FOURTH ALL INDIA TRAINING COURSE ON WASTE STABILISATION POND PRACTICES

11th - 18th SEPTEMBER
1975, MADRAS

Sponsored By

CENTRAL PUBLIC HEALTH AND ENVIRONMENTAL
ENGINEERING ORGANISATION, NEW DELHI

Conducted By

TAMILNADU WATER SUPPLY AND
DRAINAGE BOARD, MADRAS

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Central Public Health and Environmental Engineering Organisation, New Delhi

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Tamil Nadu Water Supply and Drainage Board, Madras

Dear Mr. Delegate, 9.9.1975

We welcome you to participate in the Fourth All India Training Course on Waste Stabilisation Pond Practices conducted by the Tamil Nadu Water Supply and Drainage Board on behalf of the Central Public Health and Environmental Engineering Organisation of the Government of India.

As you know this course is being sponsored by the Government of India with a view to refresh and familiarise the Senior Practising Public Health Engineers with the recent developments and current trends in the area of treatment of waste waters using the stabilisation ponds process. While we on our part are taking every step to make available the best skill and knowledge available in this area during the course, for your benefit, wewould very much appreciate if you can actively participate in the proceedings of the course and share with us and fellow delegates your varied experiences in this field. Such a participation you would agree would go a long way in making your trip as well as this course a success.

Enclosed at the end of the volume, please find two forms one for the joining and relief certificate and the other for your assessment of the various aspects of this course. The assessment form may please be filled up with a view to offer suggestions about improving the course for next year. The completed forms may be returned to us on the afternoon of 18-9-1975.

On the lighter side however, we are glad to invite your to the city of Madras which has always made a dear friend of every visitor. You will find useful information about the city as well as this part of the country in the brocheurs which come to you with the compliments, of the Indian Tourism Development Corporation. We are sure you will find these brocheurs illustrative, inviting, and rewarding. It may well lure you to plan a subsequent holiday and be with us for a little more time to enjoy our hospitality and in the process give us the chance to make a dear friend of every one of you.

Wishing you all the best during your stay with us,

Yours sincerely,

for TAMIL NADU WATER SUPPLY & DRGE.BOARD

FOURTH ALL INDIA TRAINING COURSE ON WASTE STABILIZATION

POND PRACTICES

11th to 18th SEPTEMBER 1975, MADRAS.

P R O G R A M M E

Date	Time	Topics
11-9-1975	10-00 to 10-30	Registration
	10-30 to 11-30	Inauguration by Thiru K.Govinda Menon, Chief Engineer, TWAD Board, Madras.
	11-30 to 11-45	Break
	11-45 to 12-45	Lecture :- Fundamentals of Waste-Water Treat ment. Raman
	12-45 to 2-00	Break
	2-00 to 4-30	Field Visit - Kodungaiyur Research Unit.
12-9-1975	9-30 to 11-00	Lecture - Microbiology of Waste Water Treatment. Damodar Rao
	11-00 to 11-15	Break
	11-15 to 12-45	Lecture - General Features of Waste Stabilization Ponds.
	11-45 to 2-00	Break.
	2-00 to 4-30	Field visit - Madras Refineries Limited.
13-9-1975	9-30 to 11-00	Lecture - Construction of Waste Stabilization Ponds.
	11-00 to 11-15	Break.
	11-15 to 12-45	Assignments.
	12-45 to 2-00	Break.
	2-00 to 4-30	Group Discussions.
14-9-1975	HOLIDAY -	SUNDAY
15-9-1975	9-30 to 10-30	Lecture - Aerated Lagoons. Construction (21) Srinivasan
	10-30 to 11-30	Lecture - Health Aspects Waste Stabilization Ponds. Shastri
	11-30 to 11-45	Break.

Operation & Maintenance Damodar Rao.	11-45 to 12-45	Lecture - Monitoring Effluent Disposal from Waste Stabilization Ponds - A conceptual outline.
	12-45 to 2-00	Break
Nesapakkam	2-00 to 4-30	Field Visit - Kodungaiyur Sewage Reclamation Research Unit.
16-9-1975	9-30 to 11-00	Lecture - Natural Factors - Controlling Waste Stabilization Ponds Performance.
11 & 12 Sundaramurthy		
	11-00 to 11-15	Break.
	11-15 to 12-45	Lecture - Design of Waste Stabilization Ponds.
	12-45 to 2-00	Break
	2-00 to 4-30	Field Visit - Engineering College Ponds. I.I.T. and C.P.T. Ponds.
17-9-1975	9-30 to 10-30	Lecture - Upgrading Waste Stabilization Pond Performance.
	10-30 to 11-30	Lecture - Some Special Aspects of Waste Stabilization Ponds.
	11-30 to 11-45	Break
	11-45 to 12-45	Lecture - Operation and Maintenance of Waste Stabilization Ponds.
	12-45 to 2-00	Break.
	2-00 to 4-30	Field Visit - Madras City Sewage Treatment Plant at Nesapakkam.
18-9-1975	9-30 to 10-30	Lecture - Anaerobic Ponds for Treatment of Domestic Sewage.
	10-30 to 11-30	Lecture - Waste Stabilisation Ponds for Industrial Wastewater Treatment.
	11-30 to 11-45	Break.
	11-45 to 12-45	Lecture - Utilisation of Effluents from Waste Stabilization Ponds.
	12-45 to 2-00	Break
	2-00 to 4-30	Delegates' session.
	4-30 to 4-45	Break.
	4-45 to 5-30	Valedictory.

FOURTH ALL INDIA TRAINING COURSE ON

WASTE STABILISATION POND PRACTICES

C O N T E N T S

DESIGNATIONS OF AUTHORS

NAME OF AUTHORS		DESIGNATION
P. Balakrishnan	...	Junior Water Analyst, Kodungaiyur Sewage Reclamation Research Unit, TWAD Board, Madras.
T. Damodara Rao.	...	Executive Engineer, Tamil Nadu Water Supply and Drainage Board, Madras.
S. Muthuswamy.	...	Lecturer in Public Health Engineering, College of Engineering, Guindy, Madras.
S. Perumal.	...	Junior Engineer, Kodungaiyur Sewage Reclamation Research Unit, TWAD Board, Madras.
Dr. R. Pitchai.	...	Professor, Public Health Engineering Department, College of Engineering, Guindy, Madras.
A. Raman.	...	Deputy Chief Engineer, Tamil Nadu Water Supply and Drainage Board, Chepauk, Madras.
Dr. C.A. Sastry.	...	Scientist-in-charge, N.E.E.R.I.Zonal Centre, CSIR Campus, Madras.
S. Srinivasan.	...	Executive Engineer, Tamil Nadu Water Supply and Drainage Board, Madras.

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R.M. Subramaniam.	...	Assistant Water Analyst, Kodungaiyur Sewage Reclamation Research Unit, TWAD Board, Madras.
S. Sundaramoorthy.	...	Assistant Engineer, Kodungaiyur Sewage Reclamation Research Unit, TWAD Board, Madras.
Dr. B.B. Sundaresan.	...	Professor-in-charge of Post Graduate Studies and Research, College of Engineering, Guindy, Madras.

MICROBIOLOGY OF WASTE WATER TREATMENT

T. DAMODARA RAO.

INTRODUCTION

Micro-organisms are very minute living things which can be readily distinguished under appropriate magnification. They are ubiquitious and leave their imprint in all places and activities. Their action has vital significance in waste water treatment. Some aspects of this is discussed below.

CLASSIFICATION OF MICROORGANISMS

The living things in the world can usually be divided into two general broad groups, the plants and the animals. The plants are distinguished by their ability to manufacture their own food, presence of chlorophyll and capacity for photosynthesis. The animals are parasitic, have no chlorophyll, have no capacity for photosynthesis. There is another group which can neither be placed in the category of animals nor plants. This group is referred to as protista and a major part of micro-organisms come under this class. A number of microorganisms such as crustacea, rotifers, protozoa etc. come under the category of animals. Bacteria, molds, yeasts etc. come under the group of protista. Algae come under the category of plants. The basic unit of life is the cell. All living things are made up of these. Microorganisms are either unicellular or multicellular.

THE STRUCTURE OF CELL

The cell consists of protoplasm and other bodies like nucleus, vacoules, protoplasts etc. which are contained within by a cell wall. The nucleus consists of Deoxyribonucleic acid (DNA) that contains genetic information for reproduction of identical cells. The cell may contain on

the exterior flagella, cilia and pod. The cell may also as in bacteria, the nucleus is not distinguishable separately.

There are submicroscopic particles, called Virus which are parasitic on the cells.

The cells absorbs the nourishment from the surrounding material by converting the surrounding material by enzymatic action. They give out some specific enzymes which convert the material to substances that can easily be absorbed by the cell. One example of enzymatic action is the action of human saliva on rice grains which are chewed. A sweet taste can be noticed after a while which is due to the enzyme in saliva converting the carbohydrate in the rice to sugar. The enzymes are a group of complex organic substances which are colloidal nature. They have action on specific substances only. The reaction can be represented below.

E	+ S ⟶	ES	⟶	E, +	S
substance	Enzyme	Substance Enxyme Complex		Product	Enzyme

It can be seen that after the reaction, the enzyme is available for further use.

Most of the activities concerned with living are enzymatic in action. The substances that are involved in nutrition are converted by means of the enzymes to products that are directly used up for living, i.e. metabolism. This again can be subdivided into the production of energy called catabolism and building up of new cells which is called anabolism.

For both purposes, the nutrients available in the surrounding environment is extracted and used by the microorganisms.

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Some of the important reactions are given below.

1. Poly saccharides + water Polysaccharidase Disacharides
$2(C_6H_{10})_5)$ + x H_2O ⟶ x $(12H_{22}O_{11})$

2. Disaccharide + Water Disaccharidase Monasaccharides
$x(C_{12}H_2)_{11}$ + H_2O ⟶ 2 x $C_6H_{12}O_6$

3. Starch + Water Amylax Maltose
$2(C_6H_{10}O_5)$ + x H_2O x $C_{12}H_{22}O_{11}$

4. Maltose + Water Maltase Glucose
x $C_{12}H_{22}O_{11}$ + x H_2O $2xC_6H_{12}O_6$

In case of cellulose

5. 2(Cellulose $C_6H_{10}O_5$) + Water + x H_2O Cellulase ⟶ Cellobiose

6. Cellobiose $xC_{12}H_{22}O_{11}$ + water + x H_2O Cellobiase ⟶ Glucose 2 x $C_6H_{12}O_6$

7. Alchholic fermentation
$C_6H_{12}O_6$ ⟶ 2 CO_2 + 2 C_2H_5OH + 26 Calories

8. Lactic acid fermentation

Glucose $C_6H_{12}O_6$ Enzyme ⟶ Lactic acid + energy
2 $C_3H_6O_3$ + 18 cal.

9. Partial oxidation of alcohol

Alcohol + Oxygen Enzyme ⟶ acetic acid + energy
$2C_2H_5OH$ + O_2 $2CH_3COOH$ + $2H_2O$ + 232 calories

10. Complete oxidation of acitic acid
Acetic acid + Oxygen Enzyme ⟶ Carbon dioxide + Water + Energy

$2CH_3HOOH$ + CO_2 4 CO_2 + 4 H_2O + 416 calories.

11. Complete oxidation of acitic acid.

Lactic acid + oxygen Enzyme Carbondixide + Water + Energy.
2 $C_3H_6O_3$ + 6 O_2 = 6 CO_2 + 6 H_2O + 656 calories.

12. Complete oxidation of glucose

Glucose + Oxygen $\xrightarrow{\text{Enzyme}}$ Carbondioxide + Water + Energy

$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O + 674$ calories

13. Glucose $\xrightarrow{\text{Enzyme}}$ butyric acid + Carbondioxide + Hydrogen

$C_6H_{12}O_6 \rightarrow C_4H_8O_2 + 2\ CO_2 + 2H_2$

14. Acetic acid $\xrightarrow{\text{Enzyme}}$ Methane + Carbon dioxide

$CH_3COOH \rightarrow CH_4 + CO_2$

15. $2\ NH_3 + 3\ O_2 \xrightarrow{\text{Enzyme}} 2\ HNO_2 + 2H_2O + 157.6$ cal.

