

WASTE TREATMENT STABILIZATION PONDS

by

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## INTRODUCTION

The need for a new approach to the treatment of sewage water and the disposal of other wastes in our no-deposit, no-return society is at last beginning to penetrate the consciousness of the world.

Young people especially look upon environmental problems as a particularly unwelcome legacy to be inheriting at this time. Indeed, there should be no generation gap in our fight for a cleaner environment. It is to everyone's advantage to work for cleaner air, unpolluted water and less accumulation of solid wastes. Although waste disposal problems were there hundreds of years back they did not become a potential threat to our very survival until relatively recently. It is largely the tremendous increase in population that makes this issue so critical and insistent of solution.

Taking the example of the U.S.A., in 1940 there were about 135 million Americans. In 1970 the population count was about 204 million. That is a 50% increase in population in 30 years. In the next 30 years - by the year 2000 - that figure is expected to rise by another 50% to some 300 million.

Not only are the numbers of people rising at an explosive rate, but so are per capita consumption of water and other resources ancillary to waste production. All the while our known sources of water remain essentially the same. In other words, we must continue to draw upon the same water resources which we have used for 30 years and which we will be using for the coming years.

What this all amounts to is that we must live with the conditions we create. But, those conditions are becoming almost unmanageable because of our growing numbers. The raw municipal sewage that could be dumped

almost with impunity into a river or lake because its volume was not great enough to cause serious problems, today, could well be choking that same waterway to death even after primary treatment.

The President of the U.S.A. called attention to the tremendous problems in this area on New Year's day, 1970, when he warned that "The 1970's absolutely must be the years when America pays its debt to the past by reclaiming the purity of its air, its waters, and our living environment. It is literally now or never" (1).

According to the United States president's task force on science policy, "Our national progress becomes ever more critically dependent upon the excellence of our science and technology." Dr. Lee Dubridge, the president's science advisor, put it another way. He said, "Man isn't going to solve his environmental problems by returning to cave-man living standards, but by using his intelligence to correct his abuses" (1).

The only answer to this mounting problem is in increasing more efficient systems of disposal for all wastes, leading eventually to recycling and reuse. When one considers the role of ponds in waste water treatment, perhaps the most striking contribution is found in the opportunity afforded to small communities to share in the comfort and satisfaction of a water-carried sewage disposal system which will provide generally excellent treatment, and a contribution to the cleaner environmental conditions.

In developing countries, a small minority of the population lives in houses which are sewered. Information collected by the World Health Organization (WHO) in 1962 showed that not over ten percent had piped water in their houses, and only a fraction of those houses were sewered. Where sewers did exist, the main reason for building them, especially in rural areas, may have been to recover waste water for irrigating agricultural

lands (2).

Those people who have neither piped water nor sewerage available in their houses make full use of nearby water courses for drinking, cooking, animal watering, washing and waste disposal. Traditional rules usually prevent a community from contaminating its own drinking supplies, but the downstream communities are only protected - if they are far enough away - by natural purifying forces.

Most communities in developing countries, including many large cities, have at present neither facilities for collecting and disposing of waste water nor the financial and organizational means to build and operate them. The problem is by no means a technical one - as attested by a large number of handsome engineering reports on sewerage and drainage systems which have not been built. It is, in developing as in developed countries, to present a scheme people want and are willing to pay for. The backlog of needed new utilities construction resulting from very recent urban growth, and competition for development money tend to push sewerage schemes to low priority.

In the light of the foregoing considerations, waste stabilization ponds appear especially suitable for waste water treatment in developing countries. Compared with the conventional treatment methods ponds are much cheaper to build, and since they do not require the attention of a highly skilled staff, they are also cheaper to operate. They can be run successfully with large variations in hydraulic and organic loadings. Although they require more space than conventional plants, this is often not a problem in developing countries, and in hot climates is offset to some extent by the possibility of using heavier loading.

Stabilization ponds have already been built in at least thirty-five countries as shown in Table 1. These include over twenty developing

<u>Americas</u>	<u>Europe</u>	<u>Africa</u>	<u>Eastern Mediterranean</u>
*Argentina	Finland	Ghana	Israel
Bolivia	Federal Republic of Germany	Kenya	*Pakistan
Brazil	German Democratic Republic	Mauritius	Saudi Arabia
Canada	Netherlands	Nigeria	*United Arab Republic
Colombia	Romania	South Africa	
Costa Rica	Sweden	Rhodesia	
Cuba	U.S.S.R.	Uganda	
Ecuador		Zambia	
Guatemala			
Mexico			
Nicaragua			
Peru			
Trinidad			
U.S.A.			
Venezuela			

Southeast Asia

India  
\*Thailand

Western Pacific

Australia  
Japan  
New Zealand

\*Experimental Ponds

Table 1 - Countries Where the Use of Waste Stabilization Ponds  
Has Been Reported, Listed By WHO (2) Region.

countries and are being planned in several others. Information obtained in a WHO Survey indicated that although quantitative operational data are not generally available, most plants are considered to be operating satisfactorily (2).

In the U.S.A., stabilization ponds are used quite extensively. In 1968 treatment systems in the general category of "Stabilization Ponds" constituted 34.7 percent of the 9,951 secondary treatment systems operating in this country. Stabilization ponds served 7.1 percent of the 85,600,000 people served by secondary treatment plants. Ninety percent of these ponds were in communities having a population of 10,000 or less (3).



## PURPOSE AND SCOPE

The purpose of this report is to gain knowledge about stabilization ponds which are an economical type of waste treatment method for moderate sized communities, especially where inexpensive land is available. Although there is no upper limit to the size of a community that can be served by ponds, they are not used by big cities because of the nonavailability of cheaper land.

This study was conducted by going through the available literature on stabilization ponds. The literature review data was for the most part based on the papers presented at the "2nd International Symposium for Waste Treatment Lagoons", held in 1970 (4). A nonoverflowing stabilization pond has been designed in an example for a theoretical town.

## LITERATURE REVIEW

### History

It is suspected that the Chinese invented stabilization ponds about 1000 years ago, but of course there are no records to prove it (5). It is uncertain when and where ponds were first used in the United States. During the mid-twenties, cities in California, Texas, and North Dakota used lagoons as a means of treating municipal sewage (6). It is reported by Oswald (7) that a small ponding installation at Bitterwater, San Benito County, California, was constructed about 1916 to receive oil pumping station wastes, waste boiler feed water and domestic sewage.

In 1924, Santa Rosa, California uncovered gravel pits which the City Council thought could be used as natural filters prior to discharging city sewage into the then highly-polluted Santa Rosa Creek (8). The gravel pit soon became clogged and the pit filled to a depth of about three feet and thereafter operated as an oxidation pond.

In 1925, a lagoon irrigated arrangement was set up for the city of Abilene, Texas (6). Based upon this success, an experimental pond was built at Texas A & M College in 1929 (6).

The first lagoon of record in North Dakota was in the town of Fessenden and was placed in operation during 1928 (9). This community had no nearby stream to handle the effluent from the new sewage system completed during that year; so it was decided to discharge the effluent into a pothole about a mile west of town.

In the early stages of World War II, rapid and unpredictable population increases at military installations, as well as at neighboring municipalities brought about the construction of numerous oxidation ponds

to cope with the resultant overloads upon the existing facilities. The first deliberately designed stabilization pond based on engineering concepts of treating raw sewage was placed in operation in 1949, in Maddock, North Dakota (10). This installation aroused considerable enthusiasm on the part of the North Dakota State Health Department and shortly thereafter throughout the Midwest and Southwest. The accelerated extent and use of oxidation ponds had begun.

It can be safely said that the development in the field of stabilization ponds really started from 1950 onwards. Prior to 1950, the use of stabilization ponds as a treatment method was generally discouraged. There was a tremendous increase in the stabilization ponds from 1960 - 1970. This can be seen by considering the case of ten Missouri River Basin states (5): In 1960 there were 469 stabilization ponds whereas in 1970 there were 1,743 of these installations serving different municipalities. The breakdown according to 1970 report was:

Colorado —————	100	Iowa —————	221
Kansas —————	181	Minnesota —————	140
Missouri —————	360	Montana —————	114
Nebraska —————	205	North Dakota —————	210
South Dakota —————	144	Wyoming —————	68

The number of ponds treating industrial wastes in the Missouri River Basin increased from 32 in 1960 to 150 in 1970. The most interesting fact is that during these ten years, the total number of new municipal collection systems that were built in the Missouri River Basin was 1,167. Out of these, 851 used stabilization ponds as a treatment method.

