CHAPTER 14
WASTEWATER TREATMENT PONDS

14-1, Background.

A wastewater stabilization pond is a relatively shallow body of wastewater contained in an earthen basin which is designed to treat wastewater. (“Oxidation pond" is a synonymous term.) They are used to treat a variety of wastewaters, from domestic wastewater to complex industrial waters, and they function under a wide range of weather conditions, i.e., tropical to arctic. Ponds can be used alone or in combination with other treatment processes. If sufficient land is available, ponds are a cost-effective means to provide wastewater treatment. In addition, their operation is easy and their maintenance requirements are minimal. They are usually the most prefered system in hot climate zones (see appendix D). This chapter presents some information about ponds; additional design information and detailed sample design calculations are provided in the EPA Manual 625/1-83-015. Detailed discussion of pond utilization may be found in Rich, 1980; Dinges, 1984; and Wagner and Lanoix, 1982.

14-2. Types of ponds.

Table 14-1 presents the many different ways that stabilization ponds may be classified. The bases for the classifications are type of influent, method of effluent flow management, oxygenation method, and type of biological activity. This last classification scheme is the best because it describes the dominant feature, i.e., the type(s) of biological activity occurring in a pond. However; to fully describe the different types of ponds, the effluent flow management method should also be noted.

Table 14-1. Wastewater treatment pond classifications.

Basis	Classification
Type of Influent	Untreated Wastewater
	Screened Wastewater
	Settled Wastewater
	Activated Sludge Effluent
Effluent Flow Management	Intermittent
	Continuous
Oxygenation Method	Photosynthesis
	Surface Transfer
	Mechanical Aerator
	Complete Mix
	Partial Mix
Biological Activity	Aerobic
	Aerobic-Anaerobic (Facultative)
	Anaerobic

a. Aerobic ponds. An aerobic stabilization pond contains bacteria and algae in suspension; aerobic conditions (the presence of dissolved oxygen) prevail throughout its depth. There are two types of aerobic ponds: shallow ponds and aerated ponds.

(1) **Shallow ponds.** Shallow oxidation ponds obtain their dissolved oxygen via two phenomena: oxygen transfer between air and water surface, and oxygen produced by photosynthetic algae. Although the efficiency of soluble biochemical oxygen demand removal can be as high as 95 percent, the pond effluent will contain a large amount of algae which will contribute to the measured total biochemical oxygen demand of the effluent. To achieve removal of both soluble and insoluble biochemical oxygen demand, the suspended algae and microorganisms have to be separated from the pond effluent.

(2) **Aerated ponds.** An aerated pond is similar to an oxidation pond except that it is deeper and mechanical aeration devices are used to transfer oxygen into the wastewater. The aeration devices also mix the wastewater and bacteria. Figure 13-7 illustrates various aerators which can be used in aerated ponds. The main advantage of aerated ponds is that they require less area than oxidation ponds. The disadvantage is that the mechanical aeration devices require maintenance and use energy. Aerated ponds can be further classified as either complete-mix or partial-mix systems. A complete-mix pond has enough mixing energy (horsepower) input to keep all of the bacterial solids in the pond in suspension. On the other hand, a partial-mix pond contains a lesser amount of horsepower which is sufficient only to provide the oxygen required to oxidize the biochemical oxygen demand entering the pond.

b. Aerobic-anaerobic (facultative) ponds. Three zones exist in an aerobic-anaerobic pond. They are the following:

(1) A surface zone where aerobic bacteria and algae exist in a symbiotic relationship;

(2) An anaerobic bottom zone in which accumulated solids are actively decomposed by anaerobic bacteria;

and

(3) An intermediate zone that is partly aerobic and partly anaerobic in which the decomposition of organic wastes is carried out by facultative bacteria. Because of this, these ponds are often referred to as facultative ponds. In these ponds, the suspended solids in the wastewater are allowed to settle to the bottom. As a result, the presence of algae is not required. The maintenance of the aerobic zone serves to minimize odor problems because many of the liquid and gaseous anaerobic decomposition products, carried to the surface by mixing currents, are utilized by the aerobic organisms.

c. Controlled discharge ponds. Controlled discharge ponds have long hydraulic detention times and effluent is discharged when receiving water quality will not be adversely affected by the discharge. Controlled discharge ponds are designed to hold the wastewater until the effluent and receiving water quality are compatible.

d. Complete retention ponds. Complete retention ponds rely on evaporation and/or percolation to reduce the liquid volume at a rate equal to or greater than the influent accumulation. Favorable geologic or climatic conditions are prerequisite.

