# LAGOONS AND STABILIZATION PONDS

One of the oldest means of treating wastewater is the wastewater lagoon or stabilization pond. Although the terms are usually interchangeable, the term “lagoon” usually refers to an impoundment that receives raw sewage. A “stabilization pond” is a lagoon that receives primary effluent and acts only as a secondary treatment process. Stabilization ponds can also be used to treat secondary trickling filter effluent. If this is the case, the pond is a tertiary treatment process and is called a “polishing pond”. All of these lagoon systems utilize bacteriological waste stabilization and long detention times to decompose the organic wastes that make up the BOD loading on the process. The long detention times also result in fecal coliform reduction. Ponds and lagoons can be mechanically aerated, but most are not aerated and rely on the natural oxygen transfer from wind and the symbiotic relationship between the bacteria and the algae in pond. Algae are small water plants that grow in the lagoon. They provide much of the dissolved oxygen needed to maintain aerobic conditions and avoid odors caused by anaerobic or septic conditions.

There are several advantages associated with lagoon operations. Lagoons are cheap to build. They do not incorporate a lot of equipment, so maintenance and electrical costs are low. They do not require highly trained operational personnel. They provide treatment that can be equal to some secondary treatment processes and have fewer sludge handling issues. There are also disadvantages to lagoon systems. They take up a lot of land. The effluent quality varies with seasonal temperature changes and may have suspended solids levels that can create regulatory problems. System upsets almost always result in odor problems and recovery times may be weeks or months.

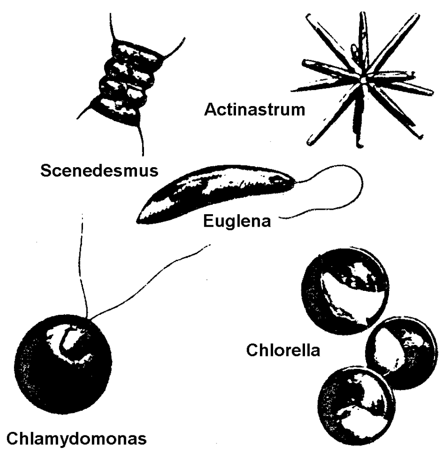
## TYPES OF LAGOONS

Lagoons and stabilization ponds are classified by the type of bacteria that are responsible for the decomposition process. The main difference in most cases is the depth of the pond.

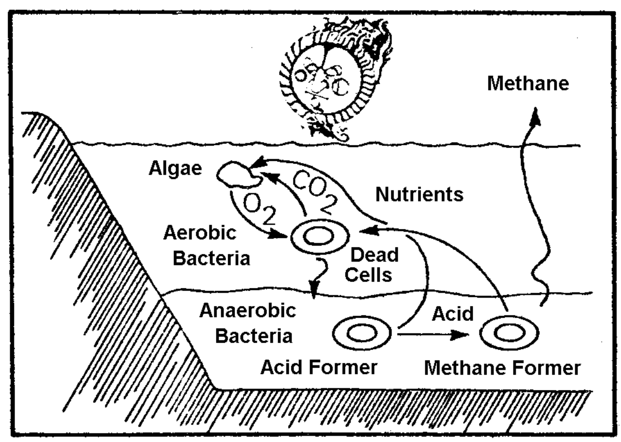
**Anaerobic lagoons** are 10-14 feet deep. They utilize anaerobic bacteria to break down the organic waste. This results in septic conditions in the lagoon and odors associated with septic sewer gases particularly hydrogen sulfide and its rotten egg odor. Most of the decomposition is accomplished by acid forming bacteria. The pH in these lagoons is usually below 6.5. Anaerobic lagoons are sometimes used as sludge impoundments. They are total retention and do not have an effluent discharge. These ponds are normally used to store and treat industrial wastes from food processing or meat packing operations. They are sometimes used as sludge ponds for RV dump sites at recreational facilities.

**Facultative lagoons** are only about 4-7 feet deep. Facultative bacteria are responsible for most of the treatment that occurs in these ponds. They are the most common design for lagoon systems that are used to treat raw wastewater. Suspended solids settle to the bottom of the pond where there is less dissolved oxygen. The facultative bacteria will become anaerobic to digest these solids. Circulation in the pond will eventually bring these bacteria to the surface where high levels of dissolved oxygen exist. When this occurs, the bacteria will become aerobic to stabilize the dissolved organics that are present.