A stabilization pond can be defined as a shallow man-made basin utilizing natural processes under partially controlled conditions for the reduction of organic matter and the destruction of pathogenic organisms in waste waters.

#### Pond Classification

Stabilization ponds are usually classified according to the nature of the biological activity that is taking place. Other classification schemes that have been used are based on the type of influent (untreated, screened, or settled wastewater, or activated sludge effluent); on the pond overflow condition (non-existent, intermittent, or continuous); and on the method of oxygenation (photosynthesis, atmospheric surface transfer, or mechanical aerators) (11).

In terms of biological activity, stabilization ponds are classified as aerobic, facultative, and anaerobic. In addition, a variety of different pond systems have been developed and applied to meet the specific requirements.

#### Aerobic Ponds

There are basically two types of aerobic ponds. The first one is high rate aerobic pond where the depth is from 6-18 inches. In this type of pond, the main objective is to maximize the production of algae by allowing maximum light penetration. In the second type, the main objective is to maximize the amount of oxygen produced and here pond depths up to 5 feet have been used. In both cases, oxygen in addition to that produced by algae enters the liquid through atmosphere diffusion. In operation the pond loading is adjusted to reflect the amount of oxygen available from photosynthesis and atmospheric reaeration. The efficiency

of BOD<sub>5</sub> conversion in aerobic ponds is high, ranging up to 95 percent, organic loading usually ranges from 60-200 pounds BOD<sub>5</sub> per acre per day.

In the decomposition process, the oxygen released by the algae through the process of photosynthesis is utilized by the bacteria in the aerobic degradation of organic matter. The nutrients and carbon dioxide released in this degradation are in turn used by the algae. The cyclic-symbiotic relationship is shown in Fig. 1 (12). Higher animals such as rotifers and protozoa will also be present in the pond, and their main function is to polish the effluent.

The particular algal group, animal group, or bacterial species present in any section of an aerobic pond will depend on such factors as organic loading, degree of pond mixing, pH, nutrients, sunlight, and temperature. Temperature has a profound effect on the operation of aerobic ponds, particularly in regions having cold winters, where it is possible for ice to cover the pond surface. The water temperature under the ice cover is only slightly above freezing, and as a result, the metabolic activities of the microorganisms are greatly reduced. The ice cover also greatly reduces photosynthetic activities and presents operational difficulties for the aeration units (if any). As a result, anaerobic conditions will soon prevail throughout the pond. In the spring, when the ice melts and better aeration and mixing are obtained in the pond, odorous anaerobic end products, such as hydrogen sulfide, are released to the atmosphere. Thus, for a short time during the spring, odor problems may be encountered.

#### Aerobic - Anaerobic Ponds

Aerobic-Anaerobic ponds are perhaps the most numerous of the pond systems, and their depth ranges from 3 - 8 feet. Three zones exist in an

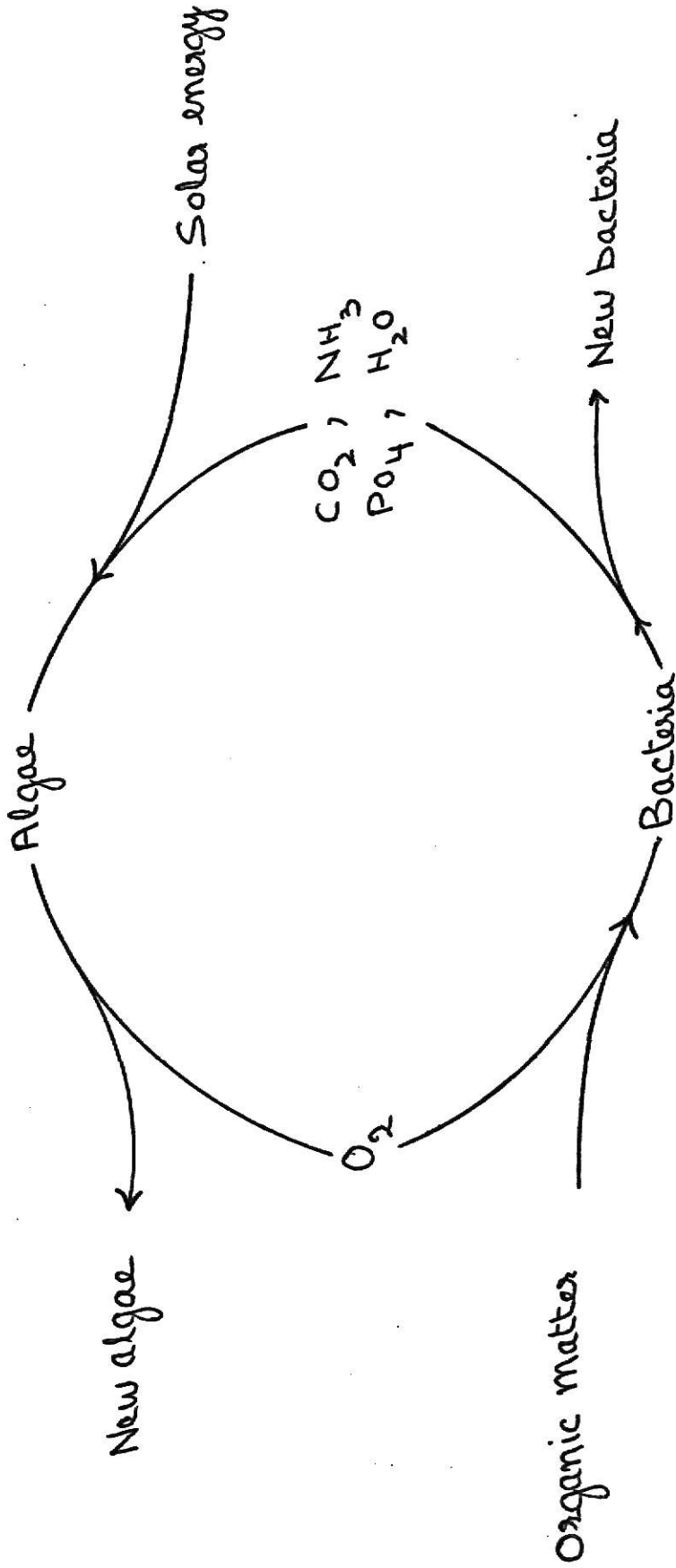


Fig. 1: Schematic Representation of the Symbiotic Relationships Between Algae and Bacteria.

aerobic-anaerobic pond, as shown in Fig. 2 (12). They are (a) an aerobic surface zone where oxygen for aerobic stabilization is produced by photosynthesis and surface reaeration, (b) an anaerobic bottom zone in which accumulated solids are actively decomposed by anaerobic bacteria; and (c) 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.

Organic loadings range from 15-80 pounds BOD<sub>5</sub> per acre, per day, and BOD<sub>5</sub> removal from 70-95 percent, depending on the concentration of algae in the effluent. BOD<sub>5</sub> removals as high as 99 percent have been obtained (3).

#### Anaerobic Ponds

Anaerobic ponds are anaerobic throughout except for an extremely shallow surface zone. To conserve heat energy and to maintain anaerobic conditions, these ponds have been constructed with depths up to 20 feet. Organic loadings are very high in these types of ponds. It ranges from 200-1000 pounds BOD<sub>5</sub> per acre per day. BOD<sub>5</sub> removals are limited to about 50-80 percent. Anaerobic ponds are usually recommended for bringing about the rapid stabilization of strong organic wastes. These ponds are usually followed by aerobic or facultative ponds to reduce the BOD<sub>5</sub> in the effluent.

