United States
Environmental Protection
Agency

Wastewater Technology Fact Sheet

Facultative Lagoons

DESCRIPTION

Facultative waste stabilization ponds, sometimes referred to as lagoons or ponds, are frequently used to treat municipal and industrial wastewater in the United States. The technology associated with facultative lagoons has been in widespread use in the United States for at least 90 years, with more than 7,000 facultative lagoons in operation today. These earthen lagoons are usually 1.2 to 2.4 m (4 to 8 feet) in depth and are not mechanically mixed or aerated. The layer of water near the surface contains dissolved oxygen due to atmospheric reaeration and algal respiration, a condition that supports aerobic and facultative organisms. The bottom layer of the lagoon includes sludge deposits and supports anaerobic organisms. The intermediate anoxic layer, termed the facultative zone, ranges from aerobic near the top to anaerobic at the bottom. These layers may persist for long periods due to temperature-induced water-density variations. Inversions can occur in the spring and fall when the surface water layer may have a higher density than lower layers due to temperature fluctuations. This higher density water sinks during these unstable periods, creates turbidity, and produces objectionable odors.

The presence of algae in the aerobic and facultative zones is essential to the successful performance of facultative ponds. In sunlight, the algal cells utilize CO_2 from the water and release O_2 produced from photosynthesis. On warm, sunny days, the oxygen concentration in the surface water can exceed saturation levels. Conversely, oxygen levels are decreased at night. In addition, the pH of the near surface water can exceed 10 due to the intense use of CO_2 by algae, 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.

The oxygen, produced by algae and surface reaeration, is used by aerobic and facultative bacteria to stabilize organic material in the upper layer of water. Anaerobic fermentation is the dominant activity in the bottom layer in 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 an ice cover persists on the water surface. As a result, many states in the northern United States and Canada prohibit discharge from facultative lagoons during the winter.

Although the facultative lagoon concept is land intensive, especially in northern climates, it offers a reliable and easy-to-operate process that is attractive to small, rural communities.

Common Modifications

A common operational modification to facultative lagoons is the "controlled discharge" mode, where pond discharge is prohibited during the winter months in cold climates and/or during peak algal growth periods in the summer. In this approach, each cell in the system is isolated, then discharged sequentially. A similar modification, the “hydrograph controlled release” (HCR), retains liquid in the pond until flow volume and conditions in the receiving stream are adequate for discharge.

A recently developed physical modification uses plastic curtains, supported by floats and anchored to the bottom, to divide lagoons into multiple cells and/or to serve as baffles to improve hydraulic conditions. Another recent development uses a floating plastic grid to support the growth of duckweed (*Lemna* sp.) plants on the surface of the final cell(s) in the lagoon system, which restricts the penetration of light and thus reduces algae (with sufficient detention time ≥ 20 days), improving the final effluent quality.

APPLICABILITY

The concept is well suited for rural communities and industries where land costs are not a limiting factor. Facultative lagoons can be used to treat raw, screened, or primary settled municipal wastewater and biodegradable industrial wastewaters.

ADVANTAGES AND DISADVANTAGES

Some advantages and disadvantages of facultative lagoons are listed below:

Advantages

Moderately effective in removing settleable solids, BOD, pathogens, fecal coliform, and ammonia.

Easy to operate.

Require little energy, with systems designed to operate with gravity flow.

The quantity of removed material will be relatively small compared to other secondary treatment processes.

Disadvantages

Settled sludges and inert material require periodic removal.

Difficult to control or predict ammonia levels in effluent.

Sludge accumulation will be higher in cold climates due to reduced microbial activity.

Mosquitos and similar insect vectors can be a problem if emergent vegetation is not controlled.

Requires relatively large areas of land.

Strong odors occur when the aerobic blanket disappears and during spring and fall lagoon turnovers.

Burrowing animals may be a problem.