16. $2\ HNO_2 + O_2 \xrightarrow{\text{enzyme}} 2\ HNO_3 + 36.6$ calories.

17. $2\ H_2S + O_2 \xrightarrow{\text{Enzyme}} 2S + 2H_2O$ + Energy.

18. $2H_2S + 4\ O_2 \xrightarrow{\text{Enzyme}} 2H_2SO_4$ + Energy.

MICROBIAL GROWTH PATTERN

The micro-organisms exhibit a welldefined growth pattern when the conditions in the environment such as food, temperature, oxygen availability, reaction etc. are most favourable to them. Since in a liquid, these factors will be changing, the micro-organisms most suited to the existing set of environmental conditions only can increase in numbers at the moment. As such, there is a preponderence of particular bacterial fauna depending on circumstances. This is likely to change as soon as the environment alters.

If any one particular group is considered, there is an initial lag. This lag is due to the micro-organisms of that particular group getting adjusted to the environmental conditions. There is a very rapid growth on a logarithmic rate of increase. This quickly exhausts the food matter. The rate of increase starts reducing and becomes zero. This phase is referred to as the declining growth rate phase. After this there is neither increase in numbers or decrease.

Even at this rate the food available is insufficient. In this states, the micro-organisms have to destroy themselves to exist. There is a reduction in numbers. This is referred to as the endogenous phase. The bacterial numbers become so small that they can exist in small numbers with food that may be available in small amounts.

ENVIRONMENTAL FACTORS AFFECTING MICROORGANISMS

Some of the factors in the environment affecting micro-organisms an discussed below:-

i. <u>Oxygen</u> The reaction that take place for release of energy is Oxidation of organic matter. When atmospheric oxygen is used for the purpose, large quantities of energy are released and the products are CO_2 and H_2O. This is referred to as aerobic action. The microorganisms which are responsible for this are called aerobic organisms. In the oxygen required for the reaction is abstracted from certain compounds like nitrates and sulphates, the reaction does not occur in full. There is a part utilisation of the energy. The end products are CO, NH_3 and CH_4 and H_2S. This reaction is referred to as anerobic. The organisms responsible are called anaerobic micro-organisms. There are another group of organisms that rearrange the molecular structure of the substance itself in such a way as to derive energy for its use. This process is called fermentation. Organic acids are produced in this reaction. Certain micro-organisms can act aerobically if atmospheric oxygen is present and anaerobically in its absence. These are said to be facultative. In nature many micro-organisms belong to this group. In the metabolic activity of all the microorganisms carbondioxide comes out due to the respiration of the microorganisms.

ii. Temperature The microorganisms can also be divided into psychrophilic group i.e. thriving in cold temperatures i.e. 4°C-20°C. It is usual for these to microorganisms to be present in cold lake water. The mesophilic microorganisms are predominant between 20°C to 50°C. They are normally present in domestic waste waters as well as other wastes. The theromophilic microorganisms thrive at high temperatures of 50°C - 65°C. These are above to act fast and bring about substantial reduction in organic content. Aerobic composting is one of the examples when they are very useful.

All microorganisms which are capable of manufacture their own food are called autotrophic organisms. Algae which come under this class may be single celled or multiple-celled. They use the carobondioxide available in dissolved from in water and with sunlight synthesise fresh cell matter.

CO2 + H20 + Sunlight --- (CHO) + O_2

In the process oxygen is released.

Some microorganisms can be autotrophic while using inorganic substances such assulphur.

When microorganisms use carbon available in organic matter they are referred to as heterotrophic. Some of them use organic matter derived from dead organisms and are called saphrophytic. Many organisms of significance in sewage treatment belong to this group.

iii. Reaction The concentration of hydrogen ion in any solution decides its pH value. For satisfactory microbial activity, suitable pH must exist. Usually microbial activity thrives when the pH is near the neutral value of 7.0 A low pH value is actually taken as indication of poor microbial activity. The activity of micro-organisms bring about flocculation and sedimentation and result in making the effluent more acceptable. An alteration in pH is actually an indication that there is discription in the desired microbial activity.

MICROORGANISMS ASSOCIATED WITH MUNICIPAL WASTES

The wastes derived from domestic sources usually have a fairly high amount of organic matter. Together with this, microorganisms associated with human intenstines soil, atmosphere etc. also are present. Some of these microorganisms are aerobic, some are anaerobic and some facultative.

If the sewage is allowed to stand, it will be noticed that initially aerobic organisms dominate for some time until the dissolved oxygen in sewage is usedup. After that the aerobic organisms become dominant. These reduce the nitrates, the sulphates which results in production of NH_3 and H_2S. Besides these, there is also production of certain organic substances such as mercaptens etc which may give rise to odours which are objectionable. The rate of destruction of organic matter is rapid in aerobic conditions and slow during anaerobic action.

To support microorganisms organic matter, nitrogen and phosphorus are necessary. For aerobic organisms it will be in the ratio of 100: 5: 2 and for anaerobic microorganisms 100 :2.5:1. Thus it can be seen that anaerobic action can take place more easily in wastes that are poor in nitrogen and phosphorus. During aerobic conditions, the organic component of the sewage is used up both for building up of the microorganisms and their respiration. The nitrogen component of the proteins gets converted to nitrates. This conversion to nitrate referred to as nitrification is an important index for aerobic activity. In anaerobic activity there are two distint phases. In the first phase, the solids in suspension are hydrolysed and go into solution. This is referred to as to liquefaction. In the second phase, the liquified matter is converted into gases. This is referred to as gasification.

Treatment of waste water can be achieved by aerobic processes such as activated sludge process, trickling filter treatment, aerobic pond etc. Usually the space required for aerobic units is small and to achieve a high quality effluent aerobic processes only will be useful. Anaerobic processes such as treatment in septic tank, anaerobic pond etc can be adopted when conditions for aerobic treatment are not found. Anaerobic treatment is very useful in reducing the initial high load of industrial effluent to levels where aerobic processes can be adopted.

Waste stabilisation ponds commonly adopted for treatment of domestic wastes combine anaerobic action in the lower portion where by the carbondioxide released is used by algae in the toplayer for photosynthesis. The release of NH_3 in lower portion will activate bacteria in the aerobic layer. This in turn will encourage formation of algal cells. The oxygen released in photosynthesis in the aerobic zone will increase bacterial population thereby increasing formation of carbon-dioxide and nitrogen compounds. This cyclic interdependence resulting in mutual benefit for aerobic bacteria and algae is called symbiosis and results in stabilisation of wastes.

CONCLUSION

The microorganisms which are found everywhere can be used for treatment of wastewaters. The environment best suited for the different groups of microorganisms can be provided in suitably designed treatment units. If their action is understood, it will be easy to recognise and correct any abnormalities that may be responsible for proper treatment of the wastes.

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GENERAL FEATURES OF WASTE STABILISATION PONDS

A. RAMAN.

INTRODUCTION

Stabilisation ponds are engineered impoundments in which organic waste material is detained for a sufficient time to effect its stabilisation. Stabilisation ponds do not employ any equipment and rely purely on natural forces for effecting purification. The detention in the ponds will be quite long compared to detention in conventional sewage treatment processes like activated sludge plants and trickling filters and will be measurable in days rather than hours.

Stabilisation ponds may be used to treat either domestic sewage or industrial wastes. The present discussion is mainly in regard to the use of waste stabilisation ponds for treating domestic sewage.

Stabilisation ponds can function successfully in all climates where sunshine is good and temperatures are not too low. The method will, therefore, be suitable for most regions in India.

The method has several advantages over other methods of sewage treatment. Stabilisation ponds do not require any equipment and can be constructed with local labour and local materials. They require little skill for operation and maintenance. They are also cheap to construct.

Sewage stabilisation ponds may, therefore, be more advantageous than conventional plants like trickling filters and activated sludge plants for our country. However, the method will require more land than other methods of sewage treatment and may be suitable only in cases where sufficient land is available and the land is not too costly and also when the quantity of sewage to be treated is not too large.

HISTORY AND STATUS

The use of ponds for the disposal of human wastes dates back to antiquity. It has been reported that in Persia, as early as 800 B.C., storage ponds for irrigation were used as receptacles for human wastes. The moats surrounding old fortresses must have functioned also as ponds for receiving and treating the wastes from the community inside. The village tanks in India receiving pollution from various sources may also be taken as unintended stabilisation ponds.

The first instance of ponding as a scientific method of waste treatment occured at Santa Rosa, California, USA. There, in 1924, sewage was discharged into a gravel seepage plot. The gravel bed soon clogged and began to function as a sewage pond giving a stabilised effluent low in BOD. Shortly thereafter ponding of sewage was carried out intentionally in Vacaville, Sonoma and Calistoga in California. The method soon found acceptance in the other states of the U.S.A. and was widely used for army camps in the war years. At present, stabilisation ponds have been widely used in Australia, South Africa, Kenya and New Zealand. Use of the method has also been reported in a few cases from such cold countries as Canada, Sweden and the Netherlands.

The first stabilisation pond to be constructed in India was probably in 1956 at the Engineering College Campus, Guindy, Madras, to treat the campus sewage. The simplicity of the system and the high degree of purification effected by it attracted much notice at that time. Subsequently in 1959, an oxidation pond was constructed at Tambaram near Madras in preference to a trickling filter for secondary treatment of the effluent from the septic tank of a T.B.Sanatorium.

$C_2H_4O_2 + O_2 \rightarrow CO_2 + H_2O$

$K_2Cr_2O_7$ = Potassium Bichromate

In 1970, it was reported that there were 50 stabilisation ponds in the country. The number must be much higher by now. In Tamil Nadu itself, there are now over 12 small-sized installations serving educational institutions, industrial townships, housing colonies and hospitals and there are also four municipal installations.

PROCESSES OF PURIFICATION

The processes effecting purification in stabilisation ponds are essentially the same as the processes involved in conventional sewage treatment. These processes may be grouped under anaerobic digestion and aerobic oxidation.

In anaerobic digestion, under favourable conditions such as temperatures above 20°C, near-neutral p^H, and absence of dissolved oxygen, anaerobic methane bacteria will remove organic matter according to equation 1 which is in a simplified form with the intermediate steps omitted.

$$(CH_2O) \text{ ---- } \frac{x}{2} CH_4 + \frac{x}{2} CO_2 \quad \ldots\ldots \quad (1)$$

The end products of the reaction are carbon-di-oxide and methane. (Ammonia is also evolved during the process due to the break-down of proteinaceous matter; but, it is not included in the equation as it does not exert any oxygen demand as in the stabilisation pond due to absence of any significant nitrification). The methane escaping during the process represents removal of organic matter from the system. Sixteen (16) grams of methane evolved in the process means the removal of 64 grams of ultimate BOD as can be seen from equation 2 below:

$$\underset{(16)}{CH_4} + \underset{(64)}{2O_2} \text{ ---- } CO_2 + 2H_2O \quad \ldots\ldots \quad (2)$$

In aerobic oxidation, the organic matter is destroyed i.e., BOD satisfied, according to equation 3. (In this simplified equation also, the role of ammonia has been neglected).

$$(CH_2O)_x + XO_2 \quad ---- \quad XCO_2 + XH_2O \quad ,.... \quad (3)$$

It will be seen that the aerobic reaction requires the supply of free oxygen. In ponds, the oxygen is supplied by photosynthetic oxygenation and surface aeration.

Photosynthetic oxygenation is brought about by algae during sunlight. The CO_2 produced by bacteria in equation 3 is utilised by the algae during sunlight for cell synthesis, evolving oxygen in the process as in the simplified equation 4 below.

$$X(CO_2) + X(H_2O) \xrightarrow{\text{Light}} (CH_2O)_x + XO_2 \quad .... \quad (4)$$

The oxygen is utilised by the bacteria for their aerobic metabolism as in equation 3. It may be seen that there is a mutual dependance between bacteria and algae in equations 3 and 4. This is usually referred to as the algae-bacteria symbiosis in oxidation ponds. It will be obvious that the quantum of photosynthetic oxygen produced in stabilisation ponds will be dependent on the light incident on the surface and therefore on the surface area of the pond.