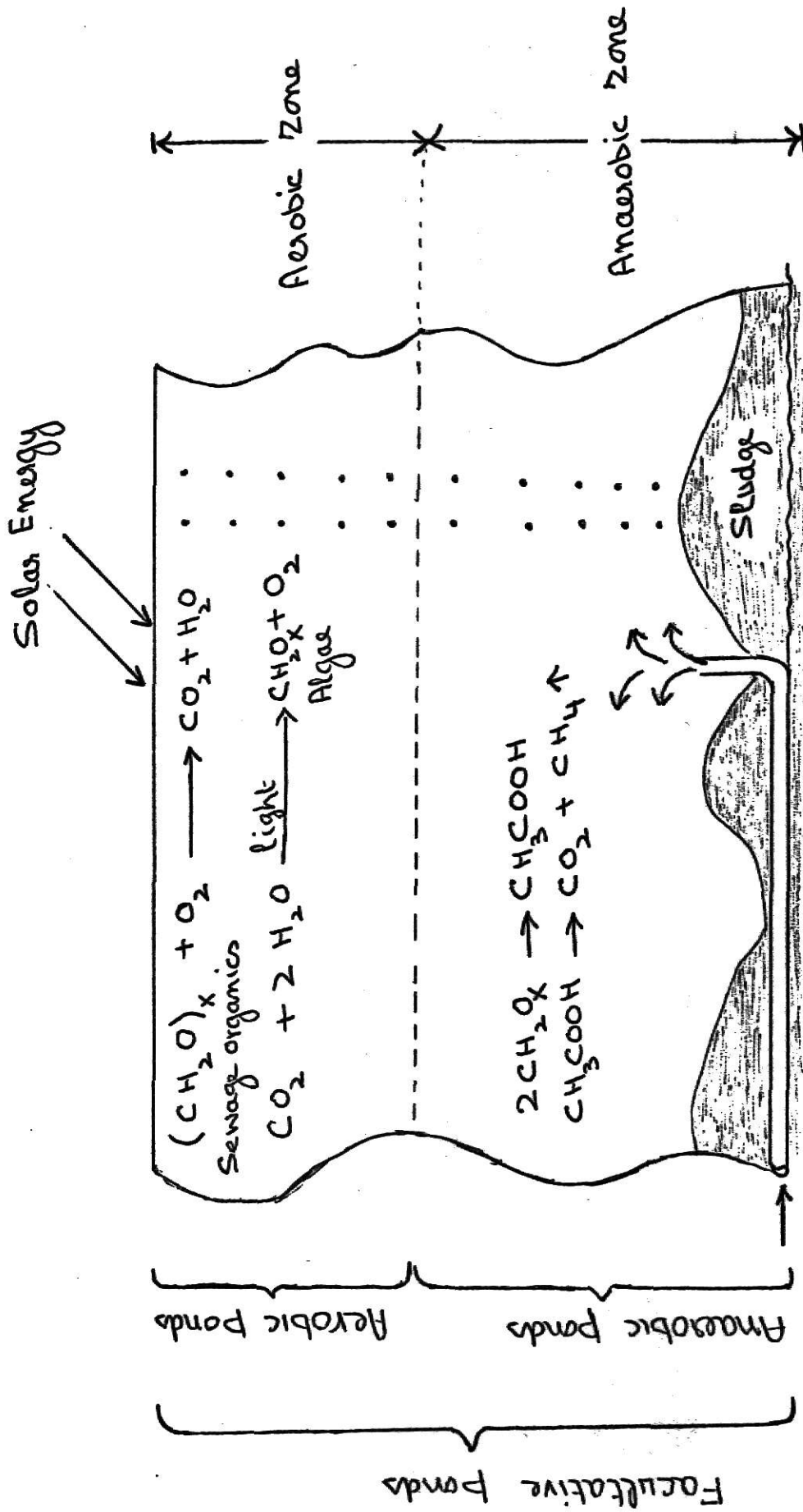


Fig. 2: Facultative Pond



The anaerobic process involves the decomposition of organic and/or inorganic matter in the absence of molecular oxygen. The microorganisms responsible for the decomposition of the organic matter are commonly divided into two groups. The first group hydrolyzes and ferments complex organic compounds to simple organic acids, the most common of which are acetic and propionic acids. This group of microorganisms consists of facultative and anaerobic bacteria, collectively called the acid formers.

The second group converts the organic acids formed by the first group to methane gas and carbon dioxide. The bacteria responsible for this conversion are strict anaerobes and are called the methane formers. The most important bacteria of this group are the ones that degrade acetic acid and propionic acid. They have very slow growth rates; and, as a result, their metabolism is usually considered rate limiting in the anaerobic treatment of an organic waste. It is in this second step that actual waste stabilization is accomplished by the conversion of organic acids into methane and carbon dioxide. Methane gas is highly insoluble, and its departure from solution represents actual waste stabilization.

Many other groups of anaerobic and facultative bacteria utilize the various inorganic ions present in the sludge. 'Desulfovibrio' is responsible for the reduction of sulfate ion  $\text{SO}_4^-$  to sulfide ion  $\text{S}^{--}$ . Other bacteria reduces nitrates  $\text{NO}_3^-$  to nitrogen gas  $\text{N}_2$  (denitrification).

To maintain an anaerobic treatment system that will stabilize an organic waste efficiently, the acid formers and the methane formers must be in a state of dynamic equilibrium. The pH range should be between 6.6-7.6. Sufficient alkalinity should be present to insure that the pH system does not drop below 6.2 because the methane formers cannot function below this point. A sufficient amount of nutrients, such as

nitrogen and phosphorous, must also be available to insure the proper growth of the biological community. Temperature is another environmental parameter. The optimum temperature ranges are the mesophilic range (85-100°F) and thermophilic range (120-135°F). These environmental conditions are summarized in Table 2 (13).

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Optimum Temperatures

Mesophilic range, 85 to 100° F

Thermophilic range, 120 to 135° F

Anaerobic Conditions

Sufficient Biological Nutrients:

Nitrogen

Phosphorous

Others

Optimum pH, 6.6-7.6

Absence of Toxic Materials

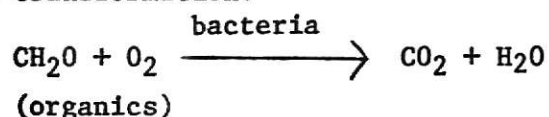
Table 2 - Optimum Conditions For Anaerobic Waste Treatment (13)

## OPERATING PROBLEMS IN PONDS

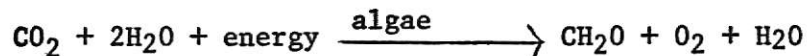
With increasingly stringent effluent requirements, waste-treatment ponds, like any other waste treatment process, may require modification to meet all objectives. The problems that occur with individual ponds, however, may not be common to all.

### Organic Matter in Effluents

An algal-bacteria symbiosis operates in both aerobic and facultative ponds. Bacteria degrade organic matter according to the following simplified transformation:



Algae in turn, reuse the carbon (as carbon dioxide) to form algal biomass:



While these equations oversimplify the transformations, they show the recycling of carbon in ponds. Unless the algae are removed, or the carbon is removed through methane fermentation in an anaerobic sludge layer, little organic reduction may occur (14).

The fate of algae discharged to receiving waters has received relatively little attention, possibly because severe problems have not developed in most instances. Two studies have shown, however, that for two differing aquatic environments, the algae did constitute a BOD load on the receiving waters and decreased the dissolved oxygen (DO) levels (15), (16). In these cases, the algae from the pond effluent were in an unfavorable environment for either their maintenance or growth, and they decayed.

### Odors

That lagoons may occasionally emit odors is shown by the very common state requirements concerning lagoon location; i.e., requirements that lagoons should be located as far from existing or future residential or commercial development as is practical or reasonable. Anaerobic ponds particularly tend to have odor problems due to hydrogen sulfide formation.

### Noxious Vegetative Growths

Without maintenance and good design, aquatic growths may develop in ponds. Deeper ponds (deeper than 3 feet) will discourage rooted growths and proper levee maintenance can handle shore-line problems. If not suitably controlled, noxious plants can choke off hydraulic operation and create large accumulations of floatable debris. The debris usually becomes septic and creates odors and conditions detrimental to photosynthetic activity.

### Seasonal Performance Variations

In most locales of the United States, there are seasonal changes in both available light and temperature. Typically, in the winter, algae activity diminishes. Biological activity may also slow down; methane fermentation in facultative ponds may practically cease (10). In Michigan no discharge is permitted until the spring thaw, when increased biological activity causes a lower effluent BOD<sub>5</sub> (17).

