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SUPPLEMENT TO FEDERAL GUIDELINES: DESIGN, OPERATION, AND MAINTENANCE OF WASTEWATER TREATMENT FACILITIES

WASTEWATER TREATMENT PONDS

MARCH 1974

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Water Program Operations
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OPERATION AND MAINTENANCE OF
WASTEWATER TREATMENT FACILITIES

U.S. ENVIRONMENTAL PROTECTION AGENCY

TECHNICAL BULLETIN

WASTEWATER TREATMENT PONDS

1. PURPOSE:

This Bulletin presents technical information which will be used by Environmental Protection Agency Regional Administrators to review grant applications involving wastewater treatment ponds.

2. RELATED PUBLICATIONS:

This Bulletin supplements the Federal Guidelines: Design, Operation, and Maintenance of Municipal Wastewater Treatment Plants. Additional process design information is contained in EPA Technology Transfer publications entitled "Upgrading Lagoons" (1) and "Upgrading Existing Lagoons" (2), and therefore is not repeated in this Bulletin.

3. TERMINOLOGY:

A wastewater treatment pond is a large, relatively shallow basin designed for long term detention of wastewater which may or may not have received prior treatment. While in the basin the wastewater is biologically treated to reduce biochemical oxygen demand and suspended solids. There are many different types of lagoons and ponds; however, the following terminology is used for the wastewater treatment ponds discussed in this Bulletin

a. Photosynthetic pond - A pond which is designed to rely on photosynthetic oxygenation (i.e. oxygen from algae) for any portion of the oxygen needed for waste treatment. This includes oxidation ponds and facultative lagoons. These ponds may have supplemental aeration by mechanical means. With regard to hydraulic flow, photosynthetic ponds are either of the (1) flow-through type, in which the pond discharges relatively continuously throughout the year; or, (2) controlled-discharge type, in which the pond is designed to retain the

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b. Aerated pond - A pond which is not designed to rely on any photosynthetic oxygenation to provide oxygen needed for biological waste treatment. Air is supplied by mechanical means. Aerated ponds are either (1) complete mix, in which sufficient energy is imparted to the wastewater to prevent deposition of solids in the pond, or, (2) partial-mix, in which only sufficient energy is used to dissolve and mix oxygen in the wastewater. Solid materials settle in the partial-mix pond and are decomposed anaerobically. There will be algae in the partial-mix aerated pond, but usually far fewer than in a photosynthetic pond.

c. Complete retention pond - This type of pond relies on evaporation and percolation exceeding inflow so that there is no discharge of pollutants. This method is acceptable at some locations with suitable climatic conditions and where consistent with water rights. Special attention must be given to protecting ground water and preventing odors.

4. USE OF THE CRITERIA:

Projects involving waste treatment ponds proposed for Federal financial assistance from EPA will be based on the criteria contained in this Technical Bulletin. Approval can be given to different designs if reasonable assurance can be given to the EPA Regional Administrator that satisfactory performance will be achieved.

There is a wide variation in the types of ponds and the wastewaters treated by such ponds, as well as the performance of ponds in different geographical locations. The criteria in this Technical Bulletin are intended to provide a conservative baseline of engineering practice, and must be applied with engineering judgement on a case-by-case basis. The EPA Regional Administrator will review each project to identify and resolve additional factors important to the design of a specific project. Responsibility for satisfactory performance, however, remains with the grant applicant. Additional construction may be necessary if completed facilities are not in compliance with effluent limitations.

It is the policy of EPA to encourage the use of new technology. EPA Regional Administrators will continue to give full consideration to new methods which may not be included in this bulletin.

5. PERFORMANCE REQUIREMENTS:

The Federal Water Pollution Control Act Amendments of 1972 (the Act) established the minimum performance requirements for publicly owned treatment works. In accordance with Section 301(b)(1)(B) of the Act, publicly owned treatment works must meet at least effluent limitations based on secondary treatment as defined by the EPA Administrator. EPA has published information on secondary treatment in 40 CFR Part 133(3). The criteria in this Technical Bulletin are intended to result in wastewater treatment ponds which can achieve effluent limitations based on the secondary treatment information. More stringent performance requirements may be necessary to meet other requirements such as water quality standards. In such cases the criteria contained in this Bulletin will have to be adjusted accordingly.

