wastewater Management

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Wastewater Technology Fact Sheet
Aerated, Partial Mix 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 nearly two-thirds are aerated lagoons (U.S. EPA, 2022). The two main types of aerated lagoons are complete mix and partial mix. Partial mix lagoons are commonly used to treat municipal and industrial wastewaters of low to medium strength and are the focus of this fact sheet.

In both types of aerated lagoon, oxygen is supplemented rather than generated solely from algal photosynthesis (see Figure 1). Aeration is provided by either mechanical surface aerators or submerged diffused aeration systems. The submerged systems can include perforated tubing with a variety of diffusers attached. A partial mix system provides only enough aeration to satisfy the oxygen requirements of the system and does not provide energy to keep all total suspended solids (TSS) in suspension. Some solids in partial mix lagoons settle and contribute to overall treatment through anaerobic fermentation. (By contrast, a complete mix system provides enough aeration to keep all solids in suspension.)

While partial mix systems are land intensive, they require much less area than facultative lagoons and can provide a higher level of treatment. Operation and management requirements for all aerated lagoons are more extensive than for facultative lagoons but less extensive than for activated sludge and similar technologies.

For information on facultative lagoons, which do not provide supplemental aeration, see EPA's wastewater technology fact sheet on facultative lagoons: https://www.epa.gov/system/files/documents/2026-08/facultative-lagoons-wastewater-tech-fact-sheet.pdf.



Example of aerated, partial mix lagoon wastewater treatment system.

Partial mix lagoons are generally designed with at least three cells in series. Total retention time depends on water temperature, with warmer water requiring shorter retention times and cooler water requiring longer retention times. In some

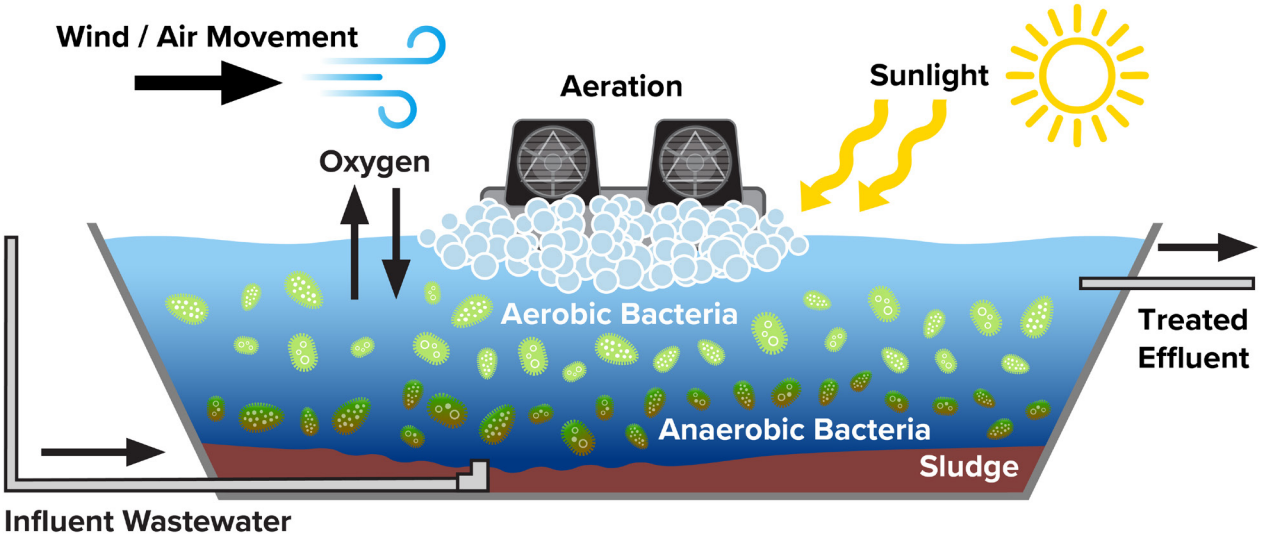


Figure 1. Process components, including floating surface mechanical aerators, in an aerated lagoon. Note that aeration of partial mix lagoons is provided by either floating surface mechanical aerators or a submerged diffused aeration system.