### Recirculation

Recirculation of pond effluent has been used effectively to improve the performance of ponds. Pond recirculation involves interpond and intrapond recirculation as opposed to mechanical mixing in the pond cell. The effluents from pond cells are mixed with the influent to the cells. In intrapond recirculation, effluent from another pond is returned and mixed with influent to the pond. Both methods return active algal cells to the feed area to provide photosynthetic oxygen for satisfaction of the organic pond. Intrapond recirculation allows the pond to gain some of the advantages that a completely mixed environment would provide if it were possible in a pond. It helps prevent odors and anaerobic conditions in the feed zone of the pond.

Both interpond and intrapond recirculation can affect stratification in ponds, and thus gain some benefits ascribed to pond mixing (3). Three common types of interpond-recirculation systems (series, parallel and parallel-series) are shown in Fig. 3.

One objective of recirculation in the series arrangement is to decrease the organic loading in the first cell of the series. While the loading per unit surface is not reduced by this configuration, the retention time of the liquid is reduced. The method attempts to flush the influent through the pond faster than it would travel without recirculation. The hydraulic retention time of the influent and the recycled liquid in the first, most heavily loaded pond in the series system is (3):

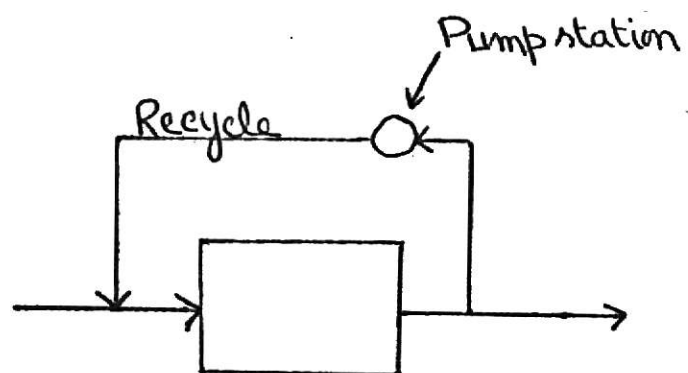
$$T = \frac{V}{(1 + r) F}$$

Where V = Volume of Pond Cell

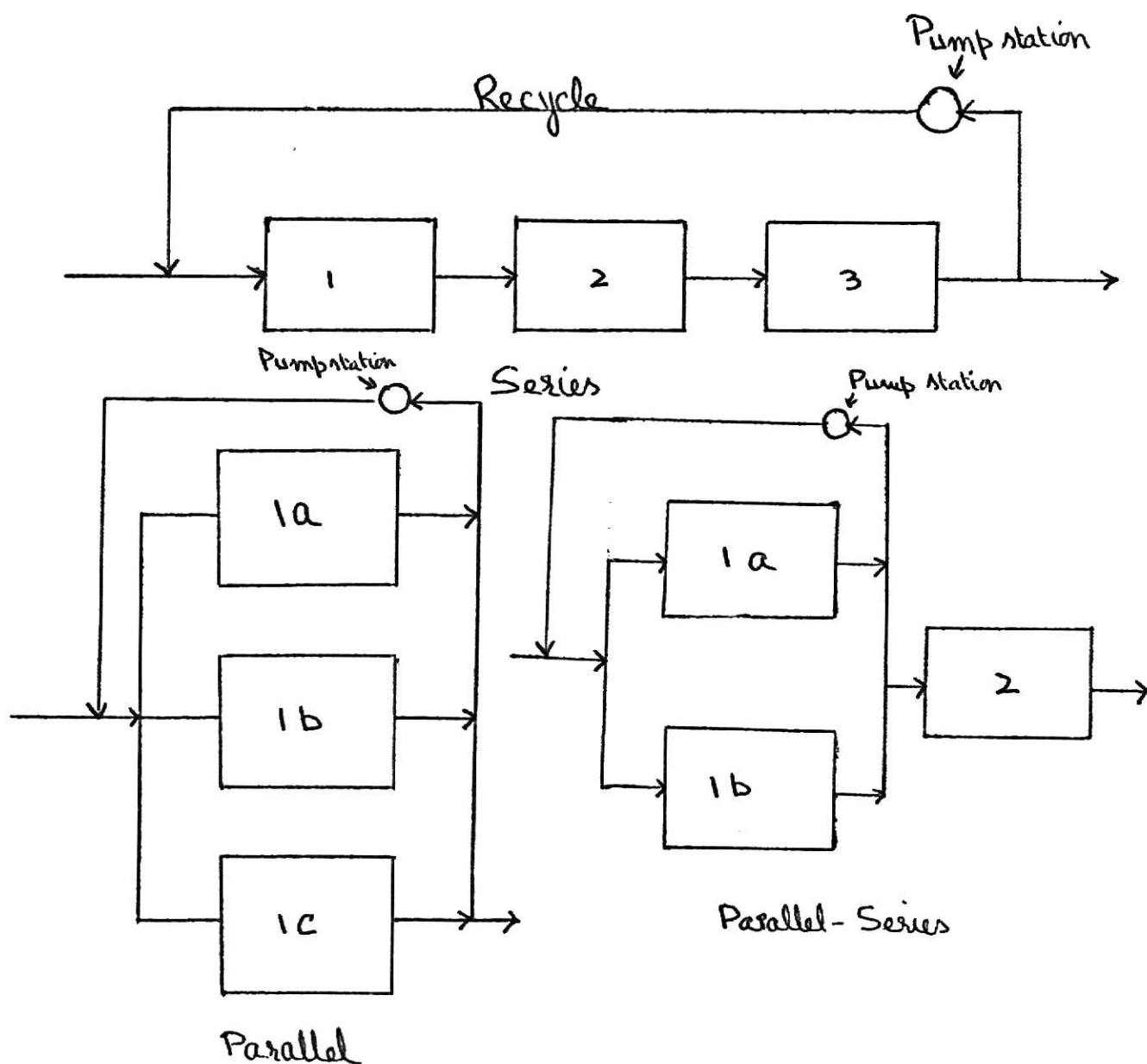
F = Influent Flow Rate

$\frac{R}{F} = r$  = Recycle Ratio

R = Recycle Flow Rate



INTRAPOND RECIRCULATION



INTERPOND RECIRCULATION

Fig. 3: Common Pond Configuration and Recirculation Systems (8).

## APPLICATION OF STABILIZATION PONDS

Stabilization ponds have been applied singly or in various combinations to the treatment of both domestic and industrial wastes. Aerobic ponds are used primarily for the treatment of soluble organic wastes and effluents from wastewater treatment plants. When more effective means are developed for separating, drying, and disposing of the algae, it is anticipated that they will become more popular. The facultative ponds are the most commonly used type and have been applied to the treatment of domestic wastewater and a wide variety of industrial wastes. Anaerobic ponds are especially effective in bringing about the rapid stabilization of strong organic wastes.

### Series - Parallel Operation

Stabilization ponds may be employed in parallel or series arrangement to achieve special objectives. Series operation is beneficial where a high level of BOD or coliform removal is important (12). The effluent from facultative ponds in series operation has a much lower algal concentration than that obtained in parallel operation, with a resultant decrease in color and turbidity. Many serially operated multiple-unit installations have been designed to provide complete treatment or to provide complete retention of the sewage, the liquid being evaporated into the atmosphere or percolated into the ground (12).

Parallel units provide better distribution of settled solids. Smaller units are conducive to better circulation and have less wave action. The additional cost of equipping units for both series and parallel operation is usually nominal.

Another advantage of recirculation in series configuration is that the BOD in the mixture entering the pond is reduced, and is given by the expression (3):

$$S_m = \frac{S_{in}}{1 + r} + \frac{r}{1 + r} S_3$$

Where  $S_m$  = BOD in the mixture

$S_{in}$  = Influent BOD

$S_3$  = Effluent BOD from the third cell

$r$  = Recycle ratio

Thus,  $S_m$  would be only 20 percent of  $S_{in}$  with a 4 : 1 recycle ratio, as  $S_3$  would be negligible in almost all cases. Thus, the application of organic load in the pond is spread more evenly throughout the ponds, and organic loading and odor generation near the feed points are less. Recirculation in the series mode has been used to reduce odors in those cases where the first pond is anaerobic (18).

