United States
Environmental Protection
Agency

Wastewater Technology Fact Sheet

Aerated, Partial Mix Lagoons

DESCRIPTION

Partial mix lagoons are commonly used to treat municipal and industrial wastewaters. This technology has been widely used in the United States for at least 40 years. Aeration is provided by either mechanical surface aerators or submerged diffused aeration systems. The submerged systems can include perforated tubing or piping, with a variety of diffusers attached.

In aerated lagoons, oxygen is supplied mainly through mechanical or diffused aeration rather than by algal photosynthesis. Aerated lagoons typically are classified by the amount of mixing provided. 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.

In some cases, the initial cell in a system might be a complete mix unit followed by partial mix and settling cells. Most energy in complete mix systems is used in the mixing function which requires about 10 times the amount of energy needed for an equally-sized partial mix system to treat municipal wastes. A complete mix wastewater treatment system is similar to the activated sludge treatment process except that it does not include recycling of cellular material, resulting in lower mixed liquor suspended solids concentrations, which requires a longer hydraulic detention time than activated sludge treatment.

Some solids in partial mix lagoons are kept in suspension to contribute to overall treatment. This allows for anaerobic fermentation of the settled sludges. Partial mix lagoons are also called facultative aerated lagoons and are generally designed with at least three cells in series, with total detention time dependent on water temperature. The lagoons are constructed to have a water depth of up to 6 m (20 ft) to ensure maximum oxygen transfer efficiency when using diffused aeration. In most cases, aeration is not applied uniformly over the entire system. Typically, the most intense aeration (up to 50 percent of the total required) is used in the first cell. The final cell may have little or no aeration to allow settling to occur. In some cases, a small separate settling pond is provided after the final cell. Diffused aeration equipment typically provides about 3.7 to 4 kg O_2/kW-hour (6 to 6.5 lbs O_2/hp-hour) and mechanical surface aerators are rated at 1.5 to 2.1 kg O_2/kW-hour (2.5 to 3.5 lbs O_2/hp-hour). Consequently, diffused systems are somewhat more efficient, but also require a significantly greater installation and maintenance effort.

Aerated lagoons can reliably produce an effluent with both biological oxygen demand (BOD) and TSS $\leq$ 30 mg/L if provisions for settling are included at the end of the system. Significant nitrification will occur during the summer months if adequate dissolved oxygen is applied. Many systems designed only for BOD removal fail to meet discharge standards during the summer because of a shortage of dissolved oxygen. Nitrification of ammonia and BOD removal occur simultaneously and systems can become oxygen limited. To achieve nitrification in heavily loaded systems, pond volume and aeration capacity beyond that provided for BOD removal are necessary. Oxygen requirements for nitrification are more demanding than for BOD removal. It is generally assumed that 1.5 kg of oxygen is required to treat 1 kg of BOD. About 5 kg of O_2 are theoretically required to convert 1 kg of ammonia to nitrate.

APPLICABILITY

An aerated lagoon is well suited for municipal and industrial wastewaters of low to medium strength. While such systems are somewhat land intensive,they require much less area than a facultative lagoon and can provide a better level of treatment. Operation and management requirements are also less than those required for activated sludge and similar technologies.

A physical modification to an aerated lagoon uses plastic curtains supported by floats and anchored to the bottom to divide existing lagoons into multiple cells and/or serve as baffles to improve hydraulic conditions. A recently developed approach suspends a row of submerged diffusers from flexible floating booms which move in a cyclic pattern during aeration activity. This serves to treat a larger volume with each aeration line. Effluent is periodically recycled within the system to improve performance. If there is sufficient depth for effective oxygen transfer, aeration is used to upgrade existing facultative ponds and is sometimes used on a seasonal basis during periods of peak wastewater discharge to the lagoon (e.g. seasonal food processing wastes).

ADVANTAGES AND DISADVANTAGES

Advantages and disadvantages of aerated, partial mix lagoons are listed below:

Advantages

Require less land than facultative lagoons.

Require much less land than facultative ponds, depending on the design conditions.

An aerated lagoon can usually discharge throughout the winter while discharge may be prohibited from an ice-covered facultative lagoon in the same climate.

Sludge disposal may be necessary but the quantity will be relatively small compared to other secondary treatment processes.

Disadvantages

Aerated lagoons are not as effective as facultative ponds in removing ammonia nitrogen or phosphorous, unless designed for nitrification.

Diurnal changes in pH and alkalinity that affect removal rates for ammonia nitrogen and phosphorous in facultative ponds do not occur in aerated ponds.

Aerated lagoons may experience surface ice formation.

Reduced rates of biological activity occur during cold weather.

Mosquito and similar insect vectors can be a problem if vegetation on the dikes and berms is not properly maintained.