Surface aeration implies the diffusion of oxygen into a body of water at the air-liquid interface. Without the aid of mechanical stirring, surface aeration is a slow process, and may contribute only about 20 kg of oxygen/hect/day. The factor is, therefore, usually neglected and photosynthetic oxygenation is considered to be the main source of oxygen in an stabilisation pond.

TYPES OF PONDS

It has been explained that aerobic oxidation and anaerobic digestion are the processes of purification in Stabilisation ponds. The ponds may be designed for widely varying degrees of aerobic and anaerobic activities and they may be classified depending on the degrees of such activities.

Ponds which are designed to function only anaerobically are termed as anaerobic lagoons. Ponds which are designed to permit both aerobic and anaerobic activities are classified as facultative ponds or more usually oxidation ponds. Stabilisation ponds which are intended to function only aerobically are called aerobic ponds.

The above classifications are based on function variations. These apart, stabilisation ponds have also been frequently classified depending on whether they treat raw sewage, settled sewage or the effluent from full scale conventional treatment plants. The respective classifications have been raw sewage ponds, settled sewage ponds and polishing lagoons or maturation ponds.

ANAEROBIC PONDS

Anaerobic ponds treat screened and degritted raw sewage. In anaerobic ponds, anaerobic conditions are maintained by restricting the surface area which may be as low as 1 hect. for 400 - 1000 kg of influent BOD_5/day. The depths used range from 1 m to 5 m.

Anaerobic ponds are characterised by glassy grey colour and by some amount of scum. The pond appearance may not be pleasant and the ponds may give off some odours. The pond may effect BOD and suspended solids reductions of 50 - 75%. The effluent will be devoid of dissolved oxygen and will carry some sulfides. The bacterial reduction in the pond may not be very high.

FACULTATIVE PONDS

Facultative ponds generally treat only raw sewage (after screning and grit removal). The suspended organic matter and the colloidal organic matter (which gets bioflocculated) in the influent settle to the bottom of the pond and undergo anaerobic digestion. The dissolved organic matter remains in the liquid layers and gets stabilised aerobically. The general process is shown in Fig.1. No doubt, there may also be some diffusion of the products of partial digestion of the sludge into the aerobic layers. Similarly, there may also be some transfer of the soluble organic matter to the anaerobic sludge layers in the form of biomass settling down.

For successful functioning, facultative ponds require adequate surface area so that aerobic conditions are maintained in the top layers by photosynthesis. The surface area is usually about 1 hect. for 100 - 300 kg. of influent BOD_5. The depth ranges from 0.9 to 2.0m

Facultative ponds have a green colour due to the presence of algae. The pond will generally be aerobic in the top layers. Dissolved oxygen tests on the pond show a diurnal variation with a minimum value at day break, maximum value at midday and again a decline towards sunset. The maximum midday D.O. values may be as high as 30 or 40 ppm, i.e., about 400 - 500% supersaturation depending on sky clearance. The minimum value may touch zero during nights or at day-break.

The p^H value in the pond will exhibit a diurnal variation similar to dissolved oxygen. The peak value may be well above 8.3 and may occassionally rise above 9.0 during midday.

The minimum value may be well above the p^H value of the influent sewage and near about 8.0.

The diurnal variations in dissolved oxygen and p^H in the ponds are the direct result of variations in photosynthetic depending on light intensity. The overall increase of pH in the pond can be attributed to the removal of the CO_2 in solution by algae during photosynthesis.

Due to aerobic conditions created by algal photosynthesis, facultative ponds may not exhibit any great odour problem. Even at night or during cloudy weather when dissolved oxygen disappears in the pond, the odour problem may not be significant.

The BOD and the suspended solids in the facultative pond effluent may be high compared to effluents from trickling filters and activated sludge plants. For example, the BOD and S.S. in the effluents from conventional treatment plants. The algal cells instead of causing oxygen deplection may actually cause D.O. to rise in the receiving waters.

To estimate the actual putrescible organic matter left over in ponds, it will be necessary to filter out the algae from the effluent and perform the BOD test on the filtered sample. The standard practice for BOD tests on oxidation pond samples is to filter the samples through No.42 Whatman's Filter Paper. The percent purification in a successful facultative pond based on filtered effluent BOD may exceed 80% most of the time. There may be considerable bacterial reduction in facultative ponds and the effluent may generally be free of pathogenic bacteria.

AEROBIC PONDS

Aerobic ponds generally treat sewage which has been settled or otherwise pretreated so that sludge accumulation may be reduced. The surface area of the pond may have to be comparitively large to provide enough oxygen to satisfy the entire influent BOD and maintain aerobic conditions for the full depth of the pond. The surface area is usually about 60 kg/hect/day. The depth is usually kept small at 0.9 m to enable full penetration of sunlight.

Polishing lagoons treating secondary effluents from conventional sewage treatment plants may also be considered as aerobic ponds. Aerobic ponds present no chance of odours as they will carry dissolved oxygen all the time. The purification in the ponds may well exceed 90%.

APPLICATIONS OF DIFFERENT TYPES OF PONDS

Anaerobic ponds, facultative ponds, and aerobic ponds from the types of ponds under consideration here.

Anaerobic ponds are not suited when the pond effluent has to be discharged into a water course or lake. The method may not also be suited when the installation has to be close to communities. But, the method may be suitable as a cheap and simple pretreatment device for sewage farming when the farm is located well away from communities and smell and apperance are not, therefore, of much concern.

Facultative ponds are well suited for treatment of sewage when the effluent has to be discharged into water-courses or lakes. They may also be useful as pretreatment devices for sewage farming when the pond and the farm have to be located close to communities. Stabilisation ponds may be ideal treatment devices for small communities like hospitals, college campuses and townships. The method is also suited for municipalities when land costs are not prohibitive. Facultative ponds may also be ideal as interim treatment methods for municipalities when due to lack of finance in due to the meagre flow in initial stages it is considered inexpedent to construct the conventional treatment plants envisaged ultimately.

Aerobic ponds may require much greater area than facultative ponds and they may not therefore have much general application. Aerobic polishing ponds may have application when a greater degree of purification is required than can be achieved in conventional treatment plants e.g. where the effluent has to be discharged into a stream which has only small flows and is used lower down for water supplies or other sensitive purposes.

Of the various types of ponds mentioned above, the facultative type oxidation pond has the greatest application in waste stabilisation pond practice and the discussions in the subsequent papers are directed mainly towards this type of pond.

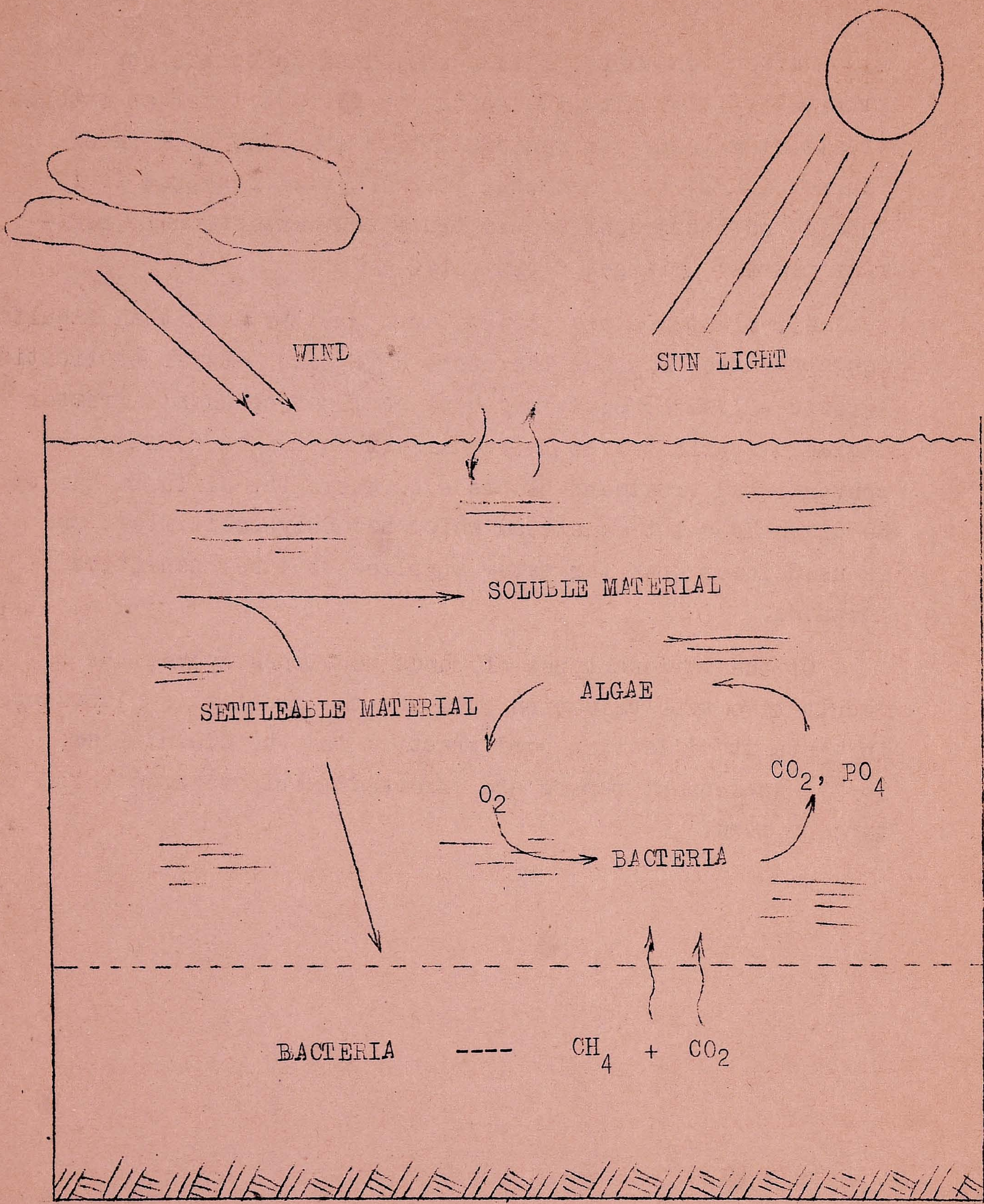

FIGURE 1 WASTE STABILISATION POND PROCESS

CONSTRUCTION OF WASTE STABILIZATION PONDS

S. SRINIVASAN.

PREFATORY

In this article it is proposed to detail the steps to be taken for the construction of the stabilization ponds after the design is completed. Although they are simple, it is necessary to give care to every detail of the construction in order to ensure economy and durability as well as good performance

2. SITE SELECTION

Site selection is particularly important when waste stabilization ponds are contemplated. The terrain must be such that the pond or ponds will meet the shape and size requirements of the process design. A topographic map of the site, showing contours at not more than 30 cm intervals., is desirable except when the terrain is steep. Nearby utilities, industries, houses, special structures, and topographical features should be shown on the map.

Consideration must be given to nearby residential areas. The requirements concerning distance from residences are naturally dependent on local customs, climate, and the type of treatment process planned. The permissible distance from the pond to a residence is determined largely by the loading applied to the pond, the adequancy of design and the standard of maintenance provided. In some cases residences have been located within 100 m of well-designed and well-operated facultative ponds. Greater distances are needed for anaerobic systems. In our country, it is considered good practice to locate facultative ponds at least 150 m from small residential colonies and 450 m from large residential areas. In the USA a minimum distance of 0.5 - 1km between a pond and a housing development is customary.

2.2. SURFACE DRAINAGE

Special attention must be paid to drainage requirements. The pond system must protect inlet and outlet devices and other features which can be damaged or destroyed by flood waters and accompanying debris. Flood waters containing large amounts of sediments may, through deposition and erosion, completely destroy an inadequately protected waste stabilization pond. Of equal importance is the drainage of normal stormwater runoff. If rainwater cannot be drained, dikes may deteriorate, insects may breed in the puddles, excessive and unwanted vegetation may grow, and maintenance requirements will increase sharply. Suitable catch water channels are necessary.

2.3. FUTURE EXPANSIONS

The site must be large enough for any anticipated expansion. Since the size of waste stabilization ponds is fixed on the basis of present flow and load, it is very important that space be readily available for the addition of similar or different units as the need arises. Fig.1 furnishes a model layout of a typical stabilization pond for a drainage scheme wherein the proposed lagoon is to be constructed in such a way that an additional lagoon could be taken up in the save or lower contour as and when necessary.