The parallel configuration more effectively reduces pond loadings than does the series configuration, because the mixture of influent is spread evenly across all ponds instead of the first pond in the series. Recirculation has the same benefits in both configurations. Pond configuration should allow full use of the wetted pond area. Transfer inlets and outlets should be located to eliminate dead spots and short circuiting that may be detrimental to photosynthetic processes. Wind directions should be studied, and transfer outlets located to prevent dead pockets where scum will tend to accumulate. Pond size need not be limited, as long as proper distribution is maintained.

#### Feed and Withdrawal

Opinion in the literature is nearly unanimous that ponds should be fed by a single pipe, usually toward the center of the pond. Such



design should be used for raw sewage treatment by ponds. It has been found that with primary or secondary effluent, a single point of entry into a pond tends to overload the pond in the feed zone, allowing odors to develop (3). In such cases, multiple-entry and single exit approach, to distribute evenly the organic load throughout the pond cell, should be used.

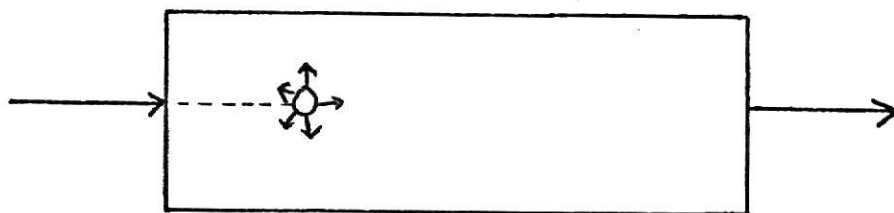
The multiple entry, multiple-exit approach has been used in the Stockton, California ponds (3). This system was developed to discourage the development of stagnant surface areas within the pond that can cause development of blue-green algae mats. Such mats can emit odors. The various methods of feed and withdrawal are shown in Fig. 4 (3).

#### UPGRADING PONDS

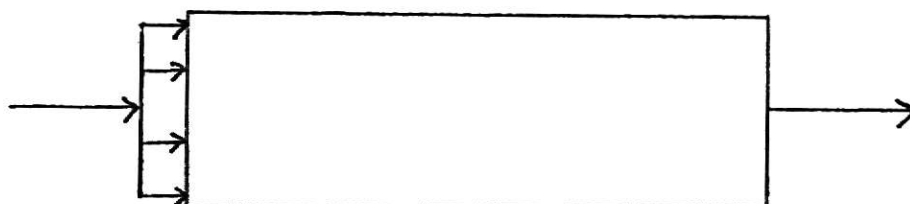
##### Algae Removal

Physical removals of the solids in pond effluents will insure that virtually all of the carbonaceous BOD and most of the nitrogenous BOD in the pond effluent will be removed. Physical removal of the algae removes virtually all the long-term BOD (3). Recovery of algae for animal feed has been investigated over the years; principal problems lie in developing a market for the product and in finding a means of separating algae in a manner consistent with the purpose of obtaining a feed. The use of coagulants such as alum generally diminishes the utility of the product (3). The pond system itself can provide for algae removal. Series ponds are recommended by some state regulatory agencies for encouraging algae sedimentation within the pond cells. A parallel-series arrangement can also encourage such sedimentation. Sedimentation ponds, however, are limited in efficiency by such factors

## SINGLE ENTRY AND SINGLE EXIT



## MULTIPLE ENTRY AND SINGLE EXIT



## MULTIPLE ENTRY AND MULTIPLE EXIT

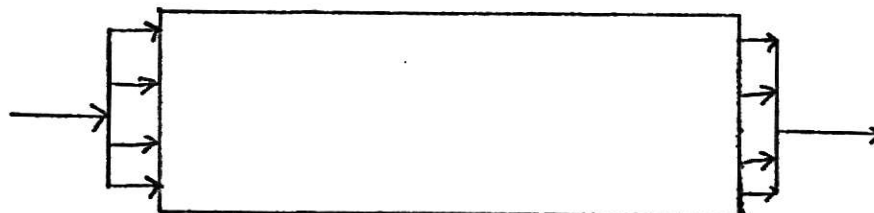


Fig. 4: Methods of Feed and Withdrawal from Ponds.

as wind mixing and species type. Wind prevents sedimentation by mixing the water. The smaller the pond, the less influence wind has on mixing. Sedimentation-pond efficiency also depends on species type. Mobile algae and crustaceans are not removed efficiently in such ponds (3).

McKinney (19), after an extensive review of available data, concluded that for small ponds (which are used most often) the best method for algae separation was the series arrangement, with the final pond used for algae sedimentation.

An algae sedimentation pond, unlike a mechanical system, is subject to variable performance caused by wind mixing, nutrient recycle from the sludge layer, and changes in algae-removal efficiencies resulting from shifts in algae species. An algae sedimentation pond cannot be expected to operate as efficiently as a mechanical system; however, such sedimentation ponds do have a place in upgrading technology since they are far simpler and more economical than mechanical systems.

#### Pond-Dike Construction

Pond dikes should be constructed in a way that minimizes seepage. Compaction afforded by the use of conventional construction equipment is usually adequate. Vegetation should be removed, and the area upon which the embankment is to be placed should be sacrificed. It is generally unnecessary to key the dikes into impervious subsoil, but this precaution may be advisable for sandy topsoil (12).

The dike should be wide enough to accommodate mowing machines and other maintenance equipment. A width of 8 ft. is generally considered adequate, and narrower dikes may be satisfactory for small installations. Slopes are influenced by the nature of the soil and the installation. For outer slopes, a 3 horizontal to 1 vertical is satisfactory. Inner

slopes are generally from 1 vertical to 3 to 4 horizontal, although slopes exceeding 1 to 5 for larger installations and 1 to 3 for smaller installations are sometimes specified (12).

The freeboard is to some extent influenced by the size and shape of the installation, as wave heights are greater on larger bodies of water. Three feet above maximum liquid level is usually specified as minimum freeboard, but 2 feet is considered adequate by some states, particularly for installations of 6 acres or less, not exposed to severe winds (12).

#### Surface Runoff Control

Ponds should not receive significant amounts of surface runoff. If necessary, provision should be made for diverting surface water around the ponds. For new installations, the diversion structure may be designed to admit surface runoff to the lagoon when necessary.

#### Liquid Depth

Optimum liquid depth for adequate circulation is influenced by pond area, greater depth being allowed for larger units. The pond area is influenced by seepage, evaporation and rainfall. Shallow ponds encourage the growth of emergent vegetation and consequently, may foster mosquito breeding. There is a distinct advantage for facilities that permit operation at selected depths up to 5 ft., and provision for additional depth may be desirable for large installations (12). Facilities for adjusting pond levels can be provided at small cost. For ponds 30 acres or larger, provision for periodic operation at depths greater than 5 feet may be advantageous (12).

#### Pond Bottom

The bottom of aerobic and most facultative ponds should be made as

level as possible except around the inlet. The finished elevation should not vary more than 5 inches from the average elevation of the bottom. An exception to this is where the bottom of a facultative pond is designed specifically to retain the settleable solids in hoppers or compartments or cells. The bottom should be well compacted to avoid excessive seepage. Where excessive percolation is a problem, increased hydraulic loading or partial sealing may merit consideration to maintain a satisfactory water level in the lagoon.

## SOIL INVESTIGATION

### Factors Affecting Scope and Extent

Investigation and exploration of soils in the field, and in the laboratory, are conducted to obtain information about the behavior of soils.

The extent and scope of a soils investigation depends upon several factors. These must be considered thoroughly in order to avoid waste of money, either by inadequate procedures for obtaining required data, or by use of methods not applicable to particular conditions.

The nature and extent of soil investigation will, of course, depend on the nature of the project, as well as on the cost of the project, but the prime factor is the early establishment of the purpose of the soil study — that is, a determination of the information and data desired for a particular project. A soil survey should not be considered as having the purpose of establishing all the physical and mechanical properties of the soils involved. Instead, it should be thought of as a means for ascertaining with reasonable accuracy, the properties of soil mass and strata which will affect the design and performance of the project in question.