6. BACKGROUND:

There are more than 4,000 publicly owned ponds in the United States. Generally these ponds are located in small communities and are designed for flows less than 1 MGD. Ponds have been used because operation is simple, operating costs are low, and land is available. The great majority of the existing ponds are the photosynthetic flow-through type.

There is a wide variation in the design of these systems. Organic loadings per acre (both in design practice and actual operation) have increased with time. Comprehensive performance data on these ponds is generally lacking, particularly for the flow-through, photosynthetic type. At the typical facility there has been no test program or, at the most, infrequent grab sampling.

Regarding the ability of flow-through photosynthetic ponds to meet secondary treatment requirements, the limited data indicates that:

a. The BOD level is borderline, but probably could be achieved by conservative design. The BOD level would not be met if the pond continued to discharge while there is prolonged ice cover over the pond.

b. The suspended solids level is generally not achieved because of the algae in the effluent.

c. Fecal coliform levels are not achieved without a positive means of disinfection such as chlorination.

d. The pH of the effluent varies markedly depending on alkalinity/CO_2 relationships. The variation is, however, rarely sufficient to require pH adjustment (4).

Despite these generalizations, it is important to note that there are reports of flow-through ponds which do achieve secondary treatment performance. Satisfactory performance appears to be attributable to either favorable year-round climate as in the Southwestern United States or conservative design (up to 6 cells).

Controlled discharge ponds have been used in the North, where, if properly operated, they can meet the BOD level. They are borderline on the suspended solids, but probably could meet the level with careful operation. Such ponds may not require positive disinfection to meet the fecal coliform levels.

Aerated ponds with suspended solids separation and disinfection, if properly designed, can meet the BOD requirements, but partial-mix units are borderline on suspended solids. Granular media filtration may be needed to assure satisfactory year round performance.

7. FLOW-THROUGH PHOTOSYNTHETIC PONDS:

Regional Administrators will make grants for this type of pond without supplemental treatment only when there is reasonable assurance that the pond will perform satisfactorily.

The determination could be based on satisfactory performance of a similar pond in a comparable environment or on pilot plant performance with conservative scale-up factors. Data from at least one year's operation should be sufficient to show satisfactory performance. Data from shorter periods may not adequately reflect seasonal variations in performance.

When Regional Administrators make such grants, the Facilities Plan should include a discussion of actions to be taken if upgrading is determined to be necessary after the plant is placed in operation.

8. CONTROLLED DISCHARGE PONDS:

The controlled discharge pond is designed to receive and retain wastewaters for six months to one year. At the end of this long-term detention, the contents of the pond are discharged during an interval of one to three weeks. Since experience with this type of pond is presently limited to Northern States with definite climatic seasons, it may be necessary to run pilot studies in States with only slight seasonal climate changes.

Ponds of this type have operated satisfactorily in Michigan using the following design criteria:

Overall organic loading: 20-25 pounds BOD_5/acre.

Liquid depth: not more than 6 feet for the first cell. Not more than 8 feet for subsequent cells.

Hydraulic detention: At least 6 months above the 2 foot liquid level (including precipitation), but not less than the period of ice cover.

Number of cells: At least 3 for reliability, with piping flexibility for parallel or series operation.

The design of the controlled discharge pond must include an anlysis showing that receiving stream water quality standards will be maintained during discharge intervals, and that the receiving watercourses can accomodate the discharge rate from the pond.

Selecting the optimum day and hour for release of the pond contents is critical to the success of this method. The operation and maintenance manual must include instructions on how to correlate pond discharge with effluent and stream quality. The pond contents and stream must be carefully examined, before and during the release of the pond contents. A Statewide program of controlled releases (keyed to tests of BOD_5, dissolve oxygen, and suspended solids, fecal coliform as well as sunlight, weather, and streamflow) has been effective.