Odors from these types of lagoons are normally not objectionable. As the hydrogen sulfide, generated in the anaerobic zone, rises to the surface the dissolved oxygen present oxidizes it into sulfates that do not cause odors. The algae that grow in the lagoon are critical to the successful stabilization of the organic load. The aerobic decomposition in the upper zone results in the uptake of dissolved oxygen and the release of carbon dioxide ($CO_2$). The algae will take in carbon dioxide ($CO_2$) and, through photosynthesis, use it to create sugars and release dissolved oxygen ($O_2$) that is used by the aerobic bacteria.




Algae Found in Lagoons




Facultative Lagoon Bioactivity

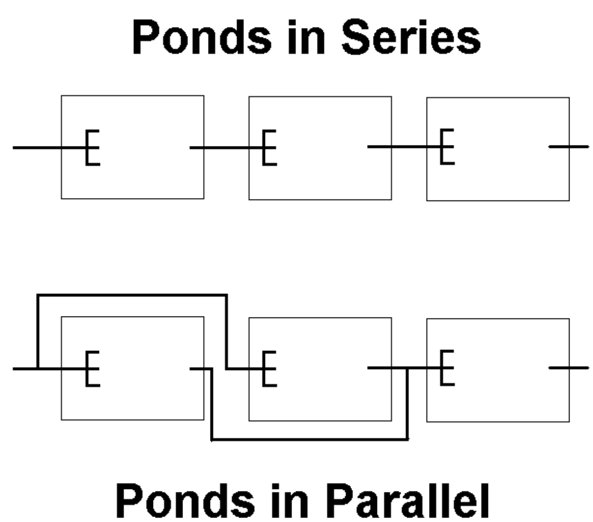
**Aerobic stabilization ponds** or lagoons are very shallow. They are only about 3 feet deep. They are most often the final cells in a multi-staged lagoon system. They are also used as polishing ponds for tertiary treatment of trickling filter plant effluent. Their shallow depth allows sunlight to penetrate to the bottom of the pond to encourage algae growth and aerobic conditions throughout the pond. The low solids loadings found in these tertiary treatment applications means that these ponds normally have no sludge zone. These ponds may be mechanically aerated. Sunlight penetration can also help dechlorinate treated effluents.

## LAGOON SYSTEM DESIGN

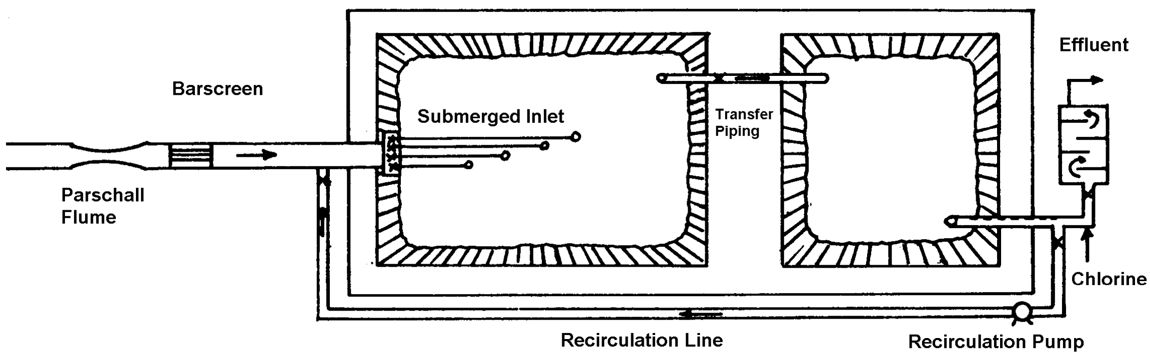
Lagoons can be single pond operations or they can be constructed using several ponds in series. The ponds are rectangular with bermed dikes to contain the wastewater. The dikes must be sloped and crowned to allow runoff from rain the run down the sides evenly. Improper grading of the dike can result in channeling the runoff, which can cause serious erosion problems. Dikes should be planted with native grasses or riprapped with rock to stabilize the soil and help prevent erosion. In areas where ponds are constructed in clay soils there is little groundwater infiltration from the pond. But in other types of soils, water leaking out of the lagoon and into the groundwater supply is a serious issue. Aquifer protection regulations may require sampling wells to monitor the groundwater around the ponds. The main concern is usually nitrate contamination. Ponds built in other types of soils may have to be lined with plastic/rubber liners or have lime and bentonite clay incorporated into the soil to seal the bottom of the pond.