Sludge accumulation rates will be higher in cold climates because low temperature inhibits anaerobic reactions.

Requires energy input.

DESIGN CRITERIA

Equipment typically required for aerated lagoons includes the following: lining systems, inlet and outlet structures, hydraulic controls, floating dividers and baffles, aeration equipment.

Every system should have at least three cells in series with each cell lined to prevent adverse groundwater impacts. Many states have design criteria which specify design loading, the hydraulic residence time, and the aeration requirements. Pond depths range from 1.8 to 6 m (6 to 20 ft), with 3 m (10 ft) the most typical (the shallow depth systems usually are converted facultative lagoons). Detention times range from 10 to 30 days, with 20 days the most typical (shorter detention times use higher intensity aeration). The design of aerated lagoons for BOD removal is based on first-order kinetics and the complete mix hydraulics model. Even though the system is not completely mixed, a conservative design will result. The model commonly used is:

$$C_e = C_o/[1 + (K_T)(t)/n]^n$$

where:

C_e = effluent BOD

C_o = influent BOD

K_T = temperature dependent rate constant

K_{20} = rate constant at 20 C

$K_{20} = 0.276\ d^{-1}$ at 20 C

= temperature coefficient (1.036)

$K_T = K_{20}\ ^{(T-20)}$

T = temperature of water

t = total detention time in system

n = number of equal sized cells in system

Detention times in the settling basin or portion of a basin used for settling of solids should be limited to two days to limit algae growth. The design of inlet and outlet structures should receive careful attention.

PERFORMANCE

BOD removal can range up to 95 percent. 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. Removal of ammonia nitrogen in aerated lagoons is usually less effective than in facultative lagoons because of shorter detention times. Nitrification of ammonia can occur in aerated lagoons or if the system is specifically designed for that purpose. Phosphorus removal is also less effective than in facultative lagoons because of more stable pH and alkalinity conditions. Phosphorus removals of about 15 to 25 percent can be expected with aerated lagoons. Removal of coliforms and fecal coliforms can be effective, depending on detention time and temperature. Disinfection may be necessary if effluent limits are less than < 200 MPN/100 mL.

The aerated lagoon system is simple to operate and reliable in performance for BOD removal. TSS removal can be influenced by the presence of algae in the lagoon, but generally is acceptable. The service life of a lagoon is estimated at 30 years or more.

OPERATION AND MAINTENANCE

Limitations

Depending upon the rate of aeration and the 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 produce acceptable effluents under these conditions. The potential for ice formation on floating aerators may encourage the use of submerged diffused aeration in very cold climates. The use of submerged perforated tubing for diffused aeration requires maintenance and cleaning on a routine basis to maintain design aeration rates. There are numerous types of submerged aeration equipment that can be used in warm or cold climates, which should be considered in all designs. In submerged diffused aeration, the routine application of HCl gas in the system is used to dissolve accumulated material on the diffuser units.

Any earthen structures used as impoundments must be periodically inspected. If left unchecked, rodent damage can cause severe weakening of lagoon embankments.

Energy

Typically, operation occurs by gravity flow in and out of the lagoon. 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 1 and 2 watts per cubic meter (5 and 10 horsepower per million gallons) of capacity, depending on the depth and configuration of the system.

$$E = 6598\ (HP)^{1.026}$$

where:

E = electrical energy, kWh/yr

HP = aerator horsepower, hp

COSTS

Construction costs associated with partially mixed aerated lagoons include cost of the land, excavation, and inlet and outlet structures. If the soil where the lagoon is constructed is permeable, an additional cost for lining should be expected. Excavation costs vary, depending on whether dirt must be added or removed. Compacting costs run between $3 to $5 per cubic yard; synthetic lining material costs about $0.50 to $1 per square foot.

Operating costs of partially aerated lagoons include power surface or diffused aeration equipment and maintenance of these units.

REFERENCES

Other Related Fact Sheets

Other EPA Fact Sheets can be found at the following web address:

http://www.epa.gov/owm/mtb/mtbfact.htm

1. *Manual of Practice FD-13*, 1988. Aeration, WPDF, ASCE.

2. Middlebrooks, E.J., et al., 1982. *Wastewater Stabilization Lagoon Design, Performance and Upgrading*, McMillan Publishing Co., New York, NY.

3. Reed, S.C., et al., 1995, 2nd ed. *Natural Systems for Waste Management and Treatment*, McGraw Hill Book Co., New York, NY.

4. U.S. EPA, 1983. *Design Manual - Municipal Wastewater Stabilization Ponds*, EPA-625/1-83-015, US IPA CERI, Cincinnati, OH.

5. WPCF, 1990. MOP FD-16, *Natural Systems for Wastewater Treatment*, WPCF, Alexandria, VA.

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