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

cases, the initial cell in a system might be a complete mix unit—due to higher loading of biochemical oxygen demand (BOD) and ammonia—followed by partial mix and settling cells. For equally sized cells, complete mix systems require about 10 times more energy input than partial mix systems. A complete mix lagoon system uses a process similar to the activated sludge process, except it does not include recirculation of mixed liquor. This results in lower mixed liquor suspended solids concentrations, requiring a longer hydraulic retention time (HRT) than activated sludge treatment. However, the HRT required for aerated lagoons is shorter than for facultative lagoons because of the faster treatment process.[2]

Aerated lagoons are constructed with a water depth of up to 20 feet, or 6 meters. There is not a standard difference in depth between partial mix and complete mix lagoons. In most cases, aeration is not applied uniformly over the entire system. Typically, the most intense aeration (up to 50 percent of the total aeration required) is used in the first cell to process the higher BOD influent. The final cell may have little or no aeration, to allow settling to occur. A small separate settling pond may follow the final treatment cell. Typically, aeration equipment is sized to maintain a minimum dissolved oxygen level of 2 milligrams per liter (mg/L) at all times. Diffused aeration systems are generally considered more efficient than surface aerators but also require significantly greater effort to install and maintain than mechanical surface aerators. Surface aeration equipment is subject to possible icing in very cold climates and requires maintenance actions such as water circulation, lagoon heating, or de-icing to ensure proper performance.



Example of a mechanical surface aerator installed at a wastewater lagoon. *Image source: Rural Community Assistance Partnership.*

BENEFITS AND CHALLENGES

Some benefits and challenges related to aerated, partial mix lagoons are listed below and discussed further in the following sections.

Benefits

- These systems need much less land than facultative lagoons to treat the same amount of wastewater because the additional oxygen and mixing yields increased biological activity.
- They can usually discharge throughout the winter because of greater intensity of treatment.
- They need a low frequency of sludge disposal compared to other secondary treatment processes (e.g., mechanical activated sludge process).
- They have shorter HRT than facultative lagoons.
- They treat wastewater more efficiently than facultative lagoon designs.
- They have lower operation and maintenance requirements than mechanical treatment plants.

Challenges

- These systems need reliable electrical input to run aerators, adding to cost of treatment.
- Surface ice formation can cause damage to the surface aerators.
- Reduced rates of biological activity during cold weather affect performance relative to mechanical treatment plants.
- Excessive algal growth can elevate effluent TSS.
- Sludge accumulation rates are higher in cold climates because low temperature inhibits biological activity that breaks down sludge.
- Desludging is an infrequent, significant rehabilitation effort which requires dedicated pre-planning and financing.
- 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.

DESIGN CRITERIA

Partial mix aerated lagoons are commonly designed with multiple cells that can operate in parallel or in series. As the number of mixed aerated cells in series increases, the total volume of all cells required to degrade BOD approaches that of a plug-flow reactor.[3] However, the design of aerated lagoons for BOD removal is based on first-order kinetics and

[2] Aeration provided in aerated lagoons significantly increases the reaction rate of the biological degradation process beyond the rate in facultative lagoons.

[3] A plug flow model assumes liquid enters as a discrete "plug" and does not interact or mix with the rest of the liquid; a plug flow reactor can be imagined as cars traveling in their own lanes on a highway without passing each other. Studies by Middlebrooks et al. (1982) have shown that a plug flow model and first-order kinetics more closely predict the performance of these lagoons when either surface or diffused aeration is used. However, a true plug flow without longitudinal dispersion is unrealistic. Most lagoons evaluated in these studies were lightly loaded and the calculated reaction rates were relatively conservative.

the complete mix hydraulics model. Even though the system is not completely mixed, a partial mix lagoon will result in a conservative design (Metcalf & Eddy, 2003). The lagoon detention time design using a series of complete mix reactors can be found in sources such as *Wastewater Engineering: Treatment and Reuse* (Metcalf & Eddy, 2003), *Small and Decentralized Wastewater Management Systems* (Crites and Tchobanoglous, 1998), and the *Recommended Standards for Wastewater Facilities* (Great Lakes–Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers, 2014).

Many states have design criteria that specify design loading, HRT, and aeration requirements. Lagoon depths range from 6 to 20 feet (1.8 to 6 meters), with 10 feet (3 meters) the most typical (U.S. EPA, 2011). Retention times range from 10 to 30 days, with 20 days the most typical (shorter retention times use higher-intensity aeration).

HRT in the settling basin or portion of a basin used for settling of solids should be limited to two days to minimize algae growth (U.S. EPA, 2011). The design of inlet and outlet structures should receive careful attention. Aerated lagoons can reliably produce an effluent with both BOD and TSS at or below 30 mg/L if provisions for settling are included at the end of the system.

Equipment typically required for aerated lagoons includes lining systems to prevent adverse groundwater impacts, inlet and outlet structures, hydraulic controls, floating dividers and baffles, and aeration equipment. Plastic curtains can be supported by floats and anchored to the bottom to divide existing lagoons into multiple cells and/or serve as baffles to improve hydraulic conditions. Another common practice is to use floating shade covers on the final cell to restrict the penetration of light to limit algae growth, improving the final effluent quality. The service life of an aerated lagoon is estimated to be 30 years or more.