All pond systems should have an influent flow meter and a barscreen for pretreatment. Pond inlets should be designed to spread the flow evenly across the pond. This is done to prevent short-circuiting and make suspended solids distribution more even. If there is no primary treatment, inlet piping to the first stage should extend out into the pond far enough that settled solids will not build up around the edge of the pond where they can create odor problems.

Influent piping is sometimes designed to allow the ponds to be set up in parallel. This type of piping scenario can also be used to create a step feed flow pattern that sends some of the raw flow to the primary cell and the rest of the flow to the secondary cell. The primary effluent would then also flow to the secondary pond. This removes some of the BOD loading from the first cell and distributes it to avoid organic overloading.



The effluent structure should be designed to minimize the amount of algae in the discharge. Algae increase the suspended solids in the effluent. A baffle is placed around the effluent pipe to help keep floating algae out of the effluent stream. Baffling is not very effective during high flow or in the summer when algae concentrations are highest. The SS issue related to algae is one of the biggest drawbacks to lagoon systems. Effluent structures should also be designed to control the water level in the lagoon. The effluent structure has an adjustable weir made of planks placed in a slotted opening. The planks or flash boards can be inserted or removed to change the overflow level and the level in the lagoon. The effluent outfall to the receiving steam should be submerged to minimize foaming problems.



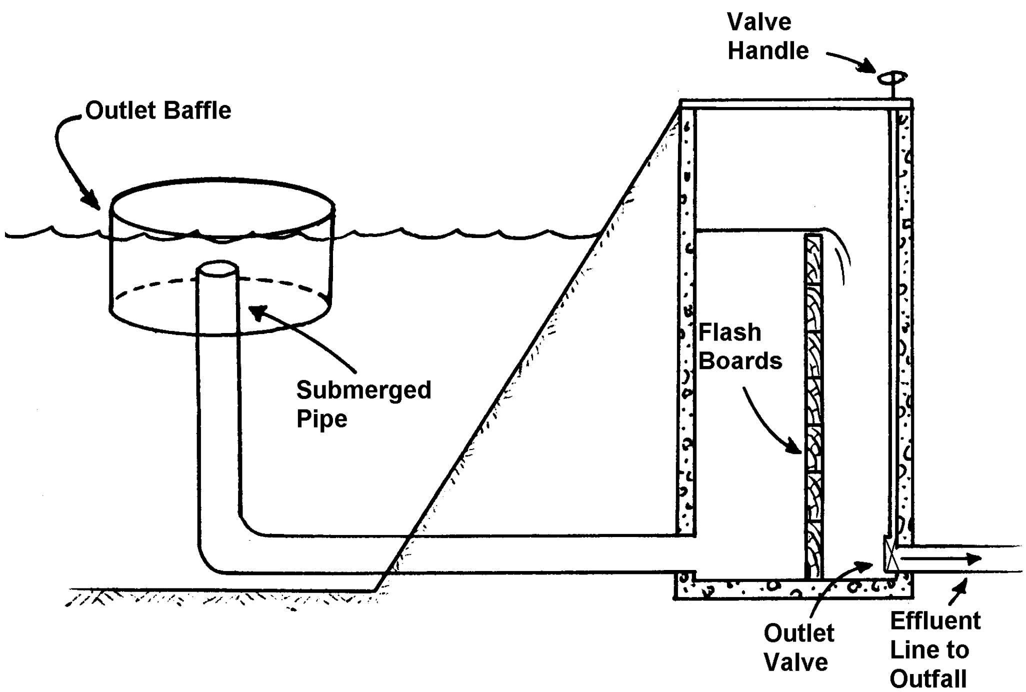

**Two Stage Lagoon System With Recirculation**

Transfer lines carry water from one pond to another. Multiple outlets and inlets are still used to help prevent short-circuiting in each stage. Recirculation is sometimes used in multi-staged lagoon systems. Water from the last cell is pumped back to the inlet of one or more of the upstream cells. The purpose of recirculation is to bring the water with higher algae and DO content up to the front of the process where the BOD loadings are the highest. It also reduces the detention time in each stage. Recirculation also moves the organic load into the secondary cells faster to spread the BOD loading more evenly. The combination of recirculation and step feed capabilities on the influent end provides the maximum amount of operational control available in non-aerated lagoon systems.