In the Michigan program, discharge of effluents follows a consistent pattern for all ponds. The following steps are usually taken:

a. Isolate the cell to be discharged, usually the final one in the series, by valving-off the inlet line from the preceding cell.

b. Arrange to analyze samples for BOD, suspended solids, volatile suspended solids, pH, and other parameters which may be required for a particular location.

c. Plan work so as to spend full time on control of the discharge throughout the period.

d. Sample contents of the cell to be discharged for dissolve oxygen, noting turbidity, color and any unusual conditions.

e. Note conditions in the stream to receive the effluent.

f. Notify the State regulatory agency of results of these observations and plans for discharge and obtain approval.

g. If discharge is approved, commence discharge and continue so long as weather is favorable, dissolved oxygen is near or above saturation values and turbidity is not excessive following the prearranged discharge flow pattern among the cells. Usually this consists of drawing down the last two cells in the series (if there are three or more) to about 18-24 inches after isolation; interrupting the discharge for a week or more to divert raw waste to a cell which has been drawn down and resting the initial cell before its discharge. When this first cell is drawn down to about 24 inches depth, the usual series flow pattern, without discharge, is resumed. During discharge to the receiving waters samples are taken at least three times each day near the discharge pipe for immediate dissolved oxygen analysis. Additional testing may be required for suspended solids.

9. COMPLETE-MIX AERATED PONDS:

This type of pond can be sesigned to meet secondary treatment requirements on a similar basis as an activated sludge process, with or without solids return (5). The criteria in this Bulletin are not applicable to a complete-mix aerated pond.

10. PARTIAL-MIX AERATED PONDS:

The process design can be based on reactor mixing, flow regime, biological kinetics, and oxygen transfer rates. As defined in this Bulletin, the partial-mix aerated pond will not include any allowance for photosynthetic oxygenation.

At least three cells will be provided with aeration in each cell (except designated clarifier cells) so that dissolved oxygen is present throughout the surface layer. It is usually beneficial to recirculate effluent high in dissolved oxygen to the pond influent. The aeration should be tapered so that the final portion of the final cell is a quiescent zone and can function as a clarifier, or a separate clarifier can be provided.

The pond volume will be sized on the basis of low temperature reaction rates, with allowance for sedimentation. Aeration equipment will be sized for the warm weather oxygen uptake rate and for mixing in the pond. Oxygen transfer will include consideration of pond depth, which, for a new pond, typically is 8 feet or greater.

In cold climates, surface aerators will be designed to ensure satisfactory operation during freezing weather, including splash guards, heated housings, and design to keep floating ice away from the aerator.

See EPA Technical Bulletin 430-99-74-001 (6) for aeration unit reliability criteria.

Partial-mix ponds may have high suspended solids on an infrequent basis due to algae. To ensure satisfactory performance, capability should be provided for algae removal. Because of the relatively low amounts of algae a granular dual media filter, along with capability for feeding a polymer filter aid, should be satisfactory.

11. GENERAL REQUIREMENTS:

The following criteria apply to the waste treatment ponds covered in this Bulletin:

a. Positive Disinfection

In the past, pond designs have relied on natural die-off of pathogens. Performance data shows that this method is not sufficiently reliable for a flow-through photosynthetic pond to achieve secondary treatment fecal coliform levels except with recommended loadings and very well managed controlled discharge systems. A positive means of disinfection must be provided except where data from a similar pond in a comparable environment shows satisfactory performance. In that case the grant applicant must agree to install positive disinfection if performance is not achieved following construction.

Chlorination can achieve the required fecal coliform kills; however, if algae are not removed, excessive chlorination can result in algae die-off and increased BOD due to algae cell decay. Echelberger, et al. (7) studied the clorination of algae laden waters and concluded that apparent algae cell lysing following chlorination to a desirable residual level significantly increases the soluble organic concentration in the water. They also concluded that if chlorine is used as the disinfectant, serious consideration should be given to effective algae removal prior to disinfection. Hom (8) presents a laboratory method to optimize the the chlorine residual and reaction time when chlorinating algae laden waters. These considerations would be important where the effluent BOD is close to the permitted value and BOD increase due to algae die-off would result in a permit violation.