14-3. Design considerations.

a. Appurtenances. In general, the only appurtenances required for wastewater treatment ponds are flow measurement devices, sampling systems, and pumps. Information regarding the selection and design of these treatment system components may be found in chapter 18 of this manual.

b. Shallow aerobic ponds. Shallow aerobic ponds are limited to a depth of 6 to 18 inches so that light can penetrate the pond to allow algae to grow throughout the pond. This type of pond produces large amounts of algae which must be separated from the wastewater so that biochemical oxygen demand and suspended solids effluent limitations can be met. The separation is typically performed by filtration. The requirement for shallow construction means that this type of pond necessitates a very large amount of land. This land requirement and the need to filter algae are such significant disadvantages that shallow aerobic ponds are not recommended.

c. Aerated ponds.

(1) **Complete-mix aerated ponds.** Complete-mix aerated ponds are designed and operated as flow-through ponds with or without solids recycle. Most systems are operated without solids recycle; however, many systems are built with the option to recycle effluent and solids. Even though the recycle option may not be exercised, it is desirable to include it in the design to provide for flexibility in the operation of the system. If the solids are returned to the pond, the process becomes a modified activated sludge process. Solids in the complete-mix aerated pond are kept suspended at all times. The effluent from the aeration tank will contain from one-third to one-half the concentration of the influent biochemical oxygen demand in the form of solids. These solids must be removed by settling before discharging the effluent. Settling is an integral part of the aerated pond system. Either a settling basin or a quiescent portion of one of the cells separated by baffles is used for solids removal. Seven factors are considered in the design of an aerated pond:

— Biochemical oxygen demand removal;
— Effluent characteristics;
— Oxygen requirements;
— Mixing requirements;
— Temperature effects;
— Solids separation; and
— Hydraulic retention time.

Biochemical oxygen demand removal and the effluent characteristics are generally estimated using a complete-mix hydraulic model and first order reaction kinetics. The complete-mix hydraulic model and first order reaction kinetics will be used by the designer of U.S. Army wastewater treatment facilities. Oxygen requirements will be estimated using equations based on mass balances; however, in a complete-mix system, the power input necessary to keep the solids suspended is much greater than that required to transfer adequate oxygen. Temperature effects are incorporated into the biochemical oxygen demand removal equations. Solids removal will be accomplished by installing a settling pond. If a higher quality effluent is required, then intermittent sand filtrations, as described in paragraph 14-4, should be used to produce an acceptable effluent quality.

(2) **Partial-mix aerated ponds.** In the partial-mix aerated pond system, no attempt is made to keep all of the solids in the aerated ponds suspended. Aeration serves only to provide oxygen transfer adequate to oxidize the biochemical oxygen demand entering the pond. Some mixing obviously occurs and keeps portions of the solids suspended; however, in the partial-mix aerated pond, anaerobic degradation of the organic matter that settles does occur. The system is frequently referred to as a facultative aerated pond system. Other than the difference in mixing requirements, the same factors considered in the complete-mix aerated pond system are applicable to the design of a partial-mix system, i.e., biochemical oxygen damand removal, effluent characteristics, oxygen requirements, temperature effects and solids separation. Biochemical oxygen demand removal is normally estimated using the complete-mix hydraulic model and first order reaction kinetics. The only difference in applying this model to partial-mix systems is the selection of a reaction rate coefficient applicable to partial-mix systems.