## CHANGING THE WATER LEVEL

When the water level in the pond needs to be raised it is a simple matter to add another piece of planking or flash board to the effluent weir slot in the outlet structure. This will raise the level by the thickness of the board. The discharge will effectively stop until the water level in the pond rises to the new overflow height. This will allow the pond to retain flow during the winter months, when bioactivity is down, if the lagoon has adequate capacity. If the pond is empty it should be filled to at least 1 foot deep with clean water, or treated effluent, before raw sewage is added. It will take 5-12 days for the algae population to grow to the point that the lagoon returns to its normal green color. Recirculation pumping can be used to do this in a case where the pond was drained for maintenance.

Lowering the water level is a little trickier. In late fall some systems lower the water level so that they can maximize their winter retention time. The problem with simply removing a board from the weir slot is that the water will leave the pond much too quickly. This can result in drawing sludge off the bottom of the pond, which can result in an upset. Before the board is removed the outlet valve must be throttled to control the discharge. When the downstream half of the outlet box floods to equalize pressures on both sides of the boards, the board can be removed. The outlet valve is then opened until the flow is 150-200% of the daily average. This will allow the pond level to drop gradually without upsetting the bio-system.




**Lagoon Effluent Structure**

## BIOLOGY AND CHEMISTRY OF LAGOONS

Biological activity and organic removal efficiency of a stabilization pond can be impacted by changes in loading, temperature, or pH. Increased organic loading (BOD) can result in anaerobic conditions that will create an upset in the primary cell of a lagoon system. Organic overload can also be caused by a reduction in the bioactivity in the pond when the temperature drops. This is a problem in the winter. When the water temperature drops to 50°F bioactivity comes to a virtual standstill. Reducing the loading on the primary cell by diverting raw flow to the secondary ponds by step feed or parallel operation can reduce the loading on the primary cell. Increasing recirculation can also help recover from an organic upset.

When sunlight hits the algae in the lagoon, photosynthesis takes place. The algae take in carbon dioxide and give off dissolved oxygen. Carbon dioxide reacts with water to form carbonic acid.

$$\mathbf{CO_2 + H_2O > H_2CO_3}$$

Carbonic acid will lower the pH. As the algae use the carbon dioxide they help buffer the pH of the lagoon. So the bioactivity of the algae will cause a fluctuation of the pH of the lagoon over the course of a day. During the day the pH of the lagoon should slowly rise to about 7.2-7.6.

When the sun goes down, photosynthesis stops. Since there is no uptake of carbon dioxide at night, the pH of the lagoon will slowly drop back to 6.8-7.0. The lowest pH will be just before dawn. If the lagoon is overloaded, the pH will drop below 6.8 because the algae can't use up the carbon dioxide as fast as the bacteria release it. The dissolved oxygen levels will also be at their lowest just before dawn because the algae aren't releasing oxygen at night.

## Loading and Detention Times

Facultative ponds are designed for a BOD loading rate of 20-35 pounds per acre per day. Aerobic polishing ponds are designed for 15-20 pounds/acre/day. Aerated lagoons can handle BOD loading of up to 50 pounds/acre/day. Detention times for facultative lagoons range from 30-60 days. Detention times for aerobic polishing ponds may be as little as 10-20 days. Raising or lowering the lagoon level can change detention times. Facultative lagoon levels should always maintain at least 4 feet of water in the pond. Aerobic lagoon levels should always maintain at least 18 inches of water in the pond. When starting up a lagoon system, the ponds should be filled with at least 12 inches of clean water before adding the wastewater flow to the process.