An important point which is sometimes overlooked is the relationship between the soil, the sampling procedure, and field and laboratory tests. This relationship must always be considered in its proper perspective. Laboratory techniques and equipments have been improved greatly in the past few years until, now, it is quite proper to assume that the results of a laboratory test on soils can be performed with the same degree of accuracy as tests on other structural materials. This means that, in general, laboratory tests reflect very accurately the properties

of the soil 'as put into the testing machine.' The properties of the soil may have been changed or modified to some degree by the manipulation necessary to prepare it for testing. However, careful laboratory technique by trained personnel can limit this change to a negligible value. To a greater degree the same is true of sampling. Sampling always modifies the in-place properties of soils. Here again careful technique by trained personnel can minimize the modifications. The engineer should consider both of these factors, but the true perspective between laboratory tests and field properties of soils must depend mainly on the extent to which the small sample tested is representative of large masses in the field.

#### Soil Data for Stabilization Ponds

Boring or test pits are dug up at least 2-3 feet below the base of the stabilization pond to determine the soil formation and slope. Soils having moderate permeability and slopes are usually preferred for stabilization ponds (21). Samples are taken for the following tests, based on ASTM standards.

- (a) Permeability
- (b) Proctor Density
- (c) Shear Strength

The first two tests are mandatory according to the Kansas Department of Health and Environment (22).

(a) Permeability is the property of a soil which permits water to flow through its pores. The value of seepage is calculated by performing the permeability test in the laboratory or in the field. Darcy, in the middle 1850's, first presented the results of his studies of flow through porous media. His equation is in use today for soil permeability studies:

$$\frac{Q}{A} = V = Ki$$

$$K = \frac{Q}{Ai} = \frac{QL}{hA}$$

Where  $Q$  = Measured Discharge

$L$  = Length of the soil through which water must flow

$h$  = Effective Head

$A$  = Total Soil Cross Section

$V$  = Velocity of Flow

$i$  = Hydraulic Gradient =  $h/L$

$K$  = Darcy's Coefficient of Permeability

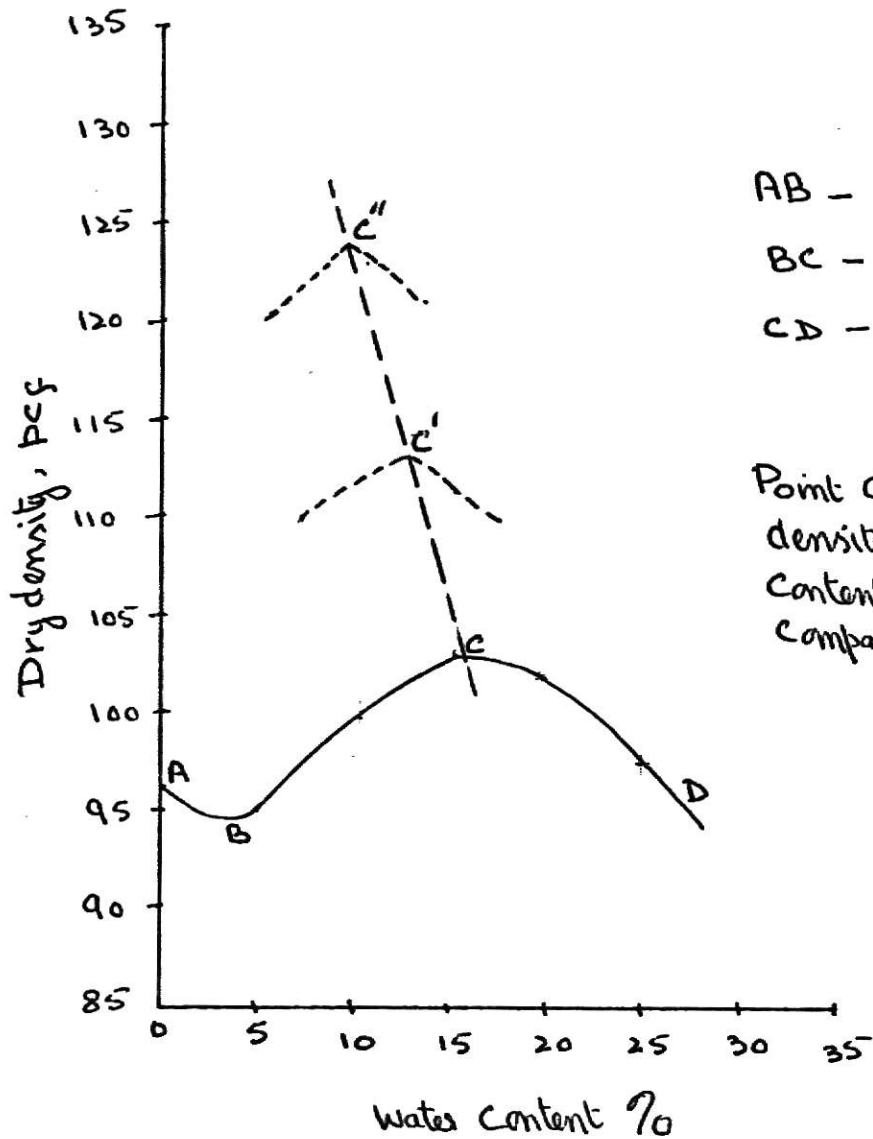
(b) The reduction in void ratio due to water flowing from the soil pores has been termed 'consolidation'. The reduction in void ratio due to air being forced out of the soil or dissolved in the soil water by mechanical means is termed 'compaction'. Although soil has obviously been used as a supporting and retaining material for thousands of years, the principles of soil compaction were first defined and successfully applied very recently — in the early 1930's, by R. R. Proctor.

In the laboratory, the soil is compacted in a circular metal container or mold 4.6 inches high and 4.0 inches in diameter (Volume =  $1/30\text{ft.}^3$ ). Compactive effort is supplied by 5.5 pound hammer with a two-inch diameter head dropping freely 12 inches. Twenty-five blows of the hammer, on each of three soil layers of equal thickness, provide 12,375 ft. lb. of energy per cubic foot of the soil. For a given compactive effort, the compacted density is a function of the water content. These relationships are illustrated by Fig. 5.



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### Water Content - Density Relationship

For any curve, each point is the result of the same compactive effort with varying water content. With increase compactive effort the curves move up and to the left as shown.

Fig. 5: Soil Compaction Relationships

(c) The property that enables a material to remain in equilibrium when its surface is not level is called 'Shear Strength'. All solids have this property to some extent. Liquids do not have shear strength, and in time (depending on the viscosity) all liquids will reach equilibrium with a level surface. Soils exhibit shear strength when not in the liquid state, although the magnitude is small compared to that of other structural materials such as steel or concrete. Shear strength is the major structural property of soils. It is this property which provides supporting ability or bearing capacity and permits slopes to be stable. There are four methods of performing the shear tests:

- (1) The Unconfined Compression Test
- (2) The Direct Shear Test
- (3) The Triaxial Test
- (4) The Vane Shear Test

The shear strength of sands may be expressed as:

$$S = N \tan \phi$$

Where  $S$  = Shear Strength of the Soil

$N$  = Normal Pressure

$\phi$  = Angle of Internal Friction

The shear strength of cohesive materials may be expressed by Coulomb's equation:

$$S = C + N \tan \phi$$

Where  $S$  = Shear Strength of the Soil

$C$  = Cohesion of the Soil

$N$  = Normal Pressure

$\phi$  = Angle of Internal Friction

**SOLVED EXAMPLE**

A Stabilization Pond for a Theoretical Town Having The Same Soil Formation And Climatological Data as Manhattan, Kansas:

**1. Population**

The design year of 2000 is selected. Hence, the design period is of 24 years.

Present Population = 275

Assuming an Annual Increase Rate of 1 Percent.

Design Population = 350

**2. Climatological Data (21)**

Average Rainfall = 32 inches per year

Average Evaporation = 50 inches per year

**3. Soil Data**

Maximum Dry Density = 103 pcf @ 22%

Optimum Moisture = 22%

Seepage = 0.136 inches per day

The Soil Data indicates that the available soil will be easy to excavate and compact; the infiltration rate is below 0.25 inches per day which is the limit in Kansas (22). Hence, no bentonite will be required for sealing.

### Treatment Plant

A nonoverflowing stabilization pond is being designed for this theoretical town. Its cost estimate is being compared with an activated sludge system which could also have been built for the same town.

#### 1. Activated Sludge System

An activated sludge package plant with a design capacity of 350 population might possibly be constructed as the treatment facility.