2.4. NATURE OF SOIL

A relatively impervious soil formation would help to avoid percolation. Rates of percolation from ponds is influenced by many factors like permeability of soil, ground water elevation etc. observed percolation rates from field studies are naturally the resultant of these interacting variables. However, solids deposited slowly seal the pond bottom and once the pond has sealed itself, the percolation will attain a low steady rate.

2.5. GROUND WATER TABLE

Knowledge of the ground water table at the proposed site of pond helps to decide the elevation of the pond since it is desirable to keep the pond elevation well above the ground water table so as to (i) avoid ground water pollution (ii) reduce difficulty in excavation and (iii) avoid possible reduction in efficiency of ponds due to the reduction in detention time brought about by the entry of ground water (2).

Ponds should be so located that drinking water wells are not within 20 meters of a pond. Contamination over longer distances from ponds located in fissured rocks, lime for-mations, limestores, or porous gravel deposits are however reported. Chemical pollutants generally travel longer distances unlike bacteria in normal soils and this factor should be taken into consideration in the location of ponds for industrial waste disposal.

3. SHAPE OF THE POND

The ponds can be oral, square rectangular or polygonal depending upon site contours. In case of rectangular ponds, it is common to have a length approximately three times the width. The ponds should be rounded off at the corners in order to minimise the accumulation of floating materials and creation of idle corners. There should be no islands or peninsulas or dead pockets in the pond.

4. NUMBER OF UNITS

In the case of large installations, it is advisable to have two or more small ponds in parallel than one big pond in order to have more facilities for repairs, maintenance, and flexibility in operation. For small ponds of less than half a hectare single units would suffice. Multiple units may include stand bye also. Ponds can be arranged either in series or in parallel. Parallel ponds give equal load distribution, where as series ponds have the reported advantage of producing superior effluents from the point of view of bacterial efficiency.

Series ponds imply high B.O.D. loading in the primary pond and relatively low B.O.D. loading in the secondary pond. Anaerobic conditions may tend to occur accompanied by some odour in the primary pond while aerobic conditions will prevail in the subsequent pond. The smaller the primary pond in relation to the secondary pond, the greater will be the tendency to have anaerobic conditions in the former. In the interest of avoiding anaerobic conditions in the primary pond, it is recommended that the primary pond be kept at about 65 to 70% of the total area.

5. FLOW MEASURING DEVICES

It is desirable to provide a flow measurement device wherever possible. Without influent flow measurements it is impossible to determine the loading of a pond system, and without effluent flow measurements it is impossible to determine the percolation and evaporation losses. If only one flow-measuring device can be provided, it is preferable to determine the volume of the influent.

A simple Vee Notch or a parshall flume or a weir is quite common, inlets carrying pretreated waste-waters though the Vee Notch is prefered due to simplicity. Although a weir is used, it is reported that grit and settleable organic solids do not present a major problem.

6. POND BOTTOM

The pond area should be cleared of all vegetation and debris. The pond bottom should be made as level as possible.

A tolerance of ± 10 cm could be permitted in the finished ground level. Where excessive percolation is anticipated as in the case of limestone and sandy gravel formation, sealing of pond bottom with a blanket of clayey soil or other local material should be considered. No special treatment is required for other soils.

7. EMBANKMENTS

The dikes (embankments) for large ponds should be constructed very carefully. There must be close supervision of the selection and placement of filling material, the measurement of moisture content, and compaction. Material containing organic matter, such as grass, must not be used in constructing the core of the embankment.

The method used for protecting the embankments will depend on the extent of protection desired and the type of material used. The outside of the embankment should be protected from erosion caused by surface run-off and wind action. Usually turf grasses will provide adequate protection; if not, some form of rock or gravel protection must be incorporated into the plans. It should be noted that the outside slope is free from weeds and trees. Appropriately graded rock, flat stone, precast concrete slabs, or some other suitable liner must be placed on the inside edge as a protection against wave action. Gravel can be used as a substitute for crushed rock, but small gravel has a tendency to move down a slope through wave action. Gravel has been used in conjunction with crushed rock or concrete mats to prevent erosion. In this state we have been using precast concrete slabs of 3 cm thick laid over gravel packing for paving inside slope.

The minimum embankment top width should be about 1.5 meters but should be increased to 3.0 meters if vehicular traffic is to be permitted for inspection purposes. Embankment slopes to be given are influenced by the nature of the soil, its stability during monsoon seasons, provision of pitching, turfing or otherwise. The outer slopes may range from 2 to 2.5 horizontal to 1 vertical while the inner may be 1 to 1.5 horizontal to 1 vertical, with lining. In soils of special nature inner embankment may also be of 2 to 2.5 horizontal to 1 vertical so that lining may be avoided, except for about 30 cm below and above the water line to resist the effect of wave action.

8. INLET ARRANGEMENT

The incoming sewer line may either bring the sewage by gravity, if contours permit, or by pressure line from a pumping station. From the inlet chamber the flow is generally carried well into the pond by means of a gravity inlet pipe laid at a constant slope on supports at intervals and terminating in a bend facing down-wards. A small concrete pad is usually required below the discharge point to act as a splash pad. Such a pad is made of about 1.2 m x 1.2m square or twice the diameter of the inlet pipe whichever is larger. The inlets may be simple or multiple depending upon the size of the pond and in any case should be submerged.

The inlet to a rectangular pond should be located at a point about one-third the length of the pond. There are however observations to show that complete mixing of the incoming sewage with the pond contents occures within a radius of about 15 meters from the inlet discharge, point. The important precaution to be observed in providing the inlet arrangements is to ensure that the incoming sewage is not discharged in the direction of the outlet thus encouraging short circuiting.

The main inlet chamber may be located as near the outer of the embankment as feasible and centrally with respect to the width of the pond. This will also permit designed distributions of flow between all the inlets when multiple inlets are necessary. Inlet chambers may accommodate the V Notch and the coarse screen may also be provided in the chamber of sewer lines directly discharge by gravity. Such coarse screens are not necessary for discharge by pumping mains since only screended sewage is pumped. The floor level of the inlet chamber should be kept higher by atleast 30 cm than the water level in the pond to ensure free fall and gravity flow conditions without any backingup into the inlet chamber. Inlet chambers may be designed, to remain open but in case it is feared that owing to stace or septic condition of raw sewage odours may be given off, the chambers may be closed suitably.

With the above concepts in view, design of inlet arrangements may be done taking into account the site conditions as well, which is of equal importance. Two typical drawings for the inlet arrangements are furnished for reference. Fig.(2) is the arrangement when the incoming sewer is by gravity. Fig.(3) is for incoming sewers by pumping.

9. POND INTERCONNECTIONS

Pond inter connections are to be provided in case multiple units are provided in series. Due importance is to be given to the relative position of the inter connections to avoid short circuiting. A simple type would be to provide a pipe line of suitable diameter through embankment and lay it about 20 cm below the water level. The lower end of the inter connecting pipe may be provided with a bend facing downward to avoid short circuiting by thermal stratification. In cases where the multiple units are operated at different levels owing to topographical or other reasons, the interconnections between each pond may be made through a chamber similar to Fig.(4). Provision of valves in between is necessary in case flow regulation between ponds is intended.

10. OUTLET ARRANGEMENTS

The outlet may be in the form of a pipe or a suitable length of the weir. To prevent floating scum as well as algae from passing out with the effluent, baffles extending to 15 cm below and 15 cm above the pond water level may be provided. The sill of the outlet weir should be placed at the desired operational level of the pond. Provision of an outlet weir instead of a pipe would enable operation of pond at different levels by simply providing timber planks. This helps in operational flexibility.

A typical arrangement for outlet is furnished in Fig.(5).

11. DRAINING OF THE POND

Arrangement for complete draining of the pond by provision of suitable draw off pipe at the required level is desirable in larger pond. This pipe must either be tight securely plugged or valved for complete closing. An alternative is to instal the outlet pipe in sections and drain the pond by removing various sections of the outlet pipe.

12. MISCELLANEOUS PROVISIONS

Fencing the pond area, warning signs indicating the nature of the facility provided, access roads and proper lighting are necessary adjuncts.

13. ESTIMATES

An estimate for the construction of a waste stabilization pond of six million litres capacity is appended. The estimate provides for rates applicable to an average town in Tamil Nadu. The proposals are estimated to cost Rs.   lakhs to instal and Rs.   to maintain annually.

APPENDIX

ABSTRACT ESTIMATE.

CONSTRUCTION OF WASTE STABILISATION POND TO TREAT 6 MILLION LITRES PER DAY.

Item No.	Description of work.	Quantity.	Rate/per	Amount
1.	2.	3.	4.	5.
1.	Site Clearance.	L.S.		2,000
2.	Earth work excavation in all solids upto a depth of 0.25 m including depositing on banks with extra lead and lift etc.	16,000 cum	2/cum	32,000
3.	Preparation of good water retaining bund including compacting and rolling in layers etc.,	15,000 cum	4.25/ 10 cum	6,375
4.	Filling up hollow pockets in pond bottom with impervious materials.	L.S		1,000
5.	Gravel packing on the inner face of bund 15 cm thick.	240 M^3	18.20/M^3	4,368
6.	Providing lining with C.C. slabs 2.5cms thickness.	1,600 sqm.	12.25/M^2	19,600
7.	Turfing the rear faces of the bund.	2,000 sqm.	0.78/M^2	1,400
8.	Providing laying and jointing 250mm RCC pipes to proper gradient/120 m upto the pond centre.	120 m	51/Meter	6,120
9.	Providing supports for the pipelines and concrete pad below inlet.	L.S		1,000
10.	Providing inlet chamber with necessary pipe connections & Vee Notch.	L.S		15,000
11.	Providing effluent control chamber including piping, control shutters etc.	L.S		4,000
12.	Scone arrangements.	L.S		1,000
13.	Providing 1.5 m high barbed wire fencing with concrete posts at 2m intervals, etc. complete.	1,200 m	50/Meter	60,000
14.	Providing necessary approach way and general lighting.			6,137
		Total. C/o.		1,60,000

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1. 2. 3. 4. 5
-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C

B/f. ..	Rs.1,60,000
P.S. and contingencies at about 5% ..	8,000
Unforeseen works at about 5%. ..	8,000
	Rs.1,76,000
ADD for land value for 9 Hectares at the rate of Rs.50,000/per hectare.	4,50,000
TOTAL..	Rs.6,26,000 or 6.26 lakhs.