Nitrification of ammonia and BOD removal can occur simultaneously if enough oxygen is provided and the system is designed with an adequate mean cell residence time. The oxygen demand for nitrification is greater than for BOD removal. When BOD and ammonia removal fail to meet discharge standards—especially during summer—there may not be enough dissolved oxygen available for lagoon microorganisms to provide the design-specified treatment. This often occurs in lagoons in cold climates that were originally designed for BOD removal, where performance becomes inadequate once temperatures rise and nitrification begins. It is generally assumed that 1.5 kilograms of oxygen are needed to treat 1 kilogram of BOD, while approximately 5 kilograms of oxygen are needed to convert 1 kilogram of ammonia to nitrate (U.S. EPA, 2011). Therefore, achieving nitrification in heavily loaded systems requires additional pond volume and aeration capacity beyond what is provided for BOD removal alone.



A partial mix aerated lagoon designed with multiple cells in series. *Image source: Rural Community Assistance Partnership.*

Sometimes, an existing facultative lagoon is converted to an aerated lagoon to improve BOD, TSS, and ammonia removal and to treat increased loadings without expanding the lagoon footprint. Floating surface aerators are the most common mechanical aeration system installed to provide aeration and mixing for lagoons, as they do not require dredging the bottom to clear space for diffused air piping. Such systems typically require an electrical source. The existing facultative lagoon must have sufficient depth to install aerators without scouring the pond bottom and liner.

PERFORMANCE

Aerated lagoons, like all wastewater treatment systems, need to meet the requirements in their National Pollutant Discharge Elimination System (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.

Partial mix lagoons can often achieve up to 95 percent BOD removal (U.S. EPA, 2011). Effluent TSS can range from 20 to 60 mg/L, depending on the design of the settling

basin and the concentration of algae in the effluent. Significant nitrification will occur in aerated lagoons during the summer months if adequate dissolved oxygen is applied. Compliance with ammonia effluent limits is a challenge in winter months, especially in cold regions. Phosphorus removal is less effective than in facultative lagoons because of more stable pH and alkalinity levels that limit phosphorus precipitation and uptake by algae. As a result, phosphorus removal of about 15 to 25 percent can be expected (U.S. EPA, 2011). Systems can effectively remove coliforms and fecal coliforms, depending on temperature and retention time. Disinfection is generally necessary if the lagoon's discharge permit includes bacteria limits.

OPERATION AND MAINTENANCE

Depending upon the rate of aeration and the operating environment, aerated lagoons may experience ice formation on the water surface during cold weather periods. Reduced rates of biological activity also occur during cold weather. If properly designed, a system will continue to function and achieve acceptable effluent quality under these conditions. The potential for ice formation on floating aerators may encourage the use of submerged diffused aeration in very cold climates. This approach involves using submerged perforated tubing, which needs routine maintenance and cleaning to maintain design aeration rates. There are numerous types of submerged aeration equipment that can be used in warm or cold climates; these different types should be considered in all designs. In submerged diffused aeration, the routine application of hydrogen chloride gas in the system dissolves accumulated material on the diffuser units.

It is important to monitor sewage sludge buildup, especially around inlet and outlet points, tanks, ultraviolet channels, and pipes. High BOD and TSS, low DO, 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. Excess algae growth can occur in the spring and summer or when mixing or aeration is inadequate, resulting in high effluent TSS and BOD and necessitating 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. If left unchecked, rodent damage can severely weaken lagoon embankments.

Partial mix aerated lagoons can experience periods of inadequate performance due to short-circuiting, organic overload, odors, inadequate nitrification, and other factors (U.S. EPA, 2024). EPA has developed a lagoon toolbox and a troubleshooting manual with useful tips and information on addressing operational problems.[4]



Dewatered lagoon for removal of sludge and sediment accumulation. *Image source: Rural Community Assistance Partnership.*

Typically, operation occurs by gravity flow in and out of the lagoon, but energy would be required if pumps are necessary for either influent or effluent. Energy is required for the aeration devices, with the amount depending on the intensity of mixing desired. Partial mix systems require between 5 and 10 horsepower per million gallons (1 and 2 watts per cubic meter) of capacity, depending on the depth and configuration of the system (Metcalf & Eddy, 2003). If all biomass in the lagoon needs to be completely suspended, at least 30 horsepower per million gallons (6 watts per cubic meter) must be provided (Rich, 2003).

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 groundwater table), berm construction, inlet and outlet structures, and lining for the lagoon.

Operating costs of partial mix lagoons include power for pumps, if needed, and surface or diffused aeration equipment. Maintenance includes servicing the units and periodic replacement of pumps and motors. 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.

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

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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		