DESIGN CRITERIA

Waste stabilization pond systems are simplistic in appearance, however, the reactions are as complicated as any other treatment process. Typical equipment used in facultative lagoons includes lining systems to control seepage to groundwater (if needed), inlet and outlet structures, hydraulic controls, floating dividers, and baffles. Many existing facultative lagoons are large, single-cell systems 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 to maximize effectiveness of the design volume. Most states have design criteria that specify the areal organic loading (kg/ha/d or lbs/acre/d) and/or the hydraulic residence time. Typical organic loading values range from 15 to 80 kg/ha/d (13 to 71 lbs/acre/d). Typical detention times range from 20 to 180 days depending on the location. Detention times can approach 200 days in northern climates where discharge restrictions prevail. Effluent biochemical oxygen demand (BOD) ≤ 30 mg/L can usually be achieved, while effluent TSS may range from ≤ 30 mg/L to more than 100 mg/L, depending on the algal concentrations and design of discharge structures.

A number of empirical and rational models exist for the design of simple and series constructed facultative lagoons. These include first-order plug flow, first-order complete mix, and models proposed by Gloyna, Marais, Oswald, and Thirumurthi. None of these has been shown to be clearly superior to the others. All provide a reasonable design as long as the basis for the formula is understood, proper parameters are selected, and the hydraulic detention and sludge retention characteristics of the system are known. This last element is critical because short circuiting in a poorly designed cell can result in detention time of 40 percent or less than the theoretical design value.

PERFORMANCE

Overall, facultative lagoon systems are simple to operate, but only partially reliable in performance. BOD_5 removal can range up to 95 percent. However, the TSS range may exceed 150 mg/L. Removal of ammonia nitrogen can be significant (up to 80 percent), depending on temperature, pH, and detention time in the system. However, the removal cannot be sustained over the winter season. Due to precipitation reactions occurring simultaneously with the daily high pH (alkaline) conditions in the lagoon, approximately 50 percent phosphorus removal can be expected. Removal of pathogens and coliforms can be effective, depending on temperature and detention time.

Limitations

Limitations may include the inability of the process to meet a 30 mg/L limit for TSS due to the presence of algae in the effluent, particularly during warm weather, and not meeting effluent criteria consistently throughout the year. In cold climates, low temperatures and ice formation will limit process efficiency during the winter. Odors may be a problem in the spring and fall during periods of excessive algal blooms and unfavorable weather conditions.

OPERATION AND MAINTENANCE

Most facultative lagoons are designed to operate by gravity flow. The system is not maintenance intensive and power costs are minimal because pumps and other electrically operated devices may not be required. Although some analytical work is essential to ensure proper operation, an extensive sampling and monitoring program is usually not necessary. In addition, earthen structures used as impoundments must be inspected for rodent damage.

COSTS

Cost information for facultative lagoons varies significantly. Construction costs include cost of the land, excavation, grading, berm construction, and inlet and outlet structures. If the soil is permeable, an additional cost for lining the lagoon should be considered.

REFERENCES

Other Related Fact Sheets

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

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

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

2. Pano, A. and Middlebrooks, E.T., 1982. Ammonia Nitrogen Removal in Facultative Wastewater Stabilization Ponds. Water Pollution Control Federation Journal, 54 (4) 344-351.

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

4. Reed, S.C., 1985. *Nitrogen Removal in Wastewater Stabilization Ponds*, Water Pollution Control Federation Journal. 57(1)39-45.

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

6. WPCF, 1990. MOP FD-16, *Natural Systems for Wastewater Treatment*, Water Pollution Control Federation, Alexandria, VA.

ADDITIONAL INFORMATION

Richard H. Bowman, P.E.
West Slope Supervisor
Colorado Department of Public Health and Environment
Water Quality Control Division
222 South 6th Street, Room 232
Grand Junction, CO 81502

Earnest F. Gloyna, P.E.
Consulting Engineer
701 Brazos, Suite 550
Austin, TX 78701

E. Joe Middlebrooks, Ph.D., P.E. DEE
Environmental Engineering Consultant
360 Blackhawk Lane
Lafayette, CO 80026-9392

Gordon F. Pearson
Vice President
International Ecological Systems & Services, IESS
P.O. Box 21240
B-1 Oak Park Plaza
Hilton Head, SC 29925

Sherwood Reed
Principal
Environmental Engineering Consultants (EEC)
50 Butternut Road
Norwich, VT 05055

Leroy C. Reid, Jr., Ph.D
1273 Annapolis Drive
Anchorage, AK 99508-4307

Office of Water
EPA 832-F-02-014
September 2002

For more information contact:

Municipal Technology Branch
U.S. EPA
1200 Pennsylvania Ave., NW
Mail Code 4201M