ANNUAL MAINTENANCE CHARGES

			Rs.
1.	Salary of two lascars at the rate of Rs.250 p.m. for each lascar.	...	6,000
2.	Repairs and renewals to shutters pipelines supports, masonry portions, lining, fencing etc.	...	3,000
3.	General lighting.	...	1,000
			10,000

$$\text{CAPITALISED COST} = \text{Rs.}6,26,000 + \frac{10,000}{0.08}$$

$$= \text{Rs.}6,26,000 + 1,25,00$$

$$= \text{Rs.}7,51,000$$

$$= \text{Rs.}7.51 \text{ lakhs.}$$

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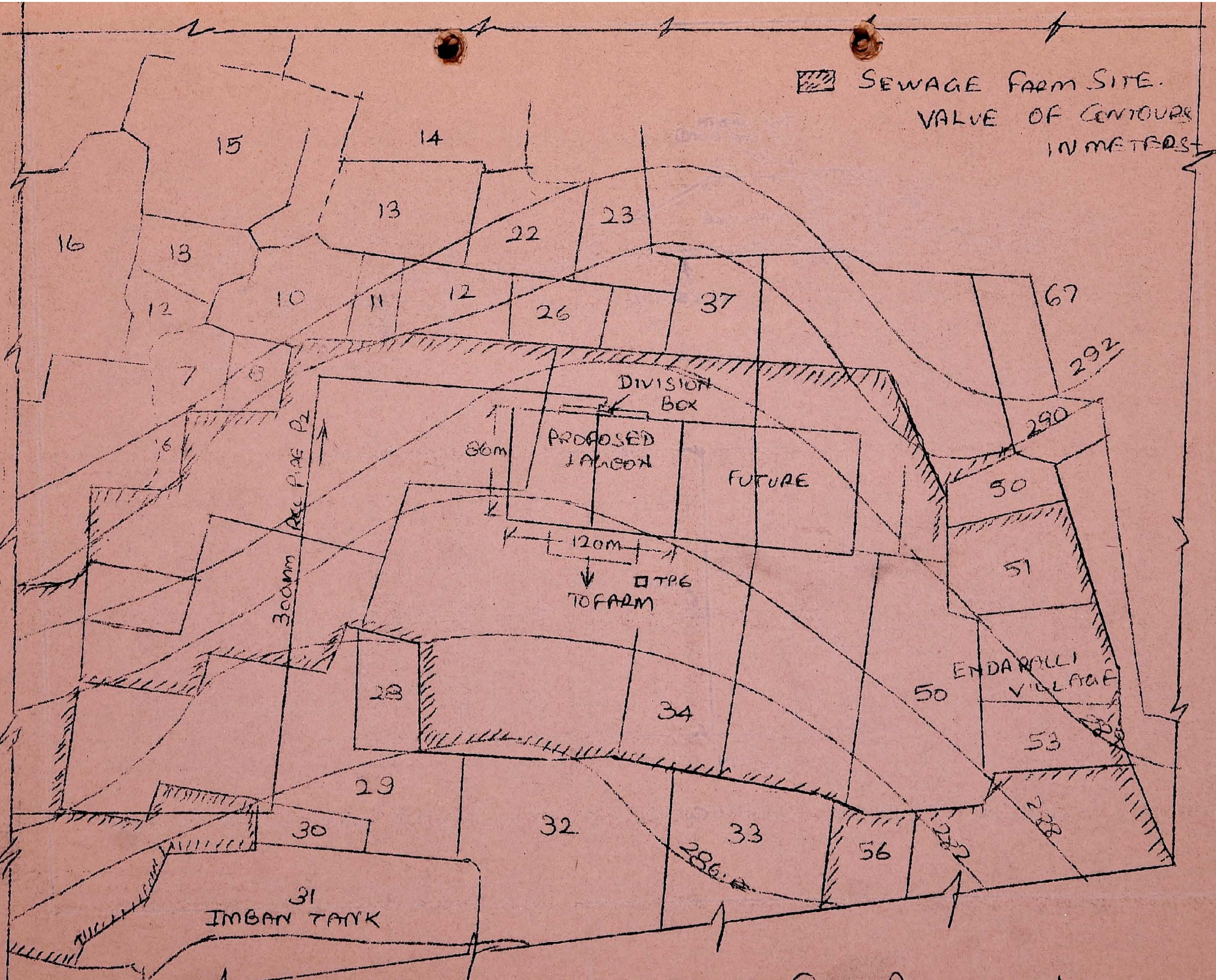

FIG. 1 SITE PLAN OF LAGOON

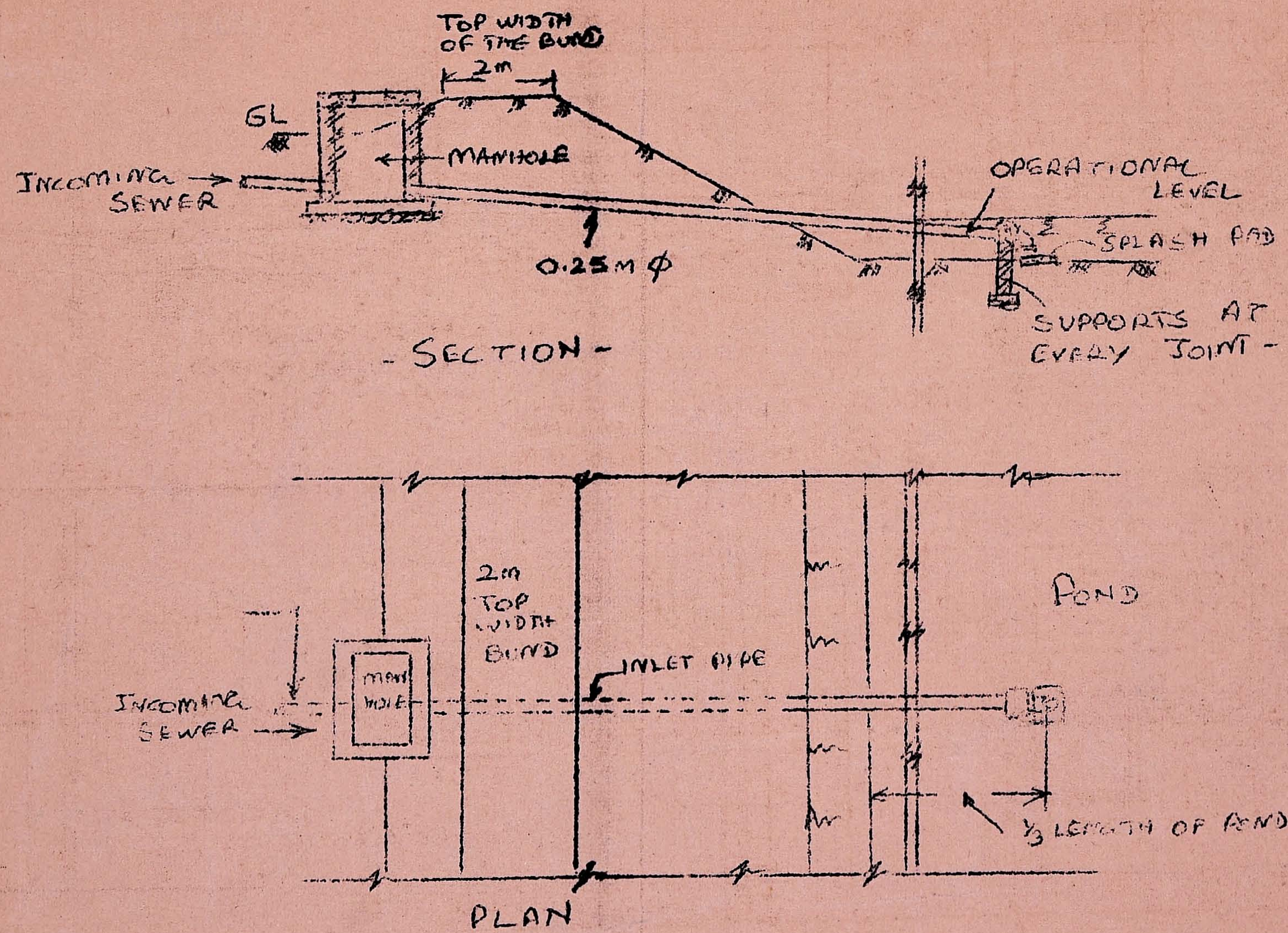

FIG. 2. TYPICAL ARRANGEMENT FOR INLET WITH GRAVITY FLOW.