d. Facultative ponds. Facultative pond design is based upon biochemical oxygen demand removal; however, the majority of the suspended solids will be removed in the primary cell of a pond system. The solids which settle out in a pond undergo digestion and provide a source of organic compounds to the water, which is significant and has an effect on the performance. During the spring and fall, overturn of the pond contents can result in significant quantities of solids being resuspended. The rate of sludge accumulation is affected by the liquid temperature, and additional pond volume is provided for sludge accumulation in cold climates. Although suspended solids have a profound influence on the performance of pond systems, most design equations simplify the incorporation of the influence of suspended solids by using an overall reaction rate constant. Effluent suspended solids generally consist of suspended organism biomass and do not include suspended waste organic matter.

e. Controlled discharge ponds. No rational or empirical design model exists specifically for the design of controlled discharge wastewater ponds. However, rational and empirical design models applied to facultative pond design may also be applied to the design of controlled discharge ponds, provided allowance is made for the required larger storage volumes. These larger volumes result from the long storage periods relative to the very short discharge periods. The unique features of controlled discharge ponds are long-term retention and periodic control discharge, usually once or twice a year. Ponds of this type have operated satisfactorily in the north-central U.S. using the following design criteria:

— Overall organic loading: 20-25 pounds biochemical oxygen demand per acre per day.
— 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 of storage above the 2 feet 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.

f. Complete retention ponds. In areas of the U.S. where the moisture deficit, evaporation minus rainfall, exceeds 30 inches annually, a complete retention wastewater pond may prove to be the most economical method of disposal. Complete retention ponds must be sized to provide the necessary surface area to evaporate the total annual wastewater volume plus the precipitation that would fall on the pond. The system should be designed for the maximum wet year and minimum evaporation year of record if overflow is not permissable under any circumstances. Less stringent design standards may be appropriate in situations where occasional overflow is acceptable or an alternative disposal area is available under emergency circumstances. Monthly evaporation and precipitation rates must be known to properly size the system. Complete retention ponds usually require large land areas, and these areas are not productive once they have been committed to this type of system. Land for this system must be naturally flat or be shaped to provide ponds that are uniform in depth and have large surface areas.

14-4. Disinfection.

Wastewater contains bacteria which can produce diseases in humans. Disinfection is the selective destruction of these disease-causing organisms. Since chlorine, at present, is less expensive and offers more flexibility than other means of disinfection, chlorination is the most practical method of disinfection. The chlorination of pond effluents requires consideration of some wastewater characteristics which are unique to pond effluents. A list of these considerations is presented below; additional information, design criteria and design examples may be found in EPA Manual 625/1-83-015.

a. Sulfide. Sulfide, produced as a result of anaerobic conditions in the ponds during winter months when the ponds are frozen over, exerts a significant chlorine demand. For sulfide concentrations of 1.0-1.8 milligrams per liter, a chlorine dose of 6-7 milligrams per liter is required to produce the same residual as a chlorine dose of about 1 milligram per liter for conditions without sulfide.

b. Chemical oxygen demand (COD). Total chemical oxygen demand concentration in a pond effluent is virtually unaffected by chlorination. Soluble oxygen demand, however, increases with increasing concentrations of free chlorine. This increase is attributed to the oxidation of suspended solids by free chlorine.

c. Suspended solids. Some reduction in suspended solids, due to the breakdown and oxidation of suspended particulates and resulting increases in turbidity, are attributed to chlorination. However, this reduction is less than that resulting from settling. Suspended solids can be reduced by 10 to 50 percent from settling in chlorine contact tanks.

d. Algae. Filtered pond effluent exerts a lower chlorine demand than unfiltered pond effluent due to the removal of algae. Chlorine demand is directly related to chlorine dose and total chemical oxygen demand.

e. Temperature. Disinfection efficiency is temperature dependent. At colder temperatures, the reduction in the rate of disinfection was partially offset by reductions in the exertion of chlorine demand; however, the net effect was a reduction in the chlorine residual necessary to achieve adequate disinfection with increasing temperature for a specific contact period.

f. Chlorine residual. Adequate disinfection can be obtained with combined chlorine residuals of between 0.5 and 1.0 milligrams per liter after a contact period of approximately 50 minutes, i.e., disinfection can be achieved without discharging excessive concentrations of toxic chlorine residuals into receiving waters. Parameters and pond design are discussed in detail in Baudy et al., 1986; Siegrist and Boyle, 1982; Winneberger, 1976; and Yonika et al., 1978.