The chlorine should be applied to the pond effluent at a concentration and contact time sufficient to achieve effluent limitations. The optimum chlorine residual will be determined when the system is operational. A contact time of 20 minutes at peak hourly flow is recommended.

b. Prevention of Short Circuiting

Multi-cell ponds, operated in series, perform substantially better than single-cell or two-cell ponds. Additional cells reduce short circuiting of untreated wastewaters through the pond. No less than three cells will be provided with the initial cell sized to avoid anaerobic conditions (see the information beginning on Page 54 of Reference 4).

The Missouri Basin Engineering Health Council (4), makes the following recommendations for photosynthetic ponds (there are, however, no performance reports on ponds using this system):

> "The first pond should be designed with a 4 ft. normal depth to give maximum surface area for photosynthesis. The inlet should be designed to give a circular, deeper, sludge storage zone below the bottom of the normal pond. This will allow maximum wind mixing to occur without stirring up the settled solids. The sludge storage section should have a maximum diameter of 100-200 ft. with a center depth of 4 to 6 ft. The raw waste inlet pipe should be located in the center of the sludge storage section so that the raw wastes enter the pond in a radial fashion to distribute the load around the inlet pipe in the same fashion that inlet structures are designed for circular clarifiers except that all of the baffles in the oxidation pond should be submerged. This will permit the heavy solids to remain around the inlet and undergo anaerobic decomposition with a minimum oxygen demand. The outlet from the first cell should have the capacity to change the depth from 3 to 5 ft in 6 inch increments to give operational flexibility as well as a drain for the entire pond. The outlet structure should be designed to minimize fluid velocities at a single point. In small plants a large pipe outlet with adjustable sections is adequate. In large plants an adjustable weir will be required. There should be three sets of baffles concentrically around the effluent structure. The first baffle should be designed to extend around the outlet structure 3-5 ft. with the baffle extending at least 6 inches to one foot above the highest water level and down to within one foot of the bottom of the pond. Thus, the effluent will be drawn from the bottom of the pond. The second concentric baffle rises from the bottom of the pond to within 6 inches of the surface at the lowest possible level. The third concentric baffle is the same as the first,

rising above the maximum surface and dropping to within one foot of the bottom of the pond. These baffles are designed to give an up and over type baffle with a bottom drawoff to minimize removal of algae from the active zone and to allow the algae to congregate at the surface within a quiescent ring that is not affected by wind action. In effect, a stilling basin is created which encourages the algae to accumulate at the light surface and minimizes mixing to interfere with sedimentation."

c. Protection of Ground Water From Pond Seepage

Ponds containing wastewater, if allowed to drain freely to aquifers or bedrock crevices, could cause significant ground water pollution. To prevent ground water degradation, ponds must be designed to minimize seepage losses and will either: (1) have sufficient distance through low permeability soil to ground water to ensure protection of the aquifers, or (2) have all submerged surfaces of the pond sealed so as to ensure protection of the ground water.

In borderlines cases the Regional Administrator may require percolation tests or observation wells and a monitoring plan.

12. SUPPLEMENTAL TREATMENT FOR FLOW-THROUGH PHOTOSYNTHETIC PONDS:

Methods of providing supplemental treatment for flow-through ponds are being researched. Methods included in this Bulletin are those which are reported to have been successful at pilot or plant scale. EPA is aware that other concepts have been proposed and some of these are being tested. The Bulletin will be revised from time to time as information on other successful methods becomes available.

Most techniques for upgrading flow-through ponds involve algae removal. Two comprehensive discussions of algae removal techniques have been prepared (9, 10). In this Bulletin, as in the EPA research program, priority has been given to those methods which retain the operational simplicity features of flow-through ponds.

Supplemental treatment must be designed for the conditions at a specific site. Pilot testing may be required, particularly if there are significant quantities of industrial waste and depending on the size of the facility.