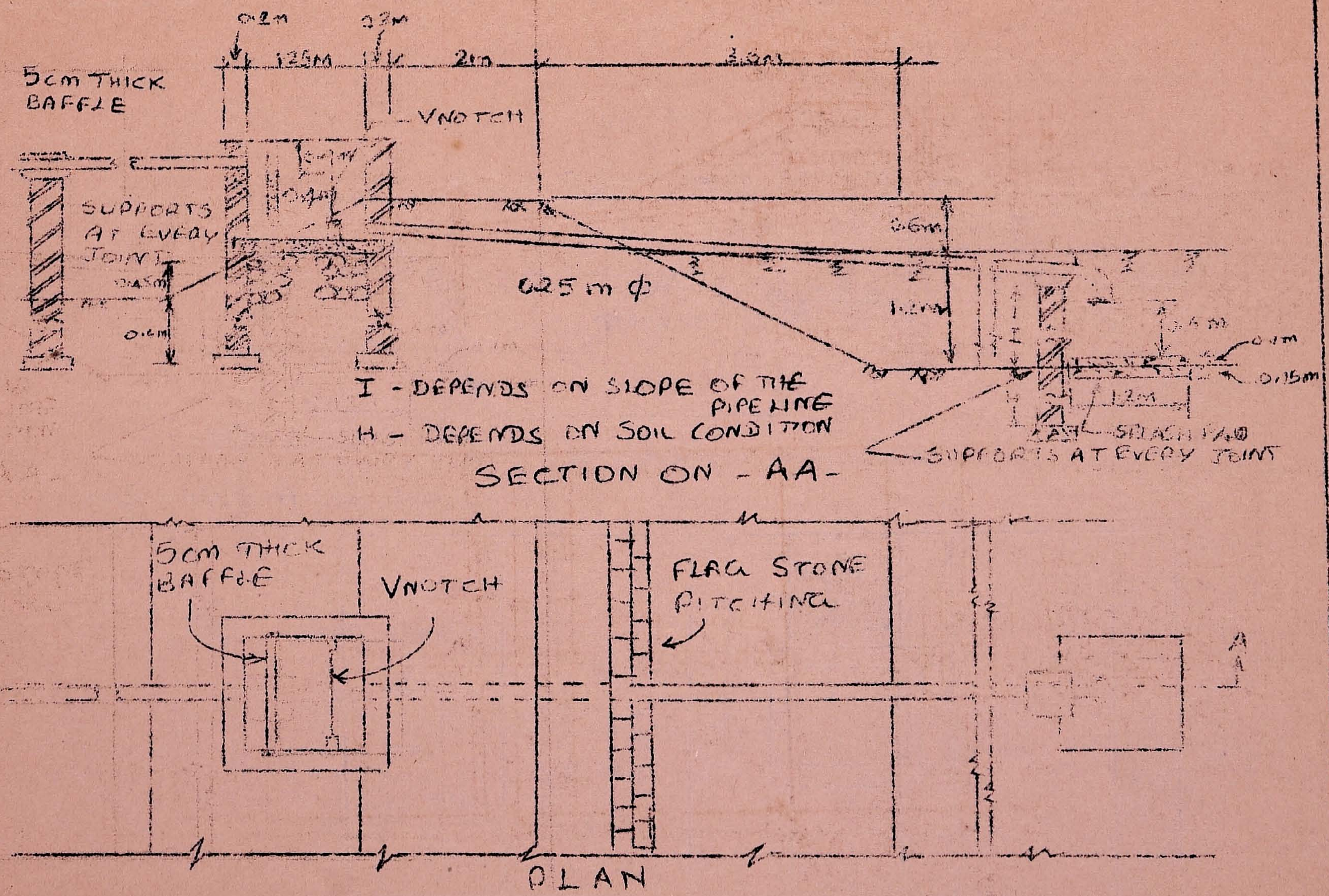

FIG 3. INLET CHAMBER FOR FORCE MAIN -

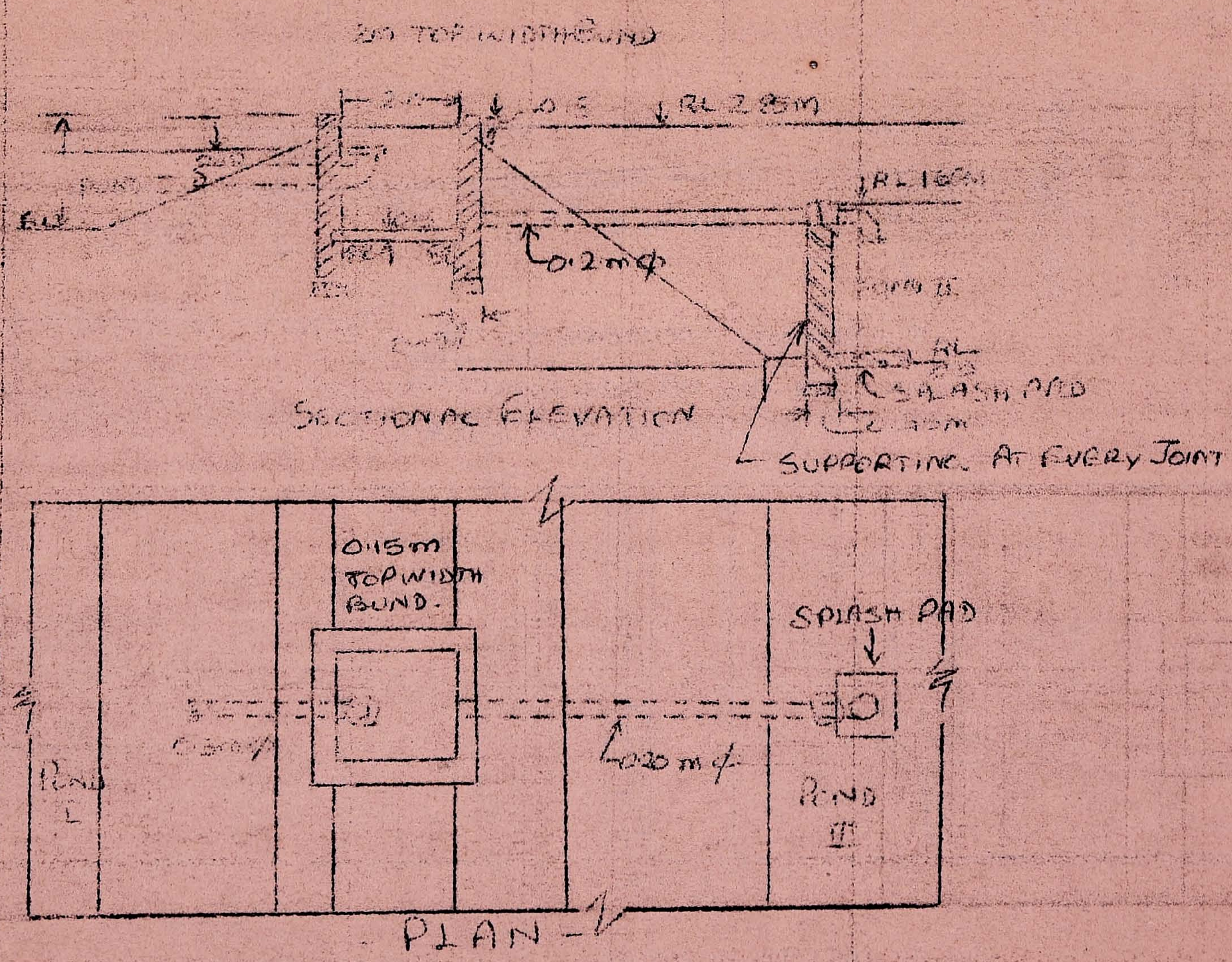

FIG. 4 INTERCONNECTING ARRANGEMENT FOR PONDS AT DIFFT. LEVELS - NOT TO SCALE -

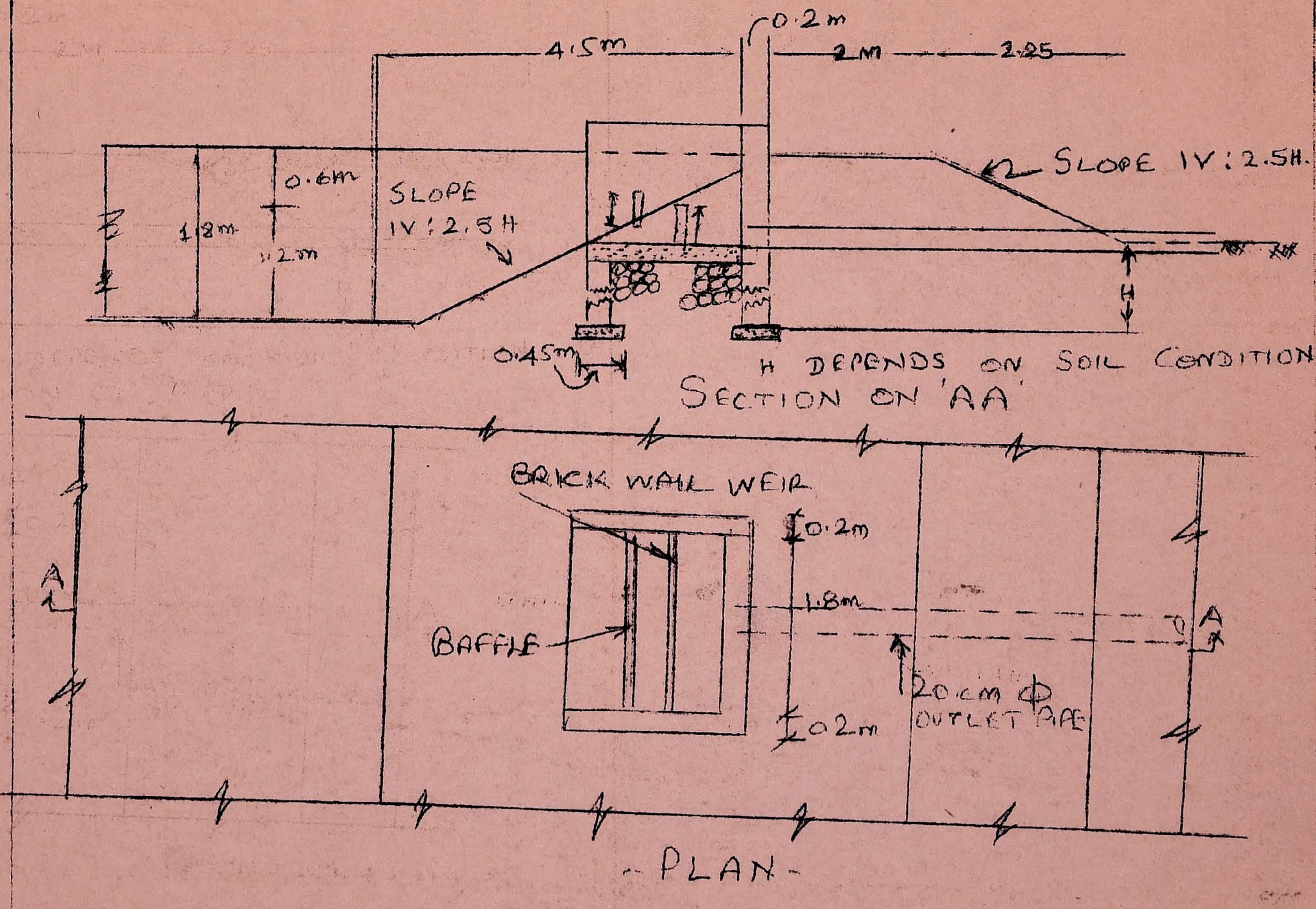

FIG. 5 DETAILS OF OUTLET CHAMBER -

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AERATED LAGOONS

S. SRINIVASAN.

INTRODUCTION:

Waste stabilisation ponds are ideal treatment devices for small communities like hotels, hospitals, townships etc. and also rural areas. Provision of these ponds in areas where the land cost is high will however result in an uneconomical project. As stabilisation is primarily due to photosynthetic oxygenations, these ponds will not ensure operational efficiency in areas of poor sunshine. Further the simplicity of a pond perhaps results in its maintenance being ignored with the consequent problems of odour, mosquito and larvae breeding etc. An aerated lagoon method of waste water processing satisfies a great need for economical high degree treatment where adequate land areas are not available at a reasonable cost and offers itself as a satisfactory choice where stabilisation ponds are not suggestible.

An aerated lagoon is essentially different from the stabilisation ponds in that the natural algal oxygenation is substituted by mechanical aeration. The lagoon is generally an earthern basin having a depth of about 2.5 to 3.5 meters of sewage which is aerated either by diffused air or by mechanical surface aerators installed on floats or rafts or on a permanent base. Raw sewage can be fed into the lagoons after screening and grit removal but without any primary settling. Detention time ranging from 3 to 5 days or more is provided depending upon the type of waste.

2. SCOPE OF APPLICATION:

The biological process in a pond with a liquid depth of about 2.5 to 3.5 meters will be a minimal aerobic action confined to a thin layer at the top while the liquid below will be subject to anaerobic actions (Fig. 1A) . Provisions of artificial aeration for such a pond may be done with two alternate aims (i) to ensure aerobic action in the entire depth (Fig. 1B)or(ii)to ensure aerobic actions in the major portion of the depth of the lagoon, leaving the bottom-most layers in an anaerobic state (Fig. 1C) . In fully aerobic systems mixing must be adequate to prevent sedimentation of suspended solids except in very limited areas and no dependence is placed on anaerobic phenomena. (8) The time required for stabilisation is however the least but the quantity of sludge to be treated is more and hence the sludge problem is intensified. In the aerobic-anaerobic process however, aerators may be to such an extent that aerobic conditions are maintained in upper layers of sufficient depth to intercept and stabilize the release of obnoxious anaerobic decomposition products such as H2S from the bottom layers.

In such a system the heavier suspended solids, including biological flocs are allowed to settle on the bottom of the lagoon where these matters subject to anerobic decomposition are free to do so. The liquid and gaseous products of decomposition released at the sludge water interface are carried by the circulating mixture into the aerobic zone above and utilised by the aerobic organisms, thus preventing the release of obnoxious gases to the atmosphere.

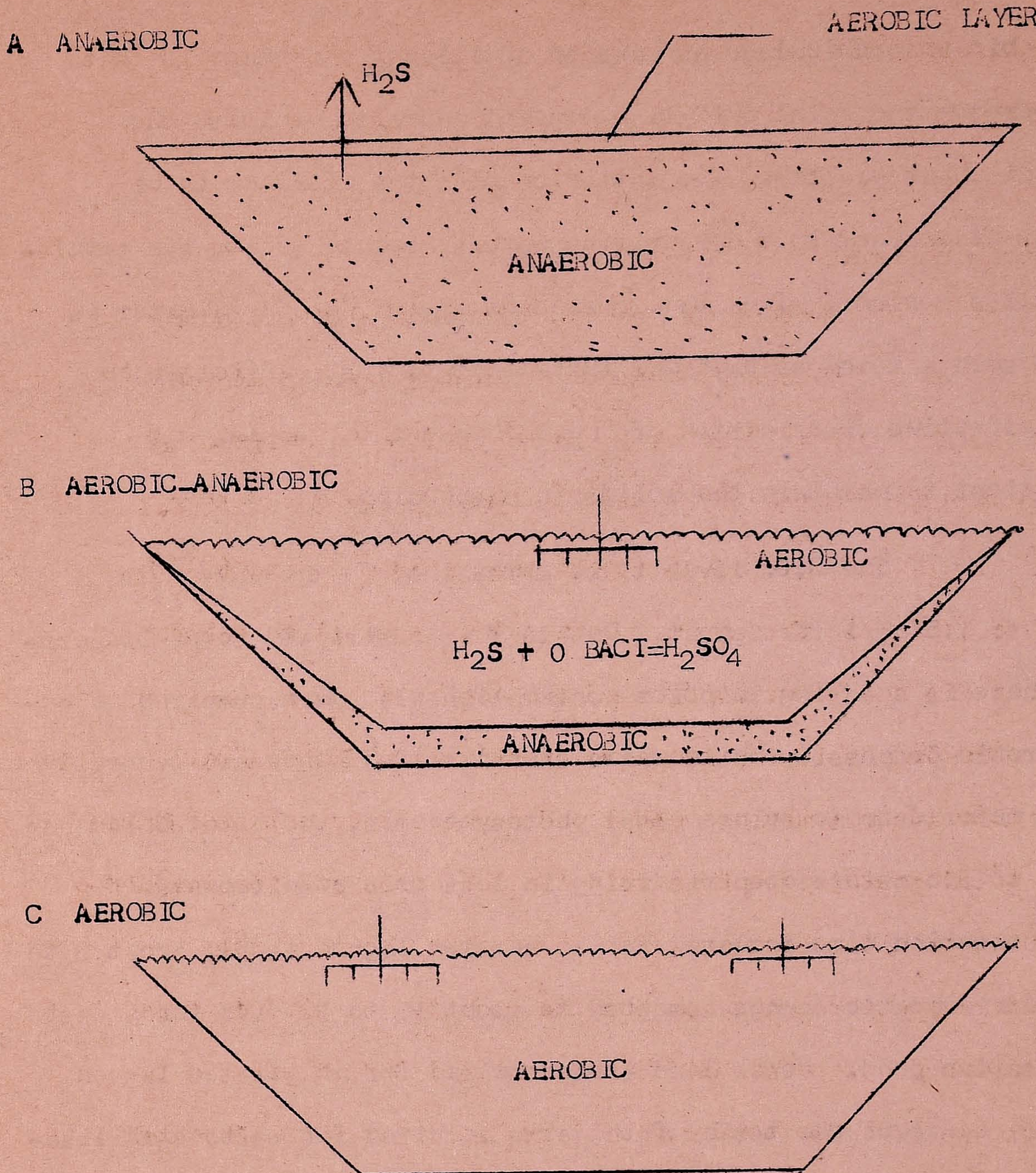

Fig.1. DEVELOPMENT OF AERATED LAGOON CONCEPT.