Estimated cost for a package plant are as follows:

##### A. Initial Cost

Purchase & Installation of Package Plant (23)	= \$52,450.00
Engineering Fee (8 percent)	= \$ 4,196.00
Legal Fee (3 percent)	= \$ 1,573.50
Construction Inspection (6 percent)	= \$ 3,147.00
Administration (2 percent)	= \$ 1,049.00
O and M Manual	= \$ 1,000.00
<b>SUBTOTAL</b>	<b>= \$63,415.50</b>
Cost of Land (23)	= \$ 2,000.00
<b>TOTAL COST</b>	<b>= \$65,415.50</b>
Cost per year @ 6 percent for 24 yrs. = $\$65,415.50 \left( \frac{A}{P}, 6\%, 24 \right)$	
	= \$65,415.50 x 0.07968
	= \$5,212.30

##### B. Annual Operational Costs (23)

Energy Requirements 23,000 KW @ 0.04 KW/hr.	= \$ 920.00
Operator 10hr/week x 52 weeks x \$3.00/hr	= \$ 1,560.00
Effluent Quality Testing \$75/month x 12	= \$ 900.00
Repairs and Maintenance @ 2 percent of plant cost (\$25,000)	= \$ 500.00
<b>TOTAL</b>	<b>= \$ 3,880.00</b>

## C. Total Annual Cost

$$\begin{aligned}\text{Total Cost per year} &= \$5,212.30 + \$3,880.00 \\ &= \$9,092.30\end{aligned}$$

## 2. Non Overflowing Stabilization Pond

Design of a non-overflowing pond is based on hydraulic flow. A three cell system is proposed for the design. The first two cells are based, hydraulically non-overflowing, on the present population. The third cell is sized such that the total system will be non-overflowing at the design population. The following environmental parameters were used:

$$\begin{aligned}\text{Rainfall} &= 32 \text{ inches per year} = 2.66 \text{ feet per year} \\ \text{Evaporation} &= 50 \text{ inches per year} = 4.17 \text{ feet per year} \\ \text{Seepage} &= 0.136 \text{ inches per day} = 4.14 \text{ feet per year} \\ \text{BALANCE} &= 5.65 \text{ feet per year}\end{aligned}$$

Cells 1 and 2 (based on present population):

$$\begin{aligned}\text{Inflow} &= 275 \times 60 \text{ gpcd} \\ &= 16500 \text{ gallons/day} \\ &= 16500 \times 365 \\ &= 6022500 \text{ gallons/year} \\ &= 6022500 \times 0.1337 \\ &= 805208 \text{ ft.}^3 / \text{year}\end{aligned}$$

Surface area required for cells 1 and 2:

$$\begin{aligned}&= \frac{805208 \text{ ft.}^3 / \text{year}}{5.65 \text{ ft/year}} \\ &= 142514 \text{ ft.}^2 \\ &= 3.27 \text{ acres}\end{aligned}$$

Cell No. 1 = 60% (3.27) = 2 acres @ 5' level.

Cell No. 2 = 40% (3.27) = 1.27 acres @ 5' level.

Cell No. 3 = (based on design population - present population)

Inflow = (350-275) x 60 gpcd = 4500 gallons/day

= 4500 x 365

= 1642500 gallons/year

= 1642500 x 0.1337

= 219602 ft.<sup>3</sup>/year

Surface Area Required =  $\frac{219602 \text{ ft.}^3/\text{year}}{5.65 \text{ ft./year}}$

= 38867 ft.<sup>2</sup>

= 0.89 acres

Total Surface Area = 3.27 + 0.89 = 4.16 acres @ 5' level.

The main cost involved in a stabilization pond is of excavation and construction of the dikes. It is economical to have the volume of soil needed for dikes to be equal to the volume of excavation.

#### Volume of Soil Needed for Dike Construction

Surface area required for the whole system = 4.16 acres

Assuming the configuration of the pond to be a square as shown in Fig. VI:

$A = 181186 \text{ ft.}^2 = 425.6 \text{ ft.} \times 425.6 \text{ ft.}$

Area of Cell 1 = 2 acres = 8708.7 ft.<sup>2</sup> = 425.6 ft. x 204.6 ft.

Area of Cell 2 = 1.27 acres = 55314 ft.<sup>2</sup> = 221 ft. x 250.3 ft.

Area of Cell 3 = 0.89 acres = 38763 ft.<sup>2</sup> = 175.4 ft. x 221 ft.

The slopes of the dikes on both the faces are 3.5 horizontal to 1 vertical. The top width is 8 feet. Let the dike be 5 feet high.

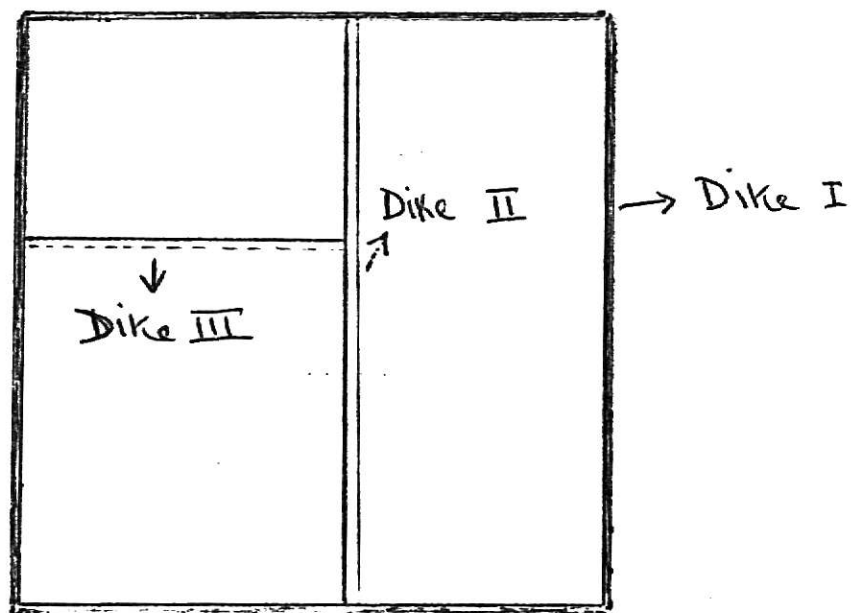
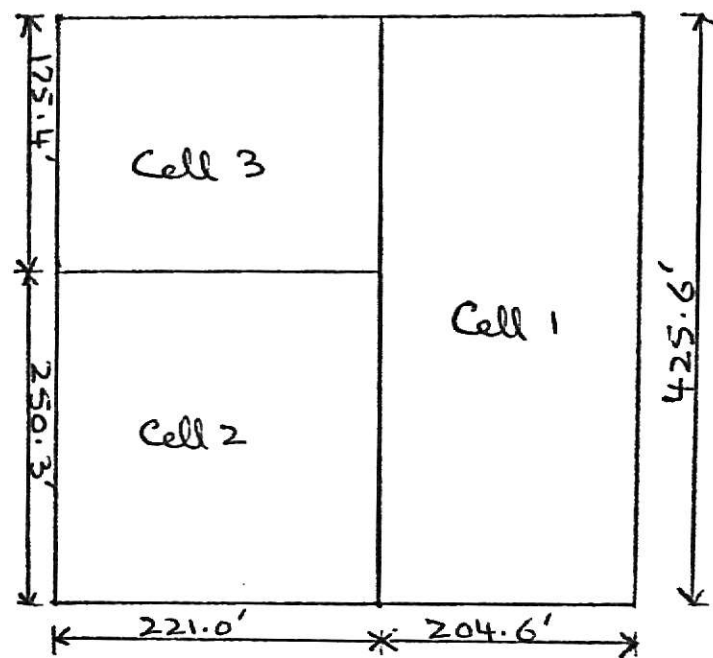