13. SUPPLEMENTAL TREATMENT METHODS:

a. Conversion to Controlled Discharge.

An existing flow-through pond can be converted to a controlled discharge pond if the previously outlined conditions are met. Usually additional land area will be required to obtain the volume required for controlled detention.

b. Intermittant Sand Filtration.

Intermittant sand filters were used in the past for flows up to about 0.25 MGD, but the high cost of labor to clean the filter sand reduced this useage. Application of pond effluents to intermittant sand filters has been successful on a pilot scale. Information to date is limited (11) and designs should be conservative. The upper limit of hydraulic loading for pond effluents should be 0.4 MGD/acre until more information is obtained. Design information is contained in Chapter 12 of Reference 12. When freezing could occur on the filter surface, the pond should be sized to retain the wastewater during freezing weather conditions or there should be an alternative operational plan to ensure effluent limitations are met

In their laboratory and prototype field studies of intermittant sand filtration of pond effluents, Marshall and Middlebrooks (11) found:

(1) Viable algae cells passed the entire depth of all the filter sands studied.

(2) Hydraulic loading rate did not affect the algae or suspended solids removal efficiency at the 0.1,0.2, or 0.3 MGD/acre employed in the laboratory study. The effects of hydraulic loading rate on suspended solids removals in the field studies were inconclusive because of the large quantities of fines washed from the filters, but volatile suspended solids removal did indicate a reduction in removal efficiency as the hydraulic loading rate was increased.

(3) Smaller effective size sands produced better algae or suspended and volatile suspended solids removals. Sand size was not a significant factor in algae removal at applied algae concentrations of 15 and

30 mg/l, but was significant when the concentration was increased to 45-50 mg/l in both the laboratory and field filters. At the 0.5 MGD/acre hydraulic loading rate, monthly mean volatile suspended solids were essentially equal for the 0.17 and 0.72 mm effective size sands. Efficiences fluctuated considerably from one sand to the other during the study period. But in general the 0.17mm effective size sand produced a better quality effluent.

c. Land Treatment of Pond Effluents.

This method of using pond effluents as a water resource has particular application in water short areas where land is readily available. Application rates vary widely depending on method of application, crops involved, and climate. Seasonal application is usually related to crop growth and additional pond capacity may be required for storage during the dormant season. Comprehensive information on land treatment systems is available (13, 14), including many examples where the wastewater has been stored in a pond before land application. Additional design information will be contained in EPA Evaluation Procedures for Land Application Systems (now in preparation). Technical assistance on complex projects is available through EPA Regional Offices, the Office of Water Program Operations, and the Robert S. Kerr Water Research Center, Ada, Oklahoma.

d. Addition of Supplemental Aeration.

A flow-through photosynthetic pond can be upgraded by the installation of diffused or mechanical aerators. For optimum efficiency in oxygen transfer and mixing the pond should be deepened about 5 feet (to about 10 feet liquid depth). Also, additional electrical power will be required to operate the aeration system.

e. Chemical Coagulation.

Coagulation followed by sedimentation, and possibly filtration has been used extensively for the removal of suspended and colloidal material from water. In the case of the chemical treatment of wastewater treatment pond effluents the data are not comprehensive (10). Lime, alum, and ferric salts are the most commonly used coagulating agents. Because of the many variables a pilot testing program will usually be necessary to ensure proper operation of the system. There must be a satisfactory method of ultimate disposition of resultant sludges.

Unless designed for constant flow, close control of the process is required to obtain satisfactory performance. Depending on the alkalinity of the wastewater, the operating cost of the chemicals for this method can be relatively high. Additional information is contained in References 1, 2, 9, and 10.

14. ADDITIONAL FIELD EXPERIENCE:

The information contained in this Bulletin will be modified as additional field experience becomes available. Those having such information are encouraged to submit it to the Director, Municipal Construction Division (AW-447), Office of Water Program Operations, U.S. Environmental Protection Agency, Washington, D.C. 20460.

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Note: Information on EPA publications can be obtained from the EPA Regional Administrator.