The aerobic anaerobic lagoons have an additional advantage in that they approach the total oxidation concept and also minimise the sludge disposal problem. The latter enables the effluent to be directly discharged to the receiving waters because of its low settleable solids content. Thus the power consumption for the aerator is kept at such a level so that the turbulence is just sufficient to ensure effective distribution of O_2 throughout the basin, but insufficient to maintain the solids in suspension.

The D.O. level to be maintained in the lagoon is about 1 to 1.5 mg/l throughout. Due to this restricted scope of aeration, there is a saving in power consumption also when compared to a full aerobic process. While waste stabilisation ponds are generally about 1 meter deep to ensure algal photosynthesis, the aerated lagoons are 2.5 to 3.5 meters deep resulting in less area requirements. Again, detention time required for an aerated lagoon isonly about 3 to 4 days for domestic sewage compared to about 10 to 15 days for a waste stabilisation pond. Hence land area required for an aerated lagoon will only be about one tenth of the area required for waste stabilisation pond. Thus the aerated lagoon is ideally suited for small communities where land is prohibitive and an optimum design would be on a aerobic-anaerobic principle with minimum power consumption such that the effluent could be directly discharged into streams. The detailed analysis of aerated lagoons in the following sections is based on the above concepts and the scope is confined to domestic sewage only.

3. FACTORS AFFECTING DESIGN

The factors affecting design would naturally be governed by the basic principles of BOD removal in biological treatment. Kinetics deals with the rate of reactions and in chemical parlance many reactions have rates which, at a given temperature are proportional to the concentfation of the reactants raised to a small integral power. For example, if Ca is the concentration of a reactant then

Rate of reaction = k.Ca for a first order reaction.

$K.Ca^2$ for a second order reaction.

$=K.Ca^n$ for an n^{th} order reaction.

where k is a proportionality constant. K = system rate constant

In aerated lagoons Bod removal is generally governed by a first order reaction and hence can be expressed mathematically as

$$\frac{d\,Le}{dt} = -K\,Le$$

where Le is the BOD to be satisfied at the end of time t and k is the system Rate constant. Integrating between limits o and t and denoting BOD at zero time as La, we get

$Le = La\,10^{-kt}$ where La is the influent B.O.D.

The system rate constant k iteelf varies with temperature of the lagoon contents and is expressed as

$$K_t = K_{20}\,\phi^{(t-20)}$$

where K_t and K_{20} are system rate constants at t and 20°C

and ϕ = Constant at 1.035 for our temperature range for aerated lagoons.

In addition, another factor of importance is the total oxygen requirements which are related to the B.O.D. removal and the quantity of biological solids in suspension. Since settling is allowed and solids in suspension are at lower concentrations in an aerated lagoon, the oxygen requirements are more or less directly related to the BOD removal (7) . Studies, have indicated that oxygen consumed is about 1.3 to 1.5 times of BOD applied. Oxygen requirements can therefore be calculated directly from the BOD.

Thus the factors which essentially govern the design of an aerated lagoon are (i) influent BOD (ii) standard of effluent BOD required (iii) Temperature of lagoon and (iv) Time of reaction, that is detention time required.

3.1. INFLUENT AND EFFLUENT B.O.D.

Domestic sewage, subject to preliminary treatment by screening and grit removal, which is fed to the lagoon would have a BOD of about 300 mg/l. The effluent BOD is governed by the efficiency of the treatment and an application of the first order formula would indicate that the efficiency for a reasonable detention would not exceed 90%. This is confirmed by figure 2 which gives a graphical representation of this equation for a k value of 0.25.

3.2. TEMPERATURE:

The liquid temperature in the aerated lagoon will depend upon the heat balance resulting from changes in ambient temperature and lagoon temperature. Heat is lost through evaporation, convection and radiation and is gained from solar radiation. This is in addition to the seasonal variation in the temperature which may be pronounced in certain locations. From the temperature relationships given above, it will be seen that for a town with a temperature range of 20°C in winter to 40°C in summer, the value of k would increase about two fold $1.035^{(40-20)} = 1.998$. In such cases the lagoon has to be designed for a lower value of k so that it would function effectively during all parts of the year. In fact, an instance has been quoted in the States, where two lagoons were designed in parallel and a satisfactory solution was obtained by operating the lagoons in series during the winter months.

3.3 SYSTEM RATE CONSTANT:

The procedure to be employed in determining the system rate constant for a waste to be treated in an aerated lagoon is by batch aeration of the waste seeded with an acclimatised effluent. The studies are conducted at constant temperature through a water bath maintaining a D.O. concentration of at least 1.0 mg/l in the waste. Samples of the aerated waste are analysed for BOD at close intervals of time. The system rate is determined from a plot of the logarithm of the B.O.D. observed against a linear scale of time. The slope of this line gives the value of the system rate constant k. Studies indicate that the valueof k would be about 0.25. The value of ϕ could also be found out by the same procedure varying the temperature in the constant water bath and comparing the results of k.

3.4. DETENTION TIME:

This is the most important parameter. The graph in Fig. 2 would indicate that a reasonable efficiency could be obtained for a detention period of about 4 to 5 days. We may analyse this by taking a typical case of domestic sewage.

In the formula $Le = La \cdot 10^{-kt}$

substituting $k = 0.25$ and

$$\frac{Le}{La} = 0.10 \text{ for } 90\% \text{ efficiency}$$

we get $t = 4$ days.

This may also be analysed from a different angle.

For a town with a rate of supply of 100 lpcd and a BOD contribution of 50 gms/day detention of 4 days amounts to a BOD loading of 0.12 to 0.15 kgm for every M^3 of lagoon volume.

4. AERATION SYSTEM AND ITS CAPACITY:

Two types of aeration equipment are available (i) by compressed air to be diffused by means of a pipe grid laid at the lower depths of the lagoon and (ii) by surface aerators of the mechanical type. The latter has fast replaced the former since surface aerators have a higher mixing potential and there is economy in running electrical lines vis-a-vis air lines over considerable distances. Surface aerators would obviously be more suitable for lagoons under aerobic-anaerobic process since the bottom layers would not be disturbed.

4.1. TYPES OF SURFACE AERATORS:

Surface aerators can be roughly classified in three groupings (24)

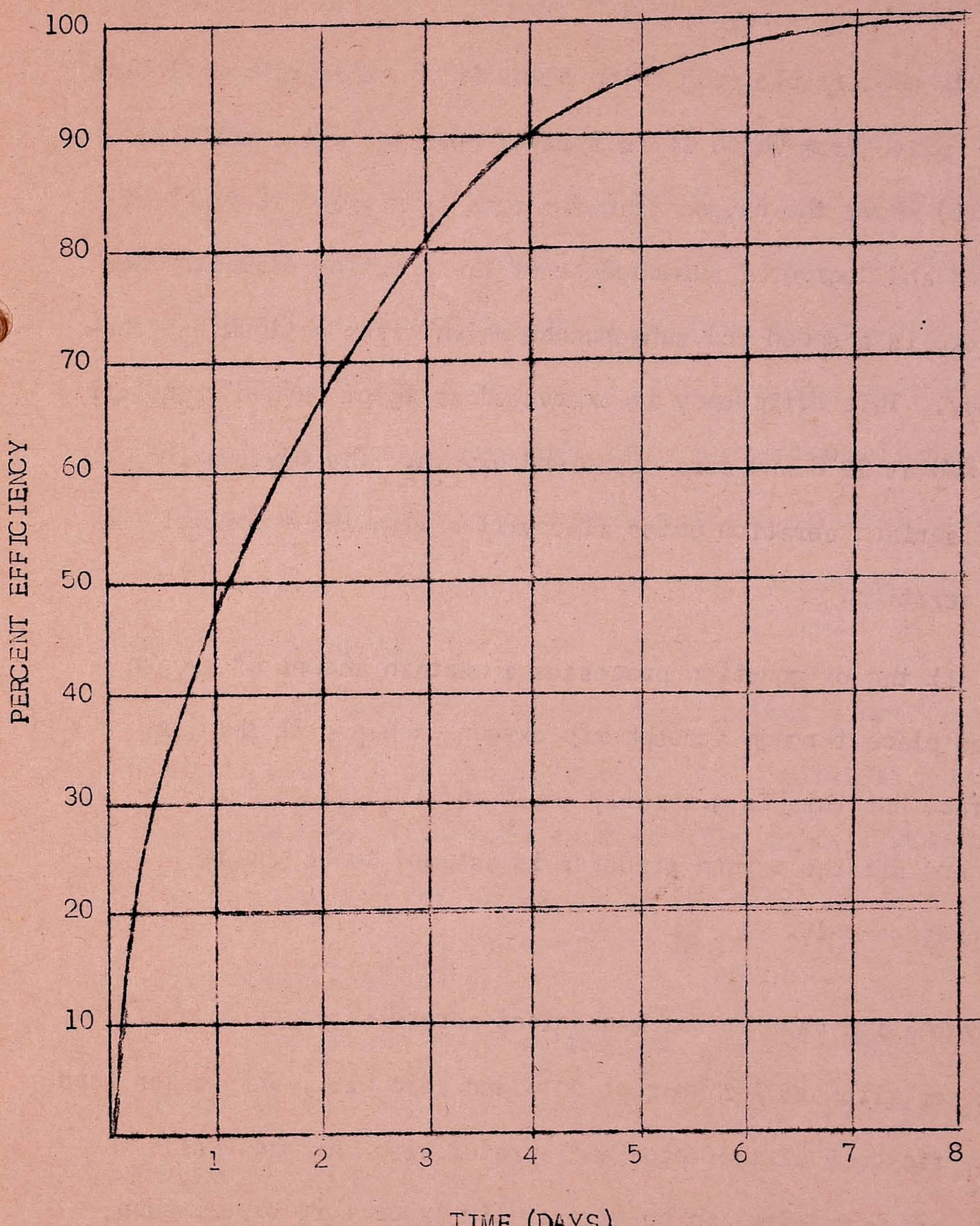

Fig.2. VARIATION OF EFFICIENCY WITH DETENTION TIME.

(i) an impellar which induces flow across the blades in a vortex action and surface liquid spray;

(ii) a surface impellar with a draft tube from which liquid is sprayed; and

(iii) a submersible pump which pumps liquid against a deflector plate from which it is sprayed over the water surface.

For (i) and (ii) above the oxygen transfer rate is related to impellar diameter, speed and degree of submergence of the rotating element. For most units there is a speed and submergence which gives optimum oxygenation efficiency. This efficiency is expressed as kg of oxygen transferred per hour per KWH at 20°C and zero dissolved oxygen. The oxygenation efficiency of surface aeration units also varies with the volume of liquid under aeration.

In all the oxygenation processes a certain amount of oxygen transfer takes place through atmospheric oxygen exchange at the air lagoon interface but this is generally small and is neglected in calculations and all the oxygen transfer is assumed to be due to mechanical aeration only.

Oxygenation capacity of mechanical aerators ranges from 1.1 to 1.5 kg of O_2 per kilowatt per hour at 20°C and zero D.O. This takes into account the efficiency of the motor and aerator also and the losses in transmission. The capacity can be assessed in laboratory experiments and correlated to field conditions by suitable correction factors.

4.2. TYPES OF AERATOR FIXINGS:

Aerators may be of the fixed type or of floating type. In the fixed type, it is essential that the liquid level in the lagoon is maintained constant so as to ensure the required degree of submergence of the aerator blades. This necessitates water tight conditions in the lagoon and discharge of effluent over a weir fixed at the desired level. The need for a water tight condition in the lagoon requires a higher investment to avoid percolations by suitable lining. Control of percolation will also be necessary when the location of the lagoon requires prevention of ground water pollution. Floating aerators could be fabricated in non-corridble material to ensure durability and the floating pontoons could be anchored to the side banks by steel ropes.

