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ABSTRACT

This student manual contains the textual material for a unit which focuses on the structural and operationally unique features of aerated lagoons. Topic areas discussed include: (1) characteristics of completely mixed aerated lagoons; (2) facultative aerated lagoons; (3) aerated oxidation ponds; (4) effects of temperature on aerated lagoons; (5) mechanical surface aerators; (6) diffused air aerator; (7) lagoon testing; (8) design considerations; (9) operational considerations; and (10) maintenance. A list of objectives, glossary of key terms, list of references, and student worksheet are included. This unit is heavily dependent upon information presented in the unit on facultative lagoons and the two units should be presented together. If it is necessary to present only aerated lagoons, material from the facultative lagoon unit should be referenced and students encouraged to read it ahead of time. (JN)

Biological Treatment Process Control

Aerated Lagoons

Linn-Benton Community College
Albany, Oregon 1984

BIOLOGICAL TREATMENT PROCESS CONTROL

AERATED LAGOONS

STUDENT MANUAL

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AERATED LAGOONS

Student Manual

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AERATED LAGOONS

Objectives

Upon completion of this unit you should be able to:

1. Describe the general characteristics of an aerated lagoon.
2. List the advantages and disadvantages of aerated lagoons as compared to facultative lagoons.
3. Describe the completely mixed aerated lagoon.
4. State the expected BOD and SS reduction when a completely mixed aerated lagoon is followed by sedimentation.
5. List the advantages and disadvantages of a completely mixed aerated lagoon.
6. Describe the facultative aerated lagoon.
7. State the expected BOD reduction for facultative aerated lagoons.
8. List the advantages and disadvantages of facultative aerated lagoons.
9. Describe the aerated oxidation pond.
10. List the advantages and disadvantages of the aerated oxidation pond.
11. Describe the effects of temperature on aerated lagoons.
12. List and describe the two major types of mechanical aerators.
13. List and describe the three major types of diffused air aeration devices.
14. List and describe the test used on influent, effluent and the ponds themselves.
15. Explain the uses of lagoon profiles.
16. Describe the flow pattern variations that can be used with aerated lagoons.
17. State the major items of concern in maintaining diffusers, air filters, blowers and mechanical aerators.

AERATED LAGOONS

Glossary

Air Manifolds - Large pipes carrying compressed air to the air diffusers.

Diffuser Orifice - The small holes in a diffused aerator device through which the compressed air passes.

D.O. Profiles - A series of D.O. readings taken throughout the width, breadth, and depth of the lagoon to detect oxygen deficient areas.

Microcount - The examination of the number and types of protozoa and filamentous bacteria present in the lagoon floc.

Parallel - Basins aligned in such a way that the flow is split between one or more basins.

Polishing Pond - The last pond in a series which could be used to remove remaining organics and/or serve to trap settleable solids.

Scouring ability - The ability of an aerator to keep all the solids in a basin suspended so that the bottom is scoured clear of solids.

Series - Basins lined up end to end so that the entire flow moves through each basin.

Sludge Inventory - Calculation and accounting for the amount and locations of solids in a treatment system.

Sludge Judge - A core sampler made of a hollow tube that is lowered into the basin and which fills up with liquid and solids in a pattern reflecting the conditions in the basin.

Solids carry over - The occurrence of solids being carried over the effluent weir and thus degrading effluent quality.

AERATED LAGOON TREATMENT

Introduction

Aerated lagoons are somewhere between a facultative lagoon system and an activated sludge treatment system. They are often compared to the conventional extended aeration activated sludge process, except that the treatment unit is an earthen basin. They were developed when overloaded conditions necessitated up-grading existing facultative ponds in order to eliminate odor problems and to increase pond efficiency. This was achieved by the mechanical induction of oxygen into the lagoon waters. This oxygen is supplied by either surface or diffused aeration devices. Because the aerated lagoon does not depend on photosynthetic reactions to provide the necessary oxygen they are built deeper, usually between 5-15 feet. These greater depths mean less surface area and therefore require less land. This makes aerated lagoons more cost efficient and they become more feasible for communities with less land available. The decreased surface area also results in less heat loss to the atmosphere which greatly aids in treatment. With the use of artificial aerators these lagoons are able to handle greater organic loadings; somewhere between 60-200 lbs of BOD/acre/day.

To acquire good treatment from an aerated lagoon system you must have a good balance between wasteload, the microorganisms, D.O., mixing and detention times. Not all the above mentioned parameters are controlled by the operator, but by being aware of what can be done to increase waste treatment the operator is more in charge of the lagoon and can actively strive to increase and maintain lagoon efficiency.

Aerated lagoons have been divided into three different types. These are the completely mixed, the facultative aerated, and the aerated oxidation pond. Each system has its advantages and disadvantages and its own basic concepts of operation.

The fact that an aerated lagoon uses some form of mechanical aeration equipment for oxygen means that there is more maintenance involved than a facultative lagoon. Besides the added equipment it is more costly to operate this type of lagoon due to the energy requirements and maintenance costs. Generally though, aerated lagoons are far more economical than an activated sludge treatment plant.

THEORY OF OPERATIONS

Aerated lagoons were developed to achieve a higher degree of secondary treatment without the high construction costs required for activated sludge plants. The first aerated lagoons were operated as a flow through activated sludge unit without any recycle and followed by large settling ponds. More recently many aerated lagoons have been used in conjunction with settling facilities which allow a recycle system of the biological solids. This enables these lagoons to meet stricter secondary treatment standards. Biological interactions in an aerated lagoon follow the same metabolism process as in a facultative lagoon. This type of metabolism is basically aerobic, although some anaerobic and facultative bacterium are sometimes present.

The advantages of aerated lagoons as compared to facultative lagoons are:

1. They require less land because they are deeper.
2. There is a relatively uniform D.O. concentration throughout the basin(s).
3. They aren't dependent upon the sun for photosynthetic reactions to provide the necessary oxygen.
4. They are able to effectively treat greater organic loadings.

Their disadvantages include:

1. Greater energy costs to supplement the required oxygen.
2. Greater maintenance program.
3. They are easily affected by temperature.
4. They generally need a sedimentation unit following the treatment process.

Aerated lagoons are divided into three types. These are the completely mixed aerated lagoon, the facultative aerated lagoon, and the aerated oxidation pond.

1. Completely Mixed Aerated Lagoon

The completely mixed aerated lagoon is a modification of the activated sludge process. It usually is without any form of sludge recycle, although some aerated lagoons are now being designed to return settled solids. All solids are maintained in suspension and all organic stabilization is dependent upon these suspended bacterial solids. The actual biological interactions are strictly aerobic, and follow the same stabilization processes as discussed under facultative lagoons. Oxygen is machine derived and algae is not present. BOD reduction in a properly designed completely mixed aerated lagoon which is provided with a 24 hour aeration time at 20°C is 48-62%. An 85% BOD and SS reduction is possible if these lagoons are followed by a settling pond and terminal rock filter. Similar reduction can be achieved by using two or more completely mixed aerated basins in series mode with a 1-5 day detention time and followed by a settling pond.

The advantages of a completely mixed aerated lagoon are:

1. The effluent BOD concentrations are highly predictable because there are no solids being deposited.
2. The aeration basins can be much smaller in surface area and depth.

The disadvantages include:

1. More temperature sensitive.
2. The aerators must be selected according to scouring abilities which mean high power levels.
3. The effluent SS are high if a settling basin following treatment isn't provided.
4. The BOD concentrations will also be higher due to these solids carry-over if settling isn't provided.

In order to produce the maximum solids degradation it is advisable to place several completely mixed lagoon cells in series followed by a sedimentation pond or basin. This makes it possible to reduce the active microbial mass by two thirds or greater. This mode of operation is of course dependent upon temperature and loading conditions. The settling pond used following the completely mixed lagoon treatment should have a 1-5 day detention time to allow adequate settling prior to effluent discharge.

Settling Ponds

In order for the completely mixed lagoon to meet secondary treatment standards it is necessary to provide some form of settling facility. Although this sometimes is a conventional settling clarifier it is usually in the form of a settling pond or polishing pond. These ponds are designed as large shallow earthen basins for the primary function of allowing SS to settle out prior to discharge. Detention times are important as they must be adequate to allow a certain degree of solids removal. It is also important that they provide a sufficient "settled solids" storage space. Algae must be reduced and odors which may form as a result of the anaerobic decomposition of the settled solids must be controlled. Algae growths can be controlled by shorter detention times and odor problems can be corrected by maintaining a minimum water depth of three feet.

Because the solids entering these ponds are, or should be, entirely stabilized, very little, if any, biological activity occurs. Therefore environmental factors such as D.O. and mixing are not a concern.

2. Facultative Aerated Lagoon

Most aerated lagoons built today are facultative aerated. These lagoons are designed with long detention times (7-20 days). They are provided with enough mixing to maintain the biological treatment of suspended and soluble organics but permit the heavier solids to settle out. The dispersed microbes and soluble organics which are kept in suspension undergo microbial stabilization, form heavy floc particles, and eventually also settle out. These "settled solids" then become part of the anaerobic zone and are further stabilized anaerobically. Oxygen is generally supplied by surface aerators. Diffused air systems can be used as long as a quiescent zone is provided to allow settling. Aeration equipment is usually designed to deliver 1.5 - 2.0 lbs O_2/HP/hr. Oxygen requirements for total oxidation of the wastes is 1.5 lbs O_2/lb BOD added. Algae may be present, especially during the warmer months, but is insignificant to the lagoon process. These algae are lower in concentration due to the artificial aeration and better design. These lagoons can achieve 70-80% BOD reduction when a 4-8 day detention time is provided.