## Lagoon System Maintenance

Most of the maintenance issues for lagoons are related to groundskeeping. Dikes must be mowed regularly. Aquatic plants and weeds must be removed from the water. Cattails and other aquatic reeds will create stagnant areas along the edge of the pond. Their deep roots can also damage liners and seals. The stagnant water is a breeding ground for mosquitoes and the lack of circulation can result in anaerobic conditions developing that can cause serious odor problems.

Rodents like muskrats and prairie dogs can burrow into the dike and cause structural damage. They should be trapped and removed. Repairs to the dike should be done immediately. Trees and shrubs should be removed from around the lagoon to keep them from blocking the wind and reducing surface oxygen transfer. Mechanical mixers should be checked and lubricated according to manufacturer's instructions. Sludge buildup is another problem in many lagoon systems. The first cell receives most of the suspended solids. When the sludge level increases over time it will reduce the effective water depth and create channeling that can reduce detention times dramatically.

## ODOR CONTROL

Odors in lagoons are usually caused by septic conditions resulting from organic overloading. In late summer blue-green algae blooms can also cause "dead fish" odors in a lagoon. Duckweed is a floating aquatic plant that can block the sunlight, which reduces the activity of the algae and results in lower DO levels. Maintaining good wind action will help control duckweed. The best way to deal with this problem in a multi-stage system is to bring in more dissolved oxygen from the polishing pond at the end to the front cell by recirculation. This will help the overloaded conditions and bring green algae into the cell. Sodium nitrate can be used to help recover from an odor-causing upset. The nitrates ($NO_3$) will provide a source of chemically bound oxygen for the bacteria to use instead of dissolved oxygen. When the bugs use the oxygen from nitrates instead of sulfates there will be less hydrogen sulfide produced and fewer odors.

**Duckweed and the blue-green color are indicators that a lagoon is going to have odor problems.**

## OBSERVATIONS AND OPERATIONAL TESTING

When a lagoon is operating properly, the algae will create a dark green appearance. When things go wrong the color of the lagoon will change. Checking the lagoon on a daily basis is necessary so that corrective measures can be taken quickly. Organic overloads caused by food processing plants and dairy farms will create a pale milky gray color. Blue green algae blooms cause dark blue colors. These begin around the edge of the pond and spread out into the center. Toxic upsets from industrial discharges such as metal plating or chemical production can cause a wide range of very colorful conditions in the lagoon. Septic conditions may result in floating solids rising to the surface. This is usually caused by low pH (below 6.5), low DO and low nitrogen concentrations.

Operational tests for lagoons should include pH, temperature, DO, BOD and TSS for both influent and effluent. It is important to know the influent and the effluent flow because they are not the same. Evaporation and infiltration can result in losses of as much as 1 inch per day during the summer months. This amounts to about 27,000 gallons per acre. If the pond level is being lowered, the effluent flow may be twice the daily influent flow. The influent flow is needed for plant loading and the effluent flow is used to calculate pounds of BOD and TSS to the stream for the monthly discharge monitoring reports (DMR's).

## STUDY QUESTIONS

1. What is the most common type of stabilization pond?

2. Where does the DO come from in a facultative pond?

3. What is the difference between running cells in series or parallel?

4. What happens to bioactivity in during the winter months?

## SAMPLE TEST QUESTIONS

1. The detention time for an aerobic lagoon system should be?

   A. 3-5 days
   B. 10-20 days
   C. 30-60 days
   D. 200-300 days

2. What is the depth of a facultative pond?

   A. 1.5-3 feet
   B. 4-7 feet
   C. 10-14 feet

3. Lagoon levels should be lowered:

   A. During the winter
   B. In late summer and early fall
   C. Each spring
   D. Always keep them the same depth

4. Why does the pH drop at night?

   A. The bugs get tired
   B. There is no photosynthesis at night
   C. BOD loadings are higher at night
   D. There's too much DO at night

5. Floating solids in the primary cell of a facultative lagoon system may mean:

   A. Septic conditions from overloading
   B. The lagoon is operating normally
   C. It is hydraulically under loaded
   D. Poor dike maintenance

6. What can be done to recover from an organic overload on a pond?

   A. Increase recirculation
   B. Run ponds in parallel
   C. Add sodium nitrate
   D. All of the above

7. Cattails in a lagoon are a problem because:

   A. They can damage the liner
   B. They harbor mosquitoes
   C. They create stagnant water, which causes odors
   D. All of the above