The aerators are normally of capacity upto about 15 H.P. only and in case higher ratings are required, multiple aeratons are provided. Spacing of aerators is restricted to less than 60 meters in order that sufficient turbulence is created.

4.3. ADDITION OF NUTRIENTS:

These are not required for domestic wastes but only for industrial wastes. Hence this is not considered in detail.

5. CONSTRUCTIONAL DETAILS:

Aerators are normally of symmetrical shape circular or square so that the aerator fixed centrally would ensure uniform action. Where multiple aerators are required, rectangular aerators could be proposed. In case, site conditions necessitate uneven shapes, the number, capacity and disposition of aerators should be such as to ensure uniform oxygenation.

The sides are in earthern bund with required slopes and bottom width for retaining the liquid depth. Gravel packing covered with precast slabs is necessary for sides to make it water tight. The bottom may also be lined with precast slabs of suitable thickness to ensure the same objective. The inlet pipe may be conveniently submerged to avoid odours and short-circuiting while the outlet weir is provided of sufficient length to avoid heading up at peak flows which would change the aerator submergence in the case of fixed aerators. A stilling baffle may also be provided in the outlet to avoid the sewage splashing over the weir owing to agitation in lagoon.

The aerator, if of fixed type may be installed over a RCC platform of size say 2m x 2m resting over 4 corner columns in RCC. A foot bridge for approach to the aerator may be provided, or in the alternative, a canoe would be sufficient especially when operation of the aerator could be done from the bank itself by suitable controls.

Sludge removal is practically not required, and the maintenance is confined to the maintenance of the civil works and the aerator.

6. SALIENT DESIGN FEATURES:

Salient features of the design are given below for ready reference for a typical domestic sewage in a town of moderate climate.

Detention required	= 4 days.
Liquid depth for lagoon.	= 2.5 to 3.5 m
Per capita supply.	= 100 lpd.
Influent BOD	= 400 mg/l or 40 gms/capita/day.

Organic loading	= 0.12 to 0.15 kg of BOD/ M^3 of lagoon volume.
Oxygen requirements	= 1.3 to 1.5 times of BOD applied.
Oxygenation capacity of aerator.	= 1.1 to 1.5 kg of O_2 per KWH
Maximum spacing of aerators.	= 60 m

A typical design for an aerated lagoon to cater to a town of population of 30000 is worked out in Appendix-1.

7. COST COMPARISONS:

Rough figures indicate that the cost of provision of an aerated lagoon for domestic sewage would work out to Rs.20/- to Rs.30/- per capita, the higher rates being applicable for lower populations ranges. Annual expenditure per capita on running charges including power and maintenance,works out to about Rs.5 to 7 per capita. A cost comparison between a waste stabilisation pond and an aerated lagoon is no doubt possible but varies to a great extent upon land cost. For a land cost of about Rs.25,000/- per hectare the combined cost of installation and capitalised running charges for an aerated lagoon are about 2 to 3 times the cost for a pond. For land costs of about Rs.1.5 lakhs per hectare the total costs for the two methods tend to be more or less equal.

8. INDUSTRIAL WASTES:

Aerated lagoons are successfully adopted for treatment of wastes from various industries. Specific advantages claimed in this regard are that aerated lagoons (i) sustain biological solids which are relatively stable at low loading rates (ii) resistance to upsets (iii) ability to treat high strength wastes,

(iv) buffering capacity for varying pH (v) relatively large heat transfer when high temperature wastes are to be treated. The principles of design are the same except that k value has to be found out for each waste.

9. CONCLUSIONS:

Aerated lagoons are ideally suited for moderate towns and also small communities, hospitals etc. Spreading of odour nuisance to the neighbouring areas is eliminated. The agitation of the liquid surface also ensures mosquito free operation as the larvae do not thrive under such conditions. The plants does not require skilled maintenance and operation costs are low at Rs.5 and 7 per capita per year.

.APPENDIX.

DESIGN OF AN AERATED LAGOON

DESIGN DATA:

Population	= 30,000 ✓
Raw sewage BOD	= 50 gm/capita/day at 20°C ✓
Per capita water supply	= 100 lpcd. ✓
Maximum summer temperature.	= 30°C ✓
Minimum Winter temperature.	= 25°C ✓
Desired effluent BOD	= 30 mg/l. ✓
System rate constant k	= 0.25 at 20°C ✓
ϕ	= 1.035.
Oxygenation capacity of aerator at 20°C for sewage.	= 1.5 kg/KWH. ✓
Permissible organic loading	= 0.15 kg/M^3 of lagoon volume. ✓

DESIGN:

Raw sewage BOD $= \frac{50 \times 1000}{100} = 500$ mg/l. ✓

Allowing 5% removal in screens and grit channel.
influent BOD $= 500 \times 0.95 = 475$ mg/l. ✓

System rate constant at 25°C for winter temperature. $= 0.25 \times 1.035^{(25-20)}$ ✓ (raised to power)

$= 0.2971$ say 0.30

$$Le = La - 10^{-kt}$$

$$\text{Log } Le = \text{Log } La - Kt \text{ Log } 10$$

$$t = \frac{\text{Log } La - \text{Log } Le}{K.\text{Log } 10}$$

$$= \frac{\text{Log } 475 - \text{Log } 30}{0.30}$$

$$= \frac{2.6767 - 1.4771}{0.30} = 3.9 \text{ days.}$$

say 4 days.

Volume of lagoon $= \frac{4 \times 30000 \times 100}{1000}$

$= 12000$ M^3

With a liquid depth of 3 meters

Area of pond required = 4000 M^2

Size of pond = 90 M x 45 M at mid depth

Organic loading for actual volume

$$= \frac{30000 \times 50 \times 1}{1000 \times 45 \times 3 \times 90} \text{ kgm / } M^3$$

$$= 0.12 \text{ kg / } M^3$$

This is in order

Total BOD load = $30000 \times \frac{50}{1000}$ = 1500 kg/day.

Oxygen requirements at 1.5 times BOD

= 2250 kg/day

Hence KW of aerator required

$$= \frac{2250}{24 \times 1.5} = 63 \text{ KW}$$

2 Nos. Aerators each of 30 KW would be provided at one third points.

HEALTH ASPECTS OF WASTE STABILISATION PONDS

Dr. C.A.SASTRY

INTRODUCTION

In their relatively short period of history waste stabilisation ponds have been referred to many different names such as Oxidation ponds, redox ponds, maturation ponds, sewage lagoons, anaerobic lagoons, facultative lagoons etc.

The term "Waste Stabilisation Ponds" has been more widely adopted as it is more descriptive of the real function and includes aerobic as well as anaerobic modes of stabilisation. The word "Waste" includes both sewage and industrial wastes.

Waste stabilisation ponds are classified according to the biological process taking place, namely aerobic, anaerobic and facultative.

i. Aerobic Ponds are shallow ponds of 1' depth or less designed to maximise the growth of algae. Aerobic conditions are maintained throughout the depth of the pond all the time and the waste material is stabilised entirely through aerobic microorganisms.

ii. Anaerobic Ponds are those designed for higher organic loading so that photosynthetic algal action is precluded and anaerobic conditions prevail through-out the pond volume. Such ponds are built deeper. The effluent from an anaerobic pond will usually have high BOD and require further treatment.

Facultative Ponds are relatively shallow about 3 to 5' depth and predominantly aerobic during the sunshine hours as well as for some hours of the night. In the few remaining hours of the night, the upper layers of the pond may or may not be aerobic but the bottom layers are generally anaerobic.

In stabilisation ponds, waste water is led into a relatively shallow pond of about 4' depth with suitable inlet and outlet devices and having a relatively large capacity to give about 10-12 days detention time. In the presence of sunlight and nutrients contained in the waste a healthy bloom of algae fluorishes together with a large number of aerobic bacteria. The treatment process depends on the effective use of bacteria for breakdown or stabilisation of organic matter and on the presence of algae for oxygen supply.

As long as sufficient quantities of nutrients are present there are only two other significant factors necessary for successful operation, namely sunlight and enough detention in the pond for the bacteria to furnish their job of stabilisation. As long as algae can provide an excess of oxygen above that required by bacteria, an aerobic environment will be maintained. If sufficient oxygen is not available particularly in the bottom layers of a pond anaerobic or facultative bacteria obtain the required oxygen from chemical compounds like nitrates and sulphates.

Algae of importance in oxidation ponds include (a) Green algae: Chlorella, Scendesmus, Chlamadamonus etc. (b) Blue green algae: Anacystics, Anabena, Oscillatoria (c) Flagelates: Euglena, Trachelomonas, Phacus etc.. and (d) Yellow green: Asterionella, Navicula, Cyclotella.

Although waste stabilisation ponds have been in use for a considerable time that have been designed on an engineering basis only recently. Effeciency of waste water treatment method in removing pathogenic organisms is often given secondary consideration. In India, where raw and treated sewage is used for irrigation and where the receiving stream with low summer flows often forms the water supply of numerous villages, removal of pathogens from waste water is of primary concern. The studies made by different workers on the removal of pathogens from sewage during treatment in oxidation ponds is summarised in this lecture. The problem of mosquito, fly and water flea breeding is also discussed. As long as the ponds are maintained properly there is no health problem associated with them.

MOSQUITOES

It is necessary to adopt good house keeping measures for ensuring freedom from mosquitoes and flies. Properly maintained ponds will not afford environs for the breeding and shelter of mosquitoes. However, shallow edges with emergent vegetation and anaerobic conditions may afford a chance for mosquitoes to breed and proliferate. At times mosquito breeding attributed to a stabilisation pond may actually occur in puddles, borrow pits and depressions in the surrounding land and therefore the general sanitation of the whole area is essential.

The usual types of mosquitoes to be guarded against in India are of the Culex varieties (culex fatigans; C.Tarsatus) responsible for spreading diseases like Filaria.

Mosquito nuisance can be effectively controlled by keeping (a) the weed growth to a minimum and (b) the water line free from marginal vegetation. Mosquito breeding can also be controlled by the adaption of larvicidal measures in the form of 1 or 2 per cent oil solution of DDT, BHC dust or 2% Malathion emulsion.

Seeding the pond with sufficient numbers of water minnows (fish) such as Gambusia, and Lebistes reticulatus is found to be useful for the control of mosquitoes as these fish feed at the upper surface of ponds, where incidentally mosquito eggs and larvae are to be found.

FLIES

Flies in which the operator of a pond may be interested are mainly two commonly occuring genera: (a) the house fly (Musca domestica) and (b) blood worms (Chironomus tentans) and(c) Tendipedi formis.

House flies will generally not be prevalent in ponds which are functioning satisfactorily. But where anaerobic conditions prevail or where raw sewage solids are held as in inlet chambers or grit channels, such flies may be found in plenty. Good house keeping and proper operation avoids flies.

Chironomous larvae or "blood worms" as they are commonly called because of their reddish worm like appearance are often found in stabilisation ponds seasonally. The adult fly has no special public health significance but causes nuisance and unaesthetic appearance in a pond. Number of special control measures are generally adopted by way of removing floating matter along with its egg masses from the corners and sides of ponds. Removal of weeds and overhanging grass also helps to remove entrapped egg masses.

WATER FLEAS

The water fleas (Cladocera) which have been reported as occuring in stabilisation ponds are (1) Moina dubia (2) Daphnia Magna (3) Simocephlus exopinosus. They have no established public health significance nor create any special nuisance condition. They are known to feed on green algae like <u>Chlorella</u> and can sharply reduce their population under certain conditions. The addition of lime at the rate of about 2 to 10 Kg over a localised area reduce their number. Their role is not known. They help in reducing bacterial numbers and stabilisation of organic matter.

Stabilisation ponds can withstand certain amount of fluctuations in the waste load. But as far as possible sudden or extreme variation in the characteristics of the waste entering the pond should be avoided. Operation and maintenance of stabilisation ponds is mainly a matter of good house keeping. This is the key note of successful working. In most respects the operation and maintenance of a pond is so simple that it tend to be neglected.

REMOVAL OF SALMONELLA

It has been observed that the sewage from any community invariably contains pathogenic micro-organisms that cause a variety of intestinal disease. Water borne diseases include based on the