The advantages to facultative aerated lagoons are:

1. The biological stabilization and solids separation happen in the same pond.
2. There is even distribution of solids, due to proper mixing, and this reduces summer anaerobic activity.
3. Less energy is required for aeration and mixing.
4. Effluent is lower in SS and BOD concentrations due to settling of solids prior to discharge.

Disadvantages are:

1. A lack of control over the biological process which is caused by the slow microbial growth.

2. Problems with solids build-up around influent line(s). (This can be reduced by extending inlet lines to introduce the influent wastes near or at the point of aeration to eliminate "dead" mixing zones.)

3. Aerobic activity during winter is decreased which greatly reduces treatment and longer detention times are needed.

4. Sludge removal is essential although the pond is designed large enough that this is hopefully done only occasionally.

5. Methane produced anaerobically in the summer months can cause resuspension of sludge and results in greater oxygen demands.

3. Aerated Oxidation Pond

Aerated oxidation ponds were developed from the need to supplement oxygen to existing overloaded oxidation ponds. This resulted in reducing the overloaded and oxygen deficient conditions. They basically perform like a high rate oxidation pond. Oxygen is added over a great portion of the pond area usually through a diffused air system. The high oxygen concentrations are distributed near the surface of the pond. This insures adequate oxygen throughout the basin but is insufficient to maintain the solids in suspension and an anaerobic layer is formed. Plastic tubing diffusers have been used with good results. These diffusers provide aeration and mixing slowly. This allows more efficient algae growth and better distribution of D.O. This is important since a major portion of the oxygen is supplied by algae especially during the warmer summer months. Normal oxidation ponds are built shallow to allow surface aeration by oxygen penetration from the atmosphere. Because deep aerated oxidation ponds are more efficient these ponds are often deepened as part of the upgrading process.

The advantages of aerated oxidation ponds are:

1. High degree of BOD removal.

2. Inexpensive means of up-grading overloaded conditions as opposed to building another type of treatment facility.

3. The selection of aeration devices are dependent on minimum scouring velocities throughout the basin.

4. Sludge removal is often infrequent.

The disadvantages include:

1. Odor problems may occur if there is a "sludge turnover."

2. Larger basins are required due to the greater surface areas required. Since these basins are already in existence this is usually not a consideration.

THE EFFECTS OF TEMPERATURE ON AERATED LAGOONS

Temperature changes in an aerated lagoon affect the biological mass in the same way it affects a facultative lagoon. Similarly, their long detention times and low biological solids considerations are more easily affected by changes in temperature than the activated sludge process. This is because at a low solids level these microorganisms are more dispersed and their reaction to temperature changes is more pronounced. Stabilization becomes slower as temperatures decrease and longer detention times are needed to achieve adequate treatment. In order to mitigate the effects of cold weather one can modify the operational mode, if there are two or more primary cells. During the warmer months these lagoons are operated in parallel and then put into series as the cold weather begins. This provides longer detention times for primary treatment and condenses the solids to form a less dispersed biological mass This can help conserve heat if it gets cold enough to ice over. The second lagoon of the series mode will usually ice over and temporarily function as an anaerobic lagoon. It is possible with this method of operation to achieve 60-70% BOD removal even during the coldest months. If possible, recycling a portion of the settled solids can be used to help lagoon performance during the cold months. This results in increased solids level in the basin(s) and re-seeds the treatment cell(s) with active microorganisms.

Besides reducing the lagoon's biological activities cold temperatures often result in heavy ice formations. Ice related problems include:

1. Damaging mechanical aerators.

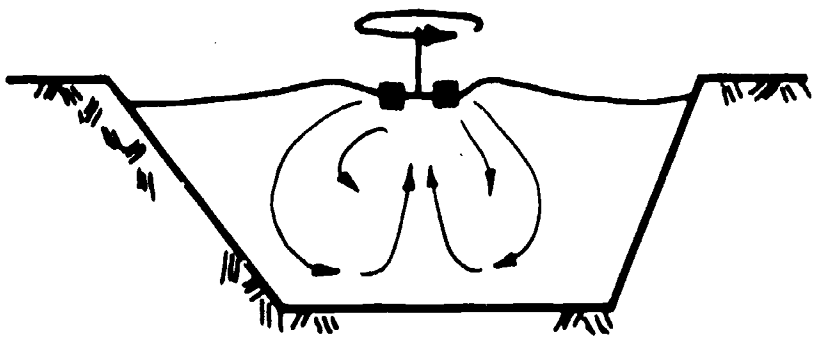
2. Embankment problems caused when heavy ice layers melt. This causes thermal expansions of the ice layers and creates considerable strain on the embankments.

3. Freezing of effluent discharge lines.

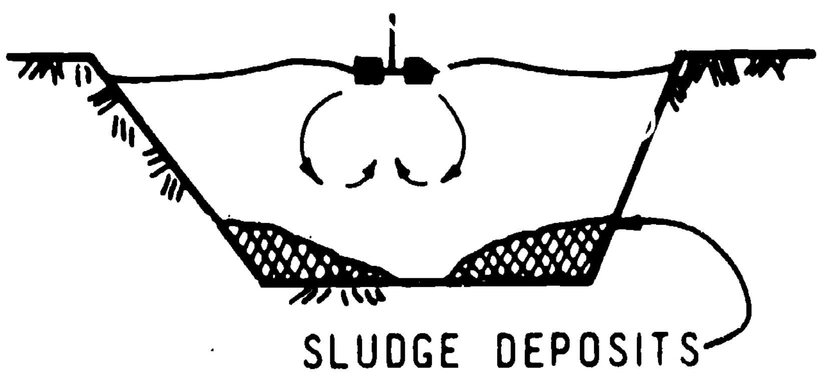
Ice can be beneficial, however, as it forms a cover for lagoons and prevents heat loss by winds, while lagoon contents continue stabilization anaerobically.

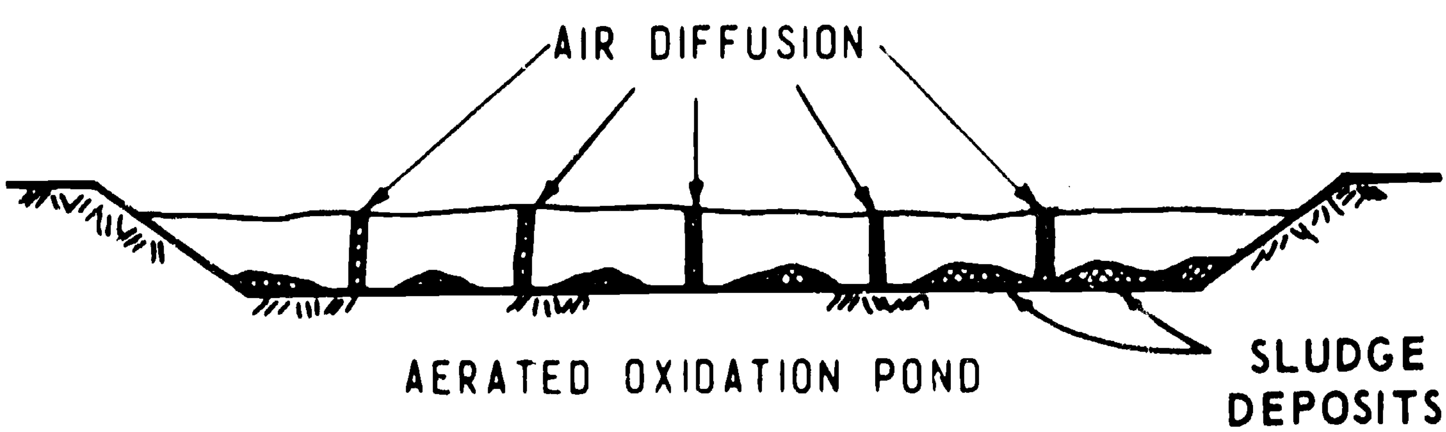
Another major consideration of temperature changes is that it affects the oxygen transfer by both the mechanical aerator and diffused air system, and affects the driving force of oxygen solubility. Careful monitoring and recording of temperature and lagoon D.O. will verify this finding.

COMPLETELY MIXED AERATED LAGOON



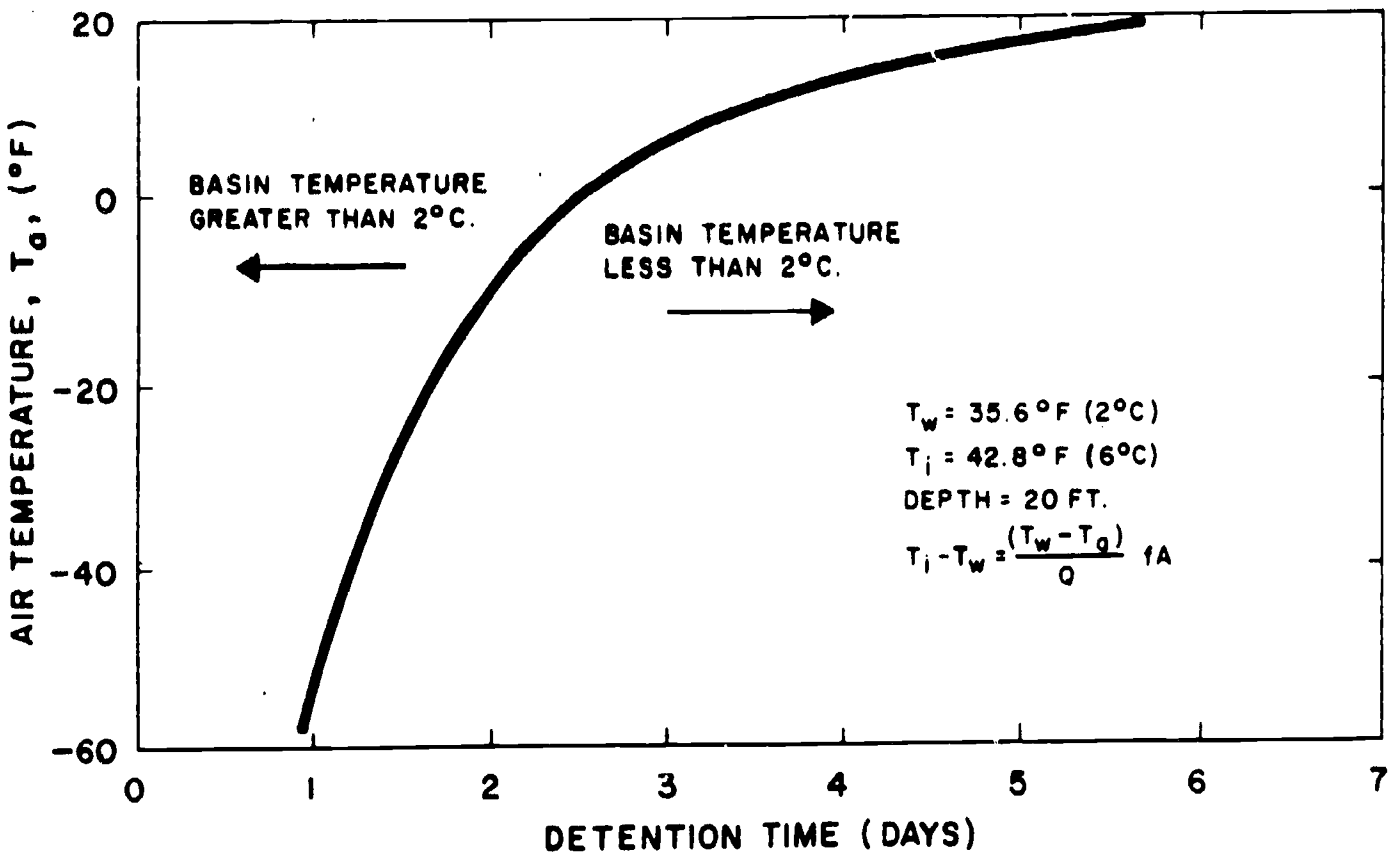
FACULTATIVE AERATED LAGOON





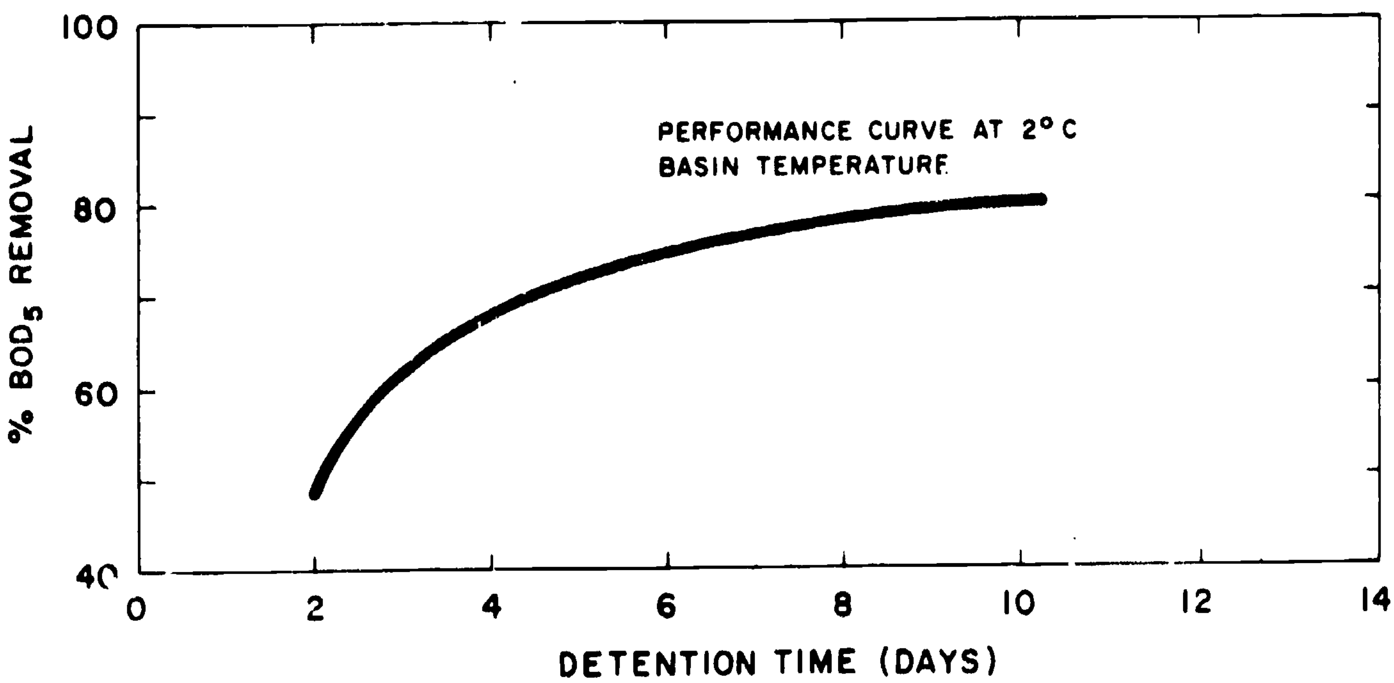
AERATED OXIDATION POND

(a)



20
0
-20
-40
-60
AIR TEMPERATURE, T_a, (°F)
BASIN TEMPERATURE
GREATER THAN 2°C.
BASIN TEMPERATURE
LESS THAN 2°C.
T_w = 35.6°F (2°C)
T_i = 42.8°F (6°C)
DEPTH = 20 FT.
$T_i - T_w = \frac{(T_w - T_a)}{Q} fA$
0
1
2
3
4
5
6
7
DETENTION TIME (DAYS)

(b)



100
80
60
40
% BOD_5 REMOVAL
PERFORMANCE CURVE AT 2°C
BASIN TEMPERATURE
0
2
4
6
8
10
12
14
DETENTION TIME (DAYS)

AERATION DEVICES

In an aerated lagoon it isn't necessary to have scouring velocities and maintain all the solids in suspension, but it is important to provide enough power to acquire a complete mix of the liquid (in completely mixed lagoons) and to maintain a uniform D.O. throughout the lagoon. For lagoons with dilute wastes and long detention times it is common for the horsepower requirements for mixing to exceed the horsepower requirements for aeration. The whole biological process in an aerated lagoon is extremely dependent upon this mixing phenomena and upon the uniform D.O. concentrations. Often surface active agents such as surfactants (i.e., grease and oils) decrease oxygen transfer rates. These surfactants cause a "film" at the water interface which provides a barrier to the diffusion of oxygen across the interface.

Mechanical Surface Aerators

The induction of oxygen into the lagoon waters for supplemented oxygen and for mixing is commonly performed by mechanical surface aerators. Although these aerators come in many kinds and shapes there are some better suited for an aerated lagoon system. It has been found that mechanical aerators deliver 80-90% of the oxygen to the waters and 10-20% is due to surface aeration. They are capable of delivering 1.5 lbs O_2/HP/hour, and are either mounted on stationary columns or on floats. Float mounting gives more flexibility in that the unit can be moved to any desired location, especially important when "dead spot" areas occur. Floating aerators are also advantageous when water levels fluctuate over a wide range and maximum efficiency of the aerator is required. Whether a fixed or floating mount, surface aerators should be moored evenly in order to reduce possibilities of sinking or turnover under adverse weather conditions. There are basically two types of mechanical surface aerators. These are the high speed type - also referred to as a propeller type aerator - and the slow speed or turbine aerator.

High Speed Aerator (Propeller)

This type of aerator operates by spraying the liquid into the air and causing oxygen-liquid contact at the water surface. The mixing action is then induced as the air becomes incorporated and dispersed into the liquid causing a high level of surface turbulence. These aerators are smaller and almost always float mounted. They are a direct drive unit; from the motor to the propeller occasional lubing of the motor is required.

Slow Speed Aerator (Turbine)

This aerator operates by creating a hydraulic jump with the air being pulled in behind the blades. These blades then shear the air into tiny bubbles. Often this type can lose oxygen transfer by speeding the blades up and causing an overlap. Slow speed aerators will always have a gear box, which will occasionally need an oil change, and a speed reducer. The paddles on this type are bigger, some as large as 12 feet, and therefore can pump more water more efficiently. They can either be float or platform mounted, but because they are sensitive to depths the pontoons of the float mounted turbine must be kept free of water and therefore may occasionally require pumping of the water inside these pontoons. The disadvantages of this aerator include the power requirements to keep the solids in suspension, and inadequate mixing and aeration may develop due to the hydraulic mixing concepts. That is, the areas near the aerator are aerobic and those further out may be anaerobic. D.O. profiles of the lagoon waters are an important tool to gauge against any "unmixed" or dead spots and corrective action should be taken if poor aeration and mixing is found.

Problems in Cold Temperatures

When the basin contents fall to temperatures of $0^{o}C$ with a heat robbing wind present, surface aerators can and do ice up. Ice build-up on the impeller shaft and supporting surface mechanism causes mechanical freeze-ups and tops the mechanism. To prevent this from happening, it is important to minimize the exposed surface areas by covering any possible parts, perhaps with a heavy tarp or plastic covering. Using plenty of lubricant (according to manufacturer's instructions) will also aid in reducing frozen parts. Excessive ice build-ups can also cause float mounted aerators to tip over and/or sink. Remove ice and/or snow manually if necessary.

Diffused Aerators

Diffused aeration systems are generally used for higher loading conditions and for deeper lagoons. This is due to the fact that diffused aeration provides better oxygen transfer. Diffused aeration is preferable to mechanical surface aerators in areas of low temperatures as they are not as affected with ice-related maintenance problems. Although diffused air can either be large or small bubble, most lagoons find large bubble more advantageous as it creates less operational problems. This is important for lagoons as lagoon diffusers are not easily accessible and diffuser maintenance is an involved and sometimes costly procedure.

The advantage of diffused air systems is the greater oxygen transfer rates which means a higher degree of treatment in high loading conditions. The disadvantage is a greater energy requirement which means a bigger cost factor. Often plugging of the diffuser orifice occurs from calcium carbonate. This can be avoided though with periodic applications of HCl (hydrochloric acid) to the air distribution system.

Although there are many individual makes of diffusers, there are basically only two different types; those which use only air and those which use air and water together. Diffusers used most commonly in a lagoon are the air gun (air and water type), plastic tubing (air only) and the bubble tube or air tube (air and water type).

Air Gun

The air gun diffuser is a combination of diffused air and surface aeration. Compressed air is delivered into an inverted siphon in the gun base where a large bubble is formed and then rises inside the gun once a specific discharge pressure is reached. This action pushes the water ahead and it rises to the surface. This type of air system is effective in cold area lagoons, and is good in deeper lagoons since it gives better mixing and aeration.

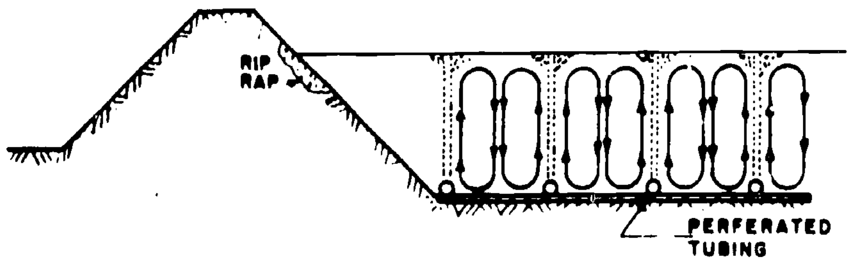
Plastic Tubing

This type of diffused air system consists of polyethylene flexible tubing with machine die-formed slits at specific intervals along the top of the tubing. Diffused air is blown through these tubes from air manifolds which supplies the air with the use of either an air compressor or blower. This type of system gives much broader distribution and is layed out in a grid system at the bottom of the lagoon. Plastic tubing is used primarily to convert existing oxidation ponds to aerated lagoons or in aerated tertiary ponds. The recommended water depth is about 10 feet to obtain the best oxygen transfer. Operating problems with clogging of the tubing from calcium carbonate is sometimes experienced. Periodic applications of HCl is needed to keep them clean. Tests should be made monthly to determine if clogging is a problem. To do this check variation in the air pressure with air volume giving a good idea as to the degree of clogging.

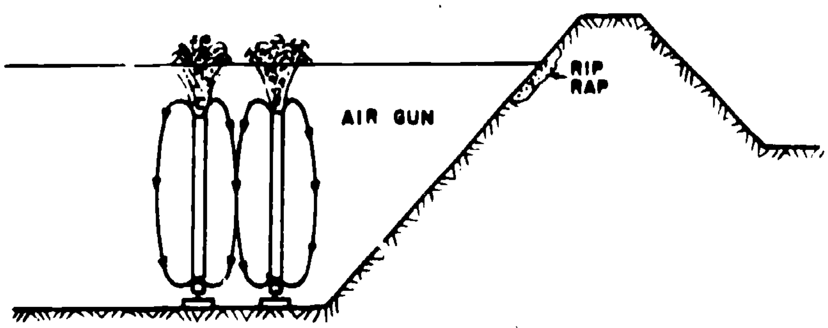
A mercury manometer connected into the air main of each tank is used for measuring the air pressure. By plotting the air pressure readings against the air flows a fairly straight line can be obtained, by which the slope indicates the degree of clogging. A rapid increase in pressure with a relatively small change in air flow indicates clogging. Steps should then be taken to unclog these lines.

Air Tube Diffuser

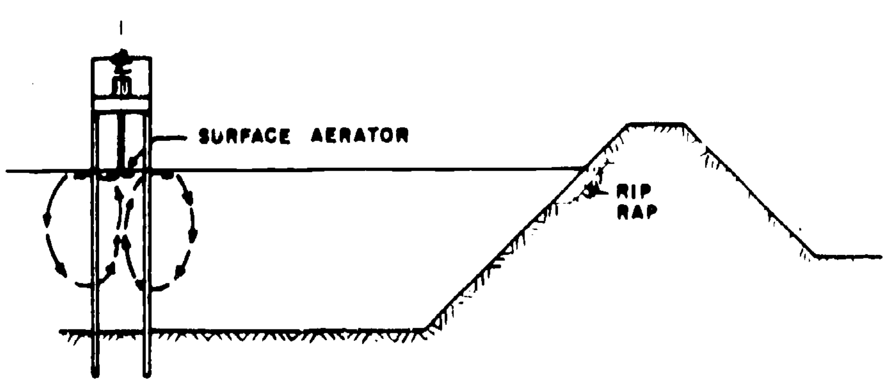
This type of diffuser uses compressed air and some type of internal helix which mixes the discharged air with the water. Air is usually discharged below the tube which can be of varying size and length. This tube ther acts as an air lift pump creating a circulation motion mixing air and water and discharging out the top of the tube. These are usually used in lagoons with depths of 15 feet or greater which insures maximum mixing with minimum air requirements.



A PERFERATED TUBING



B AIR GUN



C SURFACE AERATOR

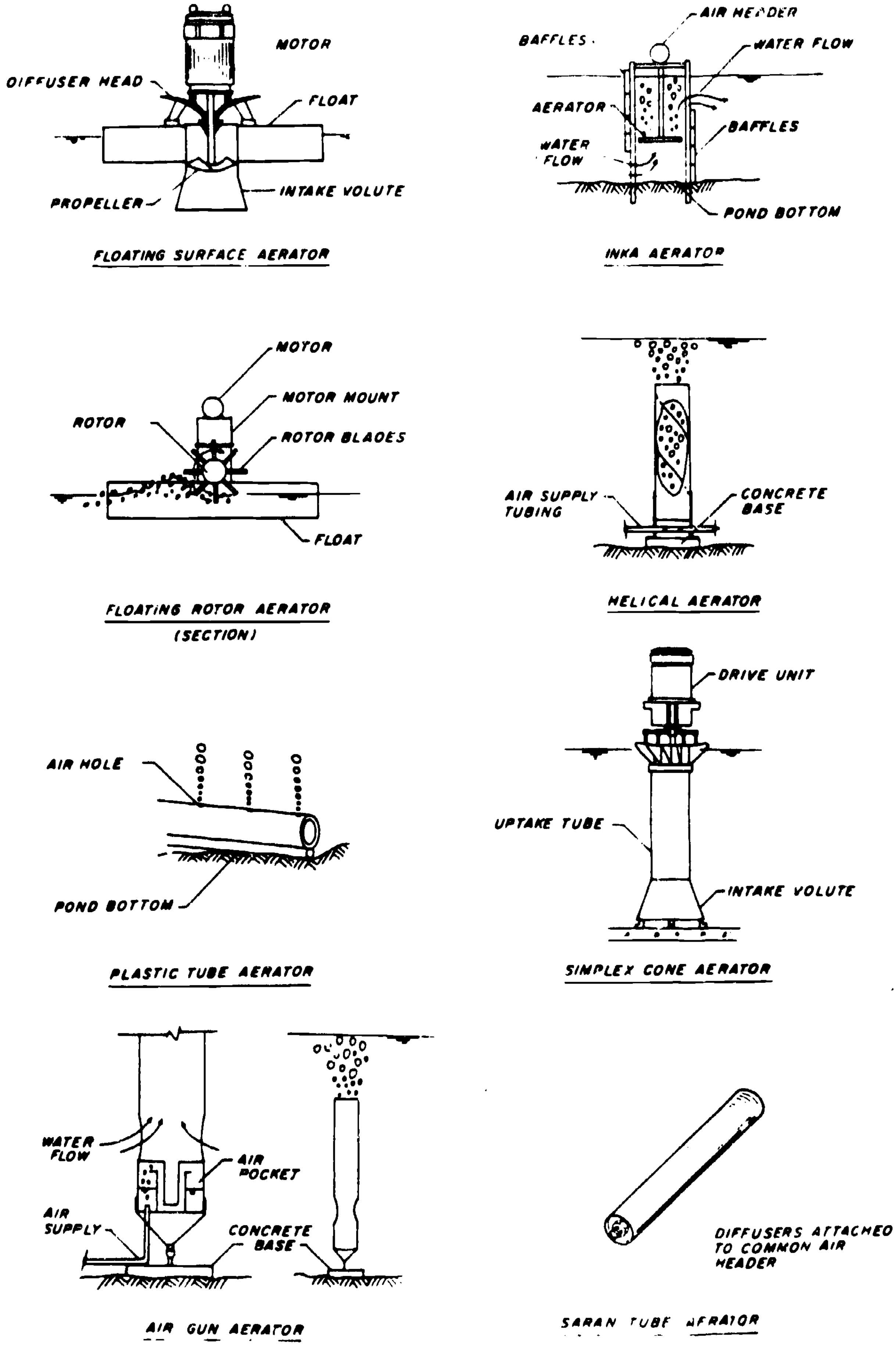


FIGURE 2
SCHEMATIC VIEW OF VARIOUS TYPES OF AERATORS

TYPES OF AERATION EQUIPMENT

Type	Application	Depth at which Commonly used, ft.	Advantages	Disadvantages
Floating mechanical aerator	Aerated Lagoons, facultative ponds.	10 - 15	Good mixing and aeration capabilities; easily removed for maintenance.	Ice problems during freezing weather; ragging problem without clogless impeller.
Rotor aeration unit	Oxidation ditch aerated lagoons.	3 - 10	Probably unaffected by ice; not affecged by sludge deposits.	Possible ragging problem.
Plastic tubing diffuser	Aerated lagoons; facultative lagoons.	3 - 10	Not affected by floating debris or ice; no ragging problem.	Calcium carbonate buildup blocks air diffusion holes; is affected by sludge deposits.
Air guns	Aerated lagoons; deep lagoons; lakes.	12 - 20	Not affected by ice; good mixing.	Calcium carbonate buildup blocks air holes; potential raggin problem affected by sludge deposits.
INKA system	Aerated lagoons; activated sludge reactors.	8 - 15	Not affected by ice; good mixing.	Potential ragging problem.
Helical diffuser	Aerated lagoons.	8 - 15	Not affected by ice; relatively good mixing.	Potential ragging problem; affected by sludge deposits.
Simplex cone	Activated sludge.		Good mixing and aeration capabilities.	
Dissolved air Aeration	Activated sludge reactors of various types.		Good aeration and mixing capabilities.	

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TYPICAL PERFORMANCE DATA FOR DIFFERENT AERATION EQUIPMENT

Type	Value Range	Remarks
Floating surface aerator, lb. O_2/hp/hr	1.8 - 4.5	
Floating rotor aerator, lb. O_2/hp/hr	3.5 - 4.2	Available in various lengths.
Plastic tube aerator		
Transfer rate, lb. O_2/hr/100 ft	0.2 - 0.7	
Air supplied, scfm/100 ft.	1 - 2	Horsepower will depend on system piping configuration
Air gun aerator		
Transfer rate, lb. O_2/hr/unit	0.8 - 1.6	
Air supplied, scfm/unit	3 - 18	
INKA aerator		
Transfer rate, lb. O_2/hr/1000 cu. ft.	10 - 100	log-log relationship
Air supplied, scfm/1000 cu. ft.	20 - 250	
Helical aerator		
Transfer rate, lb. O_2/hr/unit	1.2 - 4.2	
Air supplied, scfm/unit	8 - 30	
Simplex surface aerator		
Transfer rate, lb. O_2/hp/hr	3.0 - 4.2	
Rotation speed, rpm	30 - 45	
Dissolved air aeration		Saran tub diffusers
Transfer rate, lb. O_2/hr/unit	0.3 - 1.0	log-log relationship
Air supplied, scfm/unit	2 - 10	
Rotor aerator		Available in various lengths up to about 18 ft. for use in oxidation ditches
Transfer rate, lb. O_2/hp/hr	3.0 - 5.0	
Transfer rate, lbs. O_2/hr/ft of length	1.0 - 3.0	

LAGOON TESTING

Laboratory testing and record keeping are basically the same for an aerated lagoon as for a facultative system. The types of tests which are beneficial for process control are as follows.

Influent Testing

1. Flow - MGD) to determine lagoon loading in
2. BOD - mg/l) lbs BOD/day
3. pH - sudden changes could be due to industries
4. TSS - used to calculate % removal
5. temp - important when considering treatment efficiency
6. D.O. - could be indicative of septic conditions, possibly the result of an industrial problem. Important to monitor in order to maintain mixing and adequate D.O. for stabilization.

Effluent

1. BOD - state permit required, used for % removal
2. TSS - used for % removal and state permit (NPDES)
3. pH
4. D.O. - low D.O.'s could cause oxygen depletion of receiving waters

Aerated Pond(s)

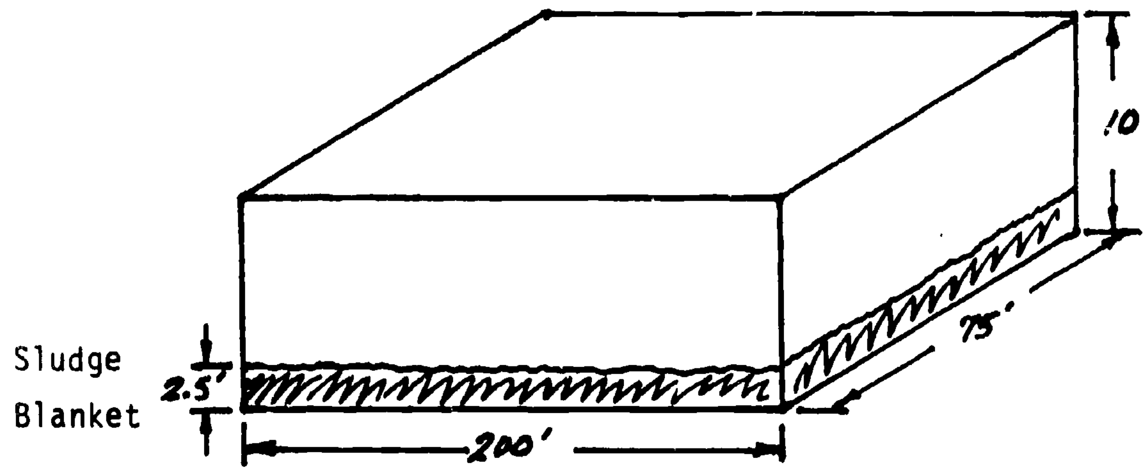
1. TSS - indicative of biological mass which is directly proportional to incoming loading
2. D.O. and temperatures - determine the rate of stabilization
3. Respiration Rate - an important parameter in an aerated lagoon, as a high RR means more D.O. is being consumed and D.O.'s will need to be maintained by increased air supply.
4. microcount - indicates floc condition and may be used to determine why a poor settling sludge is occurring.
5. SSV_{30} - gives a quick determination of sludge settleability which reflects degree of treatment and sludge condition.
6. pH
7. D.O. profiles - important for determining D.O. content and sludge inventory.

D.O. Profiles

Completely Mixed Lagoons - D.O. profiles are useful in this type of lagoon to determine if a complete mix status is being maintained and mixing is adequate, or if "dead" spots have developed. These low D.O. areas can harbor anaerobic activities and create problems with odor and filamentous organisms. The D.O. in a complete mix unit should be uniform throughout the basin. If low D.O.'s are found in spots, an increase in air flow to the lagoon is needed, if possible. Another D.O. profile should then be performed to ascertain that mixing is again being maintained. Generally lagoons have an optimum operating level which achieves the best oxygen transfer and efforts should be made to maintain the lagoon at that level.

Aerated Facultative Lagoons - D.O. profiles are useful in this type of lagoon not only for a check of D.O. content, but can be used to determine the total lbs of sludge accumulated in the anaerobic zone. This is achieved by using the D.O. probe to determine the Depth of Blanket (DOB). One can assume that when zero D.O. is monitored on the D.O. meter the sludge or blanket has been reached. A simple subtraction then tells the operator the total feet of the sludge blanket. Of course the lagoon water total depth must also be known to make this calculation. By performing this sludge D.O. profile in several areas, an average sludge blanket can be reached and an estimated lbs of sludge can be calculated.

Example



Average Depth of Blanket = 2.5 ft

Average Solids Conc. = 3% (30,000 mg/l)

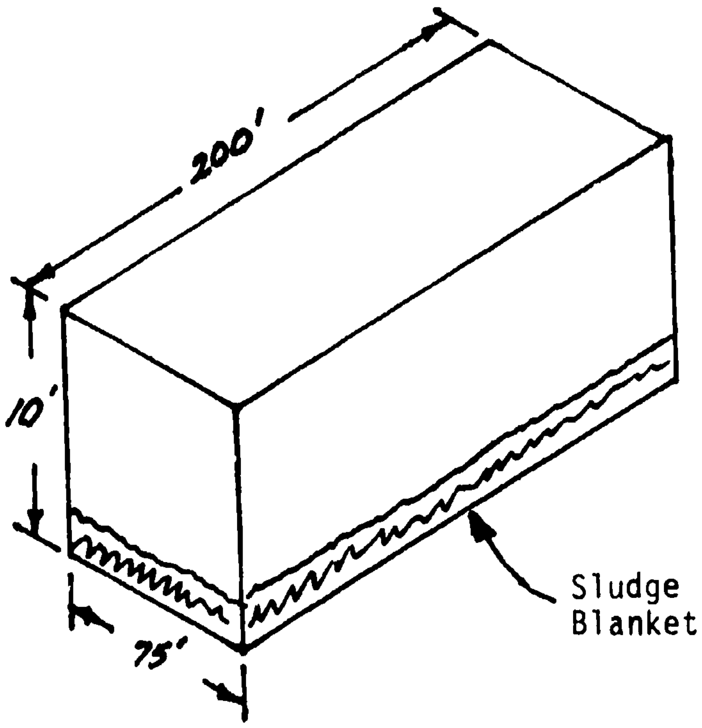
Lagoon Vol = 200' x 10' x 75' x 7.48 gal/ft^3
= 1.122 MG

Sludge Vol = 200' x 2.5' x 75' x 7.48 gal/ft^3
= 0.2805 MG

lbs Sludge = 0.2805 MG x 30,000 mg/l x 8.34
= 70,180 lbs

Another method used to determine sludge depths and sludge inventory in lbs is by the use of a sludge judge. By using a sludge judge a representative lagoon core sample can be retrieved. A clear plastic sludge judge is good because the sludge blanket can be actually seen and measured. By saving the complete core samples from several points a sludge inventory can be calculated. To do this the composite of these core samples needs to be tested for total solids.

Example



Core Sample
Composite TSS = 7550 mg/l

Lagoon TSS = 50 mg/l

Sludge TSS = 7550 - 50

= 5700 mg/l

Vol = 200' x 75' x 10' x 7.48 gal/ft^3

= 1.122 MG

lbs Sludge = 1.122 MG x 7500 x 8.34

= 70180 lbs

If it becomes necessary to remove the accumulated solids this calculation becomes important to estimate the total lbs of sludge. By determining a pumping capacity an estimated time frame for this sludge removal program can also be made. The build-up of accumulated solids in aerated lagoons becomes a special consideration if the blanket becomes too deep. The turbulence of the aerators may then resuspend these settled solids--creating an increased oxygen demand and causing poor effluent quality.

DESIGN CONSIDERATIONS

Aerated lagoons are designed and operated in much the same way as a facultative lagoon system. The differences, however, include:

1. Depths between 5-15 feet, with 10-15 feet an optimum depth in regards to oxygen transfer. In extremely cold climates they are often as deep as 20 feet or greater to control excessive heat loss to atmosphere by reducing the surface area.

2. Their shape is almost always rectangular.

3. Side slope is 3:1 and rip rap is essential to control erosion caused by lagoon water agitation from aeration.

4. Inlets are located at one end and outlets at the opposite end. Inlets should extend out into basin to the first aeration zone in order to minimize any unmixed or "dead" spots. Both inlets and outlets should be 1/5 to 1/3 of the total water depth from the lagoon bottom.

5. Aeration devices are provided to supply necessary oxygen.

6. Algae is not significant to the lagoon process, except for the aerated oxidation pond during the summer months.

7. The biological interactions are basically the same except they are more sensitive to changes in temperatures.

8. Aerated basins may equal 2 acres/MG/day where facultative systems equal 4 acres/MG/day. This is the result of the greater depths of aerated lagoons.

9. Pre-treatment devices are especially important as grit and other inerts will contribute to solids build-up and decrease sludge storage. Rags and other debris can be harmful to mechanical aerators and cause operational problems.

10. Most aerated facultative lagoons are designed to hold a controlled rate of solids build-up for the design of that lagoon. Often sludge removal is necessary.

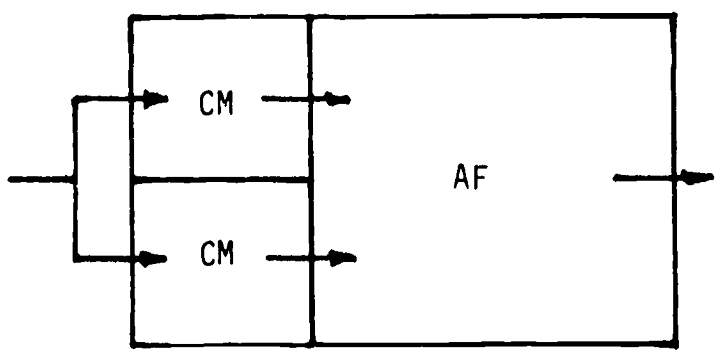
Operational Considerations

Aerated lagoons operate much the same as facultative lagoons. There are usually two or more cells which means a series or parallel mode is possible. Once again series would be used for colder temperatures and longer detention times in the primary stage(s) where parallel would be used for higher loadings and for summer operations when oxygen demand is the greatest. The difference with aerated lagoons is there is often more possibilities if 2 types of aerated lagoons are available. Some possible combinations are as follows:

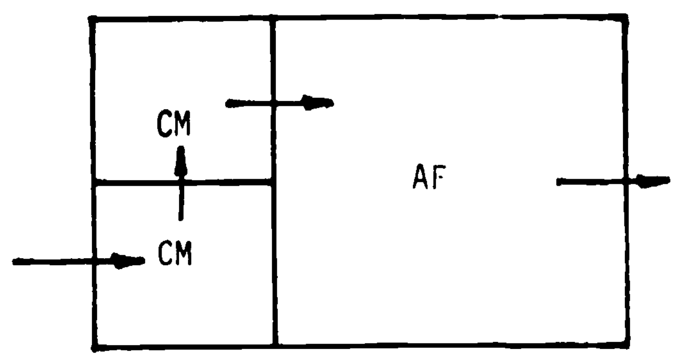
AF = aerated facultative

CM = complete mix

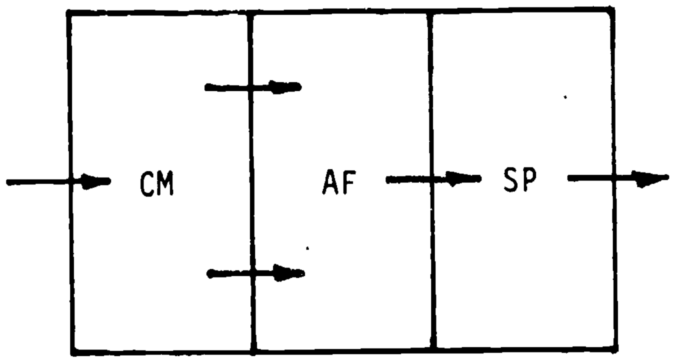
SP = settling pond (facultative lagoon)



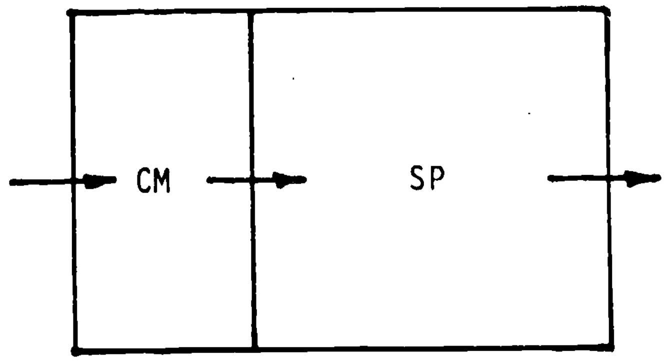
PARALLEL MODE



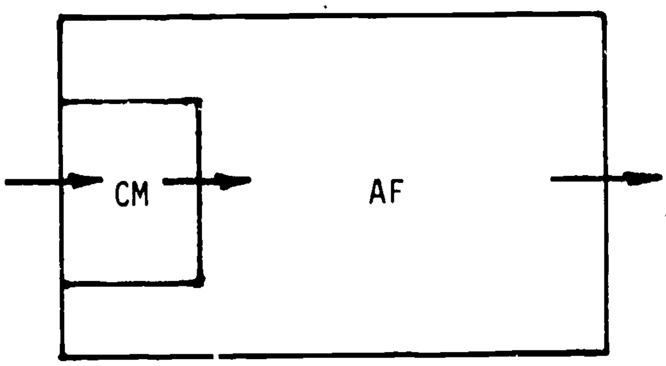
SERIES MODE



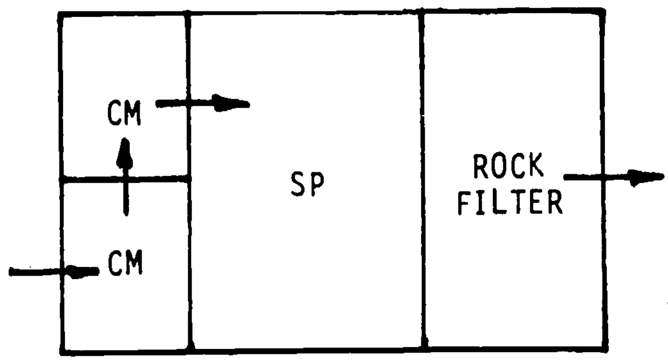
SERIES MODE



SERIES MODE



SERIES MODE



SERIES (or PARALLEL) MODE

Aerated lagoons are usually designed to operate under variable depths to control detention times and to maintain the optimum water level for optimum oxygen transfer. The optimum oxygen transfer rate is dependent upon the type of blower or air compressor used, or upon the type of mechanical aeration device being employed. Once an optimum level has been determined it is important to maintain the lagoon at that depth. A permanent, easily legible staff gauge is helpful and readings should be monitored and recorded daily.

Design Considerations

* Typical Loading Rates

Type of Pond	BODs Loading lbs/acre/day		BODs Conversion (Percent)	
	Average Conditions	Cold	Average Conditions	Cold
Anaerobic	200-500	200	50-85	40
Aerobic	80-120	60	80-95	70
Facultative	25-50	15	80-95	70
Facultative Aerated	40-100	30	80-95	70
Complete Mix Aerated	-	-	80-95	70

*George B. Olte: Design of Stabilization Ponds, Thesis, University of California, Berkeley, 1972.

TYPICAL DESIGN DATA FOR ACTIVATED SLUDGE PROCESSES

Item	Process				
	Complete Mix	Contact Stabilization	Extended Aeration	Aerated Lagoons	Oxidation Ditch
Mean cell residence time, θ_c, 1/day	6 - 12	6 - 12	20 - 30	10 - 30	20 - 30
Feed-to-microorganism ratio, F/M lb BOD/lb MLVSS/day	0.2 - 0.4	(0.2 - 0.6)	0.05 - 0.15	0.05 - 0.2	0.03 - 0.10
Volumetic loading lb BOD/1000 cu. ft./day	50 - 100	30 - 80	10 - 25	60 - 70	10 - 20
Temperature coefficient, θ	1.0 - 1.02	1.0 - 1.02	1.06 - 1.09	1.06 - 1.09	1.06 - 1.09
Mixed liquor suspended solids, MLSS, mg/L	2000 - 5000	1000 - 3000 (4000 - 10000)	3000 - 6000	2000 - 3000	3000 - 8000
Volatile fraction of MLSS	0.7 - 0.9	0.6 - 0.9	0.6 - 0.8	0.6 - 0.8	0.6 - 0.8
Hydraulic detention time, θ_h, hr.	2 - 6	0.3 - 0.5 (3 - 6)	18 - 36	0.5 - 6 (days)	0.5 - 4 (days)
Recycle ration, R/Q	0.25 - 1.0	0.25 - 1.0	0.5 - 1.5	0.25 - 0.75	0.25 - 0.75

TYPICAL DESIGN DATA AND INFORMATION STABILIZATION POND PROCESSES

Item	Process			
	High Rate	Facultative (Algal surface layer)	Facultative (aerated surface)	Anaerobic
Organic loading, lb BOD/acre/day	60 - 120	15 - 60	30 - 100	400 - 800
Power requirements hp/1000 cu. ft.	0.05 - 0.2 (mixing)	None	0.05 - 0.7 (aeration)	None
Detention time, days	4 - 10	7 - 30	7 - 20	20 - 50
Depth, ft.	1 - 1.5	3 - 6	3 - 10	8 - 15
Pond size, acres	10	10	10	2
Number of ponds	2 - 6	2 - 6	2 - 6	2 - 6
Operation	Series/parallel	Series/parallel	Series/parallel	Series/parallel
Pond Configuration				
Shape	Not important	Not important	Not important	Not important
Inlet	Multiple-entry arranged to obtain maximum dispersion of incoming wastewater	Multiple-entry near bottom in center	Multiple-entry near bottom in center	Multiple-entry near bottom in center
Outlet	Multiple or single exit	Multiple-exit designed to reduce algae carryover	Multiple or single exit designed to reduce algae carry-over	Multiple or single exit

MAINTENANCE

The symptoms of improper operation usually are not apparent for some time. Therefore, constant and careful operation and systematic maintenance are required to maintain the efficiency of and prolong the life of the aeration system. Regular testing and accurate and complete records are essential as guides to proper operation and maintenance.

One effective method to insure systematic maintenance is the Simple Automatic Maintenance (SAM) system. This system insures that every piece of equipment is properly maintained on a routine basis. Some examples of a SAM system application are shown on the following pages.

YEAR 1 | YEAR 2 | YEAR 3 | YEAR 4 — TOTAL WORK ORDERS PER YEAR | PRIORITY | SPECIAL FIELD | EQUIPMENT NO

ENVIROTECH

S IMPLE
A UTOMATIC
M AINTENANCE

FREQUENCY: DAILY, WEEKLY, MONTHLY, QUARTERLY, SEMI-ANNUALLY, ANNUALLY

#1 BLOWER
(NAME OF EQUIPMENT)

BLOWER BLDG. LAGOON
(LOCATION)

(IMPLEMENTATION DATE)

EQUIPMENT NO: 270

PREVENTIVE MAINTENANCE SYSTEM

DRIVE UNIT

MAKE RELIANCE MODEL DUTY MASTER
TYPE P
SERIAL NO 9054871ITE
CODE B DESIGN
FRAME SER FACTOR 1.5
HP 500 RPM CYCLES 60
PHASE 3 SEAL NO
BEARING NOS
GREASE None
Chevron O.C/Turbin Oil INSTALLED 8/ /79
VOLTS 2300/4000 AMPS 115/66
OTHER

DRIVEN UNIT

HOFFMAN MODEL 79203A1
TYPE GS-29574
SERIAL NO 0579055
SIZE RPM 3574
GPM /AH
IMPELLER DIA
MATERIAL SEAL NO
BEARING NOS
GREASE None
Mobil D.T.E Medium INSTALLED / /

COUPLING UNIT

MAKE MODEL
TYPE
SERIAL NO
GREASE
OTHER

SCHEDULED PREVENTIVE MAINTENANCE

NO | REF | FREQ | HRS | (DESCRIPTION OF WORK - WEEKS TO BE PERFORMED) | TIME

PLANNED MAINTENANCE

1. WEEKLY CHECK OIL FOR PROPER LEVEL AND DISCOLORATION. IF DISCOLORED FLUSH AND CHANGE OIL
2. EVERY SIX MONTHS CHANGE OIL
3. YEARLY TAKE MEGGER AND AMP. READINGS.

DRIVEN UNIT:

1. WEEKLY INSPECT FOR UNUSUAL NOISE AND VIBERATION, OIL FOR PROPER LEVEL (NOT OVER ½ FULL)
2. WEEKLY CHANGE OUTER AIR FILTERS AND CLEAN USED ONES
3. MONTHLY CHANGE INNER AIR FILTERS AND CLEAN USED ONES
4. EVERY SIX MONTHS CHANGE OIL

COUPLING UNIT: 1. YEARLY CHECK FOR PROPER ALIGNMENT

SPARE PARTS: CARBON RINGS AND BEARINGS

TOTAL WORK ORDER COSTS PER YEAR — YEAR 4 | YEAR 3 | YEAR 2 | YEAR 1 — LOCATION

AL-36

BEST COPY

YEAR 1	YEAR 2	YEAR 3	YEAR 4	PRIORITY	SPECIAL FIELD	EQUIPMENT NO

TOTAL WORK ORDERS PER YEAR

ENVIROTECH

S IMPLE
A UTOMATIC
M AINTENANCE

FREQUENCY
DAILY
WEEKLY
MONTHLY
QUARTERLY
SEMI ANNUALLY
ANNUALLY

AMMONIA PUMP
(NAME OF EQUIPMENT)

BLOWER BLDG. LAGOON
(LOCATION)

(IMPLEMENTATION DATE)

EQUIPMENT NO
269

PREVENTIVE MAINTENANCE SYSTEM

DRIVE UNIT	DRIVEN UNIT	COUPLING UNIT
MAKE RELIANCE MODEL DUTY MASTER	MAKE PENNWALT MODEL 44-126	MAKE MODEL
TYPE GS	TYPE DUAL HEAD METERING PUMP	TYPE
SERIAL NO C48H052M	SERIAL NO A1-25090	SERIAL NO
CODE M DESIGN B	SIZE 3" RPM	GREASE
FRAME SER FACTOR	GPM 3,000 TAH	OTHER
HP ¼ RPM 1725 CYCLES 60	IMPELLER DIA	
PHASE SEAL NO	MATERIAL SEAL NO	
BEARING NOS	BEARING NOS	
GREASE	GREASE	
OIL DATE INSTALLED / /	OIL SHELL 85W90 DATE INSTALLED 8/79	
VOLTS 115/230 AMPS 3.2/2.6		
OTHER		

SCHEDULED PREVENTIVE MAINTENANCE

NO	REF	FREQ	HRS	(DESCRIPTION OF WORK - WEEKS TO BE PERFORMED)	TIME

PLANNED MAINTENANCE

DRIVE UNIT:
1. YEARLY M_EGGER MOTOR AND TAKE AMP READINGS.

DRIVEN UNIT:

1. EVERY SIX MONTHS CHECK BELT FOR WEAR AND PROPER ADJUSTMENT

2. YEARLY CHANGE OIL

TOTAL WORK ORDER COSTS PER YEAR

LOCATION

PLANNED MAINTENANCE SCHEDULE 2ND HALF YEAR

AL-37

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ENVIROTECH

SIMPLE **A**UTOMATIC **M**AINTENANCE

FREQUENCY: DAILY / WEEKLY / MONTHLY / QUARTERLY / SEMI-ANNUALLY / ANNUALLY

ACID PUMP
(NAME OF EQUIPMENT)

BLOWER BLDG. LAGOON
(LOCATION)

(IMPLEMENTATION DATE)

EQUIPMENT NO: 268

PREVENTIVE MAINTENANCE SYSTEM

DRIVE UNIT	DRIVEN UNIT	COUPLING UNIT
MAKE: RELIANCE MODEL: DUTY MASTER	MAKE: PENNWALT MODEL: 44-116	MAKE: MODEL:
TYPE: GS	TYPE: SINGLE HEAD METERING PUMP	TYPE:
SERIAL NO: C48H052M	SERIAL NO: A1-08301	SERIAL NO:
CODE: M DESIGN: B	SIZE: 3" RPM:	GREASE:
FRAME: SER FACTOR: 1.35	GPM: 1500 TAH:	OTHER:
HP: ½ RPM: 1725 CYCLES:	IMPELLER DIA:	
PHASE: 1 SEAL NO:	MATERIAL: SEAL NO:	
BEARING NOS:	BEARING NOS:	
GREASE:	GREASE: NONE	
OIL: DATE INSTALLED: / /	OIL: SHELL 85W 90 DATE INSTALLED: 8/79	
VOLTS: 115/230 AMPS: 5.2/2.6		
OTHER:		

AL-38

SCHEDULED PREVENTIVE MAINTENANCE

NO	REF	FREQ	HRS	(DESCRIPTION OF WORK · WEEKS TO BE PERFORMED)	TIME
				PLANNED MAINTENANCE	
				DRIVE UNIT.	
				1. YEARLY MEGGER MOTOR AND TAKE AMP READINGS	
				DRIVE UNIT:	
				1. EVERY SIX MONTHS CHECK BELT FOR WEAR AND PROPER ADJUSTMENT	
				2. YEARLY CHANGE OIL AND CHECK DIAPHRAMS FOR OIL LEAKAGE.	

TOTAL WORK ORDER COSTS PER YEAR — YEAR 1, YEAR 2, YEAR 3, YEAR 4

LOCATION

DIFFUSER AIR SYSTEMS

Operation and Maintenance

I. Maintain accurate records of the following:

A. Weather conditions - temperature, barometric pressure, humidity, wind & precipitation, evaporation

B. Air filter conditions - operation time period, date & type of servicing, checks on efficiency

C. Blowers - pressures, service time, (some come equipped with running time read in hrs) date and type of servicing, checks on efficiency, air influent and discharge temperatures.

D. Power - consumed by blowers (or air compressors)

E. Quantity of air compressed

F. Quantity of air flow to each basin

G. Air pressures off each air header to the individual basins

H. Visual observations on the air distribution in each basin

I. Permeability and make of diffusers installed

J. Details of all cleaning operations and changes in diffusers

K. Accurate log of operational changes, shut-downs, unusual incidents or incoming waste type

Diffuser Clogging

II. Diffuser clogging is usually a problem for the fine bubble type diffuser. It is for this reason that large bubble type diffusers are preferable in lagoon systems. Diffuser clogging is either "air-side" or "liquor-side", and it appears that "air-side" clogging aggravates "liquor-side" clogging.

A. Air-side clogging results from:

1. Dirt in air from inadequate air filtering

2. Oil in air from internally lubed compressors or improper operation of viscous filter

3. Rust, scale, or debris from corroded air piping or diffuser holders, or from oxidation of organic pipe coating

4. Wastewater solids entering diffuser system through leaks or broken diffusers when air pressure is off

B. Liquor-side clogging results from:

1. Organic solids and fine silt entering porous media when air pressure is off.

2. Oil in wastewater

3. Precipitated deposits (iron salts - industrial wastes, carbonates from hard water)

4. Organic growths

5. Miscellaneous debris lodging in diffusers during construction or when cell is empty

6. Condensation of moisture in diffuser system. This is found in spring and early summer when humidity is high and air temperature is high in relation to wastewater temperature.

AIR FILTERS

I. General operation and maintenance

A. Neglecting air filters may cause serious clogging of diffusers, less air delivery by the blowers, and damage to the filtering equipment.

B. A schedule of necessary maintenance operations should be posted and routinely followed.

C. Keep accurate records of all inspections, maintenance and repairs.

D. Reduce the amount of raw dirt and dust in air by oiling adjacent dusty roads or parking areas. If possible eliminate weeds and cottonwood trees with fluffy seed carriers.

E. If too many units are out of service it is better to reduce air supply rather than risk excessive velocities through overloaded air filters.

II. Types

A. Viscous filters - uses labyrinth of oil-coated surfaces which the air passes through. This type of filter will handle a lot of dust without problems and removes heavy particles. This is good for primary filtering.

B. Dry filters - The medium consists of special paper, cloth or felt. Dust particles are removed by a straining action, and efficiency increases as it is used because the retained particles increase straining characteristics.

C. Electronic filters - gives dust particles an electrostatic charge which causes particles to be removed from the air stream by the attraction to elements of opposite polarity. This type will remove very fine dust and smoke and is good for smoky areas.

D. Bag filters - are lined with loose air-separated asbestos fibers.

III. Air filter maintenance (specific types) -

A. Manual filters

1. Regular maintenance schedule and frequent inspections are important.

2. Look for breaks in dry filtering media, leaks of unfiltered air; unusual blanking caused by freezing vapor, seed fluff or other debris.

3. Remove outside filter (if possible) and spray with high power hose to remove dust and dirt. Completely dry before using again.

B. Automatic filters

1. An indicator device which registers any failure of moving parts is recommended. Without such a device the automatic screens should be inspected every shift.

2. Motor and drive units should have a thorough inspection every three months for proper lubrication.

3. Failure of the cleaning mechanism could result in a fire caused by sparking of over-accumulated dirt. Monitor routinely for safety purposes!

4. When there is a primary filter, seed fluff could cause arcing and result in a fire.

5. Automatic sprinklers are recommended for electronic filters.

6. Failure of movement in the automatic viscous type filter may cause blanking, and oil and sludge may be drawn from the pan into the air stream. The result will be clogging of the diffuser.

7. The correct viscosity of the oil bath is imp tant and therefore keep the oil bath clean.

8. Periodic and thorough manual clearing of automatic electronic filters is necessary. To do this wash down in place with a pressure spray of filter oil.

C. Bag-type filter (with pre-coat filter media)

Maintenance consists of changing the pre-coat filter media when the pressure through the filter reaches the level prescribed by manufacturer's instructions.

BLOWERS

Operation and Maintenance

Blower operations depend on the type of blower system being used. Always refer to the manufacturer for specified maintenance and oil types. Blower maintenance includes:

Motor:

1. Daily inspection of oil levels - fill as necessary
2. Weekly oil check for discoloration - flush and change if necessary
3. Daily check and record all voltage and amperage readings

Blower:

1. Daily check and record any inlet and/or outlet pressure gauges
2. Daily check for unusual noise, vibration, or overheating
3. Check oil levels - fill as needed

MECHANICAL AERATORS

Operation and Maintenance

I. Records

A. Time each aerator is in service (record watt meter)

B. Power consumed by the aerator (record watt meter)

C. Dates and details of all repairs and servicing including lubrication.

D. Log all changes in operation, shut downs and other incidents.

II. Types - flexible due to

A. Variable speed drive

B. Variation of the aerator time cycle

C. Adjustment of the rotor element

D. Variation of the number of units in operation

III. Maintenance

A. Regular maintenance and lubrication according to manufacturer's recommendations.

B. Inspect and check units periodically for general operating conditions.

C. Rotors should be kept clean of debris to insure maximum surface agitation and oxygenation.

D. Variable speed drives should be operated and maintained in strict accordance with supplier's recommendations.

E. Manufacturer's bulletin and instructions should be referred to for specific information relative to the operation of any particular mechanical aerator.

References

1. "Air Diffusion and Sewage Works," Manual of Practice No. 5, Water Pollution Control Federation, Washington, D.C., 1971.

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3. Otte, George B., "Design of Waste Stabilization Ponds," B.S. (University of California, Berkeley), 1972.

4. Champlin, Robert L., "Supplementary Aeration of Lagoons in Rigorous Climate Areas," Water Pollution Control Research Series, Project No. 17050 DVO, 10/71.

5. Yunt, Fred.; Hancuff, Tim; Brenner, Dick; Shell, Gerry; "An Evaluation of Submerged Aeration Equipment - Clean Water Test Results," Texas, 1980.

6. Tchobanoglous, George, "Wastewater Treatment for Small Communities," Prepared for presentation at the Conference on Rural Environmental Engineering, Vermont, 1973.

7. Eddo, Howard, "Design and Operation of Aerated Lagoons for Municipal Treatment in Cold Climates," Design Seminar, Alaska, 1972.

AERATED LAGOONS

Worksheet

1. Aerated lagoons are similar to ______________________ except the activity takes place in earthen basins.

2. Aerated lagoons are usually (deeper or shallower) than facultative lagoons.

3. Aerated lagoons can generally handle (higher or lower) organic loads than facultative lagoons.

4. Aerated lagoons consume more __________ and require more ______________ time.

5. The three types of aerated lagoons are:

   ____

   ____

   ____

6. The _________________ type aerated lagoon provides sufficient aeration to suspend all of the solids but not necessarily enough to keep the entire system aerobic.

7. The ____________________ type aerated lagoon provides sufficient air to maintain the biological activity but allows solids to settle.

8. The ______________________ type aerated lagoon is essentially a high rate oxidation pond with air usually supplied by diffused air aeration.

9. The completely mixed aerated lagoon can be expected to reduce BOD by _______% without sedimentation and ______% with sedimentation.

10. During freezing weather ________ can cause damage to mechanical aerators.

11. Ice can cover lagoons and minimize _______ loss.

12. The two types of mechanical aerators are:

____

____

13. The _____________ type aerator is small, direct drive and sprays liquid into the air.

14. The _____________ type aerator has large blades, gear drive and creates a hydraulic jump to pull air into the liquid.

15. The three types of diffused air aerators are:

____

____

16. Profiles can be used in lagoons to measure _________________ and to estimate the accumulation of ______________________.

17. SAM stands for _____________ ________________ ___________________.

18. Give one advantage and one disadvantage for each type of aerated lagoon:

Type	Advantage	Disadvantage
Completely Mixed		
Facultative Aerated		
Aerated Oxidation Pond		