Fig. 6: Configuration of a Non-Overflowing Stabilization Pond



$$\begin{aligned}
 \text{Volume for Dike I} &= 4 [425.6 \times 8 \times 5 + 425.6 \times 5 \times 17.5] \text{ft.}^3 \\
 &= 4 [17024 + 37240] \text{ft.}^3 \\
 &= 4 (54264) \text{ft.}^3 \\
 &= 217056 \text{ ft.}^3 \\
 &= 8039 \text{ yd.}^3
 \end{aligned}$$

$$\begin{aligned}
 \text{Volume for Dike II} &= [425.6 \times 8 \times 5 + 425.6 \times 5 \times 17.5] \text{ft.}^3 \\
 &= (17024 + 37240) \text{ft.}^3 \\
 &= 54264 \text{ ft.}^3 \\
 &= 2009 \text{ yd.}^3
 \end{aligned}$$

$$\begin{aligned}
 \text{Volume for Dike III} &= [221 \times 8 \times 5 + 221 \times 5 \times 17.5] \text{ft.}^3 \\
 &= [8840 + 19337.5] \text{ft.}^3 \\
 &= 28177.5 \text{ ft.}^3 \\
 &= 1043.6 \text{ yd.}^3
 \end{aligned}$$

$$\begin{aligned}
 \text{Total Volume before compaction} &= [8039 + 2009 + 1043.6] \text{yd.}^3 \\
 &= 11091.6 \text{ yd.}^3
 \end{aligned}$$

$$\text{Total Volume needed after compaction} = \frac{11091.6}{0.75} = 14788.8 \text{ yd.}^3$$

$$\text{Surface Area} = 4.16 \text{ acres} = 181186 \text{ft.}^2 = 20131.7 \text{yd.}^2$$

$$\begin{aligned}
 \text{Depth of Excavation} &= \frac{14788.8 \text{yd.}^3}{20131.7 \text{yd.}^2} = 0.7346 \text{ yds.} \\
 &= 2.2 \text{ ft.}
 \end{aligned}$$

$$\text{Total Height} = 2.2 \text{ ft.} + 5 \text{ ft.} = 7.2 \text{ ft.}$$

That gives us a Free Board of 2.2 ft.

The cost of excavating and compacting 1 yd.<sup>3</sup> = \$1.00 (24).

#### A. Initial Costs

Total cost of excavation and compaction = \$14,788.80

Cost of control structure, Entrance structure, seeding,  
Sterilization, pipes, sewers, and other items. = \$16,000.00

SUBTOTAL = \$30,788.80

## A. Initial Costs (cont.)

Cost of Land	= \$ 8,000.00
Engineering Fee (8 percent)	= \$ 2,463.00
Legal Fee (3 percent)	= \$ 923.66
Administration (2 percent)	= \$ 615.77
Construction Inspection (6 percent)	= \$ 1,847.33
O and M Manual	= \$ 1,000.00
<b>TOTAL</b>	<b>= \$45,638.66</b>

$$\begin{aligned}
 \text{Cost per year @ 6 percent for 24 years} &= \$45,638.66 \left( \frac{A}{P}, 6\%, 24 \right) \\
 &= \$45,638.66 \times 0.07968 \\
 &= \$ 3,635.50
 \end{aligned}$$

## B. Annual Operational Costs

Operator 10 hr/week x 52 weeks x \$3.00/hr	= \$ 1,560.00
Maintenance and Repairs @ 2 percent of \$30,788.80	= \$ 615.50
<b>TOTAL</b>	<b>= \$ 2,175.50</b>

## C. Total Annual Cost

$$\$3,636.50 + \$2,175.50 = \$ 5,812.00$$

## COMPARATIVE COSTS AND FACILITY SELECTION

<u>Treatment Type</u>	<u>Total Constr. Cost</u>	<u>Annual Constr. Cost</u>
Activated Sludge	\$65,415.50	\$5,212.30
Nonoverflowing Pond	\$45,638.66	\$3,636.50

<u>Treatment Type</u>	<u>Annual Operational Cost</u>	<u>Total Annual Cost</u>
Activated Sludge	\$3,880.00	\$9,092.30
Nonoverflowing Pond	\$2,175.00	\$5,812.00

Since both the treatment systems will satisfactorily treat the wastewater, economics will control the design selection. For this reason, the nonoverflowing stabilization pond has been selected as the best possible facility for the theoretical town. Moreover, this type of treatment guarantees no pollution to the waters of the town and, at the same time offers optimum treatment of the wastewater.

Location

The site will be located as far as possible from human habitation or from any area which may be built up within a reasonable future period. The site will meet all building separation requirements as set forth by the Kansas Department of Health and Environment. Moreover, it shall be so located that the local prevailing winds will blow from the pond to uninhabited areas.

Construction Methods

All dikes and pond floors will be compacted to adequate densities. Cells I and II will be sterilized to the maximum operating level of 5 feet. Cell III will be planted entirely to grass until it is put into operation where upon it shall also be sterilized to the 5 feet level.

All dike backslopes will be seeded to native grass. Dike toeslopes, down to the maximum operating level, will also be seeded to grass. The grass not only offers a pleasant appearance, it also assists in dike erosion control. All dikes will have 3.5 horizontal to 1 vertical slopes to facilitate mowing operations.

Suitable level control structures will be constructed to insure that flow may be controlled between cells. Initial operation will be to Cell I only. When Cell I reaches 5 feet level, the transfer structure to Cell II will be opened. At the same time, the 5 feet level in Cell I is maintained. Cell III will be used when required.

The inlet structure shall be equipped with a V-notch weirs to facilitate the measurement of flow. All cells will contain a fiberglass post which will be marked at 0.5 feet intervals to facilitate measurement of water level.

The entire area shall be fenced to discourage trespassers. Adequate warning signs will be provided on the fence to inform the public as to the nature of the treatment facilities.

## FINANCING

Cost of Total Treatment Facility	= \$45,638.66
Cost of Land	= \$ 8,000.00
Financing Eligible for Grant	= \$37,638.66
EPA Grant (75% of Eligible Grant)	= \$28,229.00
Theoretical Town's Share	= \$17,409.66
Cost/Year @ 6 percent for 24 yrs. = $\$17,409.66 \left(\frac{A}{P}, 6\%, 24\right)$	
	= $\$17,409.66 \times 0.07968 = \$1,387.20$

A summation of the annual costs for the town are as follows:

Construction Cost/Year	= \$ 1,387.20
Operator Wages	= \$ 1,560.00
Replacement, Repairs, Maintenance	= \$ 615.80
<b>TOTAL</b>	<b>= \$ 3,563.00</b>

Assuming that there are 150 water connections in the town:

$$\begin{aligned} \text{Cost/User} &= \frac{\$3,563.00}{150} = \$23.75/\text{year} \\ &= \$ 1.89/\text{month} \end{aligned}$$

It is suggested that an initial charge of \$2.50 per/user/month be levied. Income would be as follows:

Total Income (150 users/\$2.50/month)	= \$4,500.00/year
Total Expenditure	= \$3,563.00/year
Reserve	= \$ 937.00/year

Adjustments of the monthly rate can be made after a period of time if the reserve so dictates. This adjustment may be either an increase or decrease in the service charge.

Operation and Maintenance Manual

The town shall be required, as part of Environmental Protection Agency's grant assistance, to provide an operation and maintenance manual for the facilities. This manual will outline all operation and maintenance requirements for the stabilization pond.

## CONCLUSIONS

This study reveals that stabilization ponds provide simple, economical and low maintenance waste treatment for small communities. However, the degree of treatment possible with ponds may be inadequate to meet future discharge standards. Therefore, a definite need exists to develop a system which can simply, and economically, upgrade the pond effluents to a level which satisfies future discharge requirements. The problem of polluting the waterways can be completely eliminated by building the non-discharging stabilization ponds.

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WASTE TREATMENT STABILIZATION PONDS

by

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B.S., Peshawar University, Pakistan, 1974

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AN ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Civil Engineering .

KANSAS STATE UNIVERSITY  
Manhattan, Kansas

1976

## ABSTRACT

The purpose of this study is to gain knowledge about stabilization ponds which is an economical type of waste treatment method for moderate sized communities where cheap land is available. A stabilization pond for a theoretical town has been designed and its cost estimates have been compared with an Activated Sludge Treatment Method. Treatment by stabilization pond is found to be more economical.

In U.S.A., stabilization ponds are used quite extensively. In 1968, treatment systems in the general category of "Stabilization Ponds" constituted 34.7% of the 9,951 secondary treatment systems operating in this country. Stabilization ponds served 7.1% of the 85,600,000 people served by secondary treatment plants. 90% of these ponds were in communities having a population of 10,000 or less.

Stabilization ponds have already been built in at least 35 countries. These include over 20 developing countries, and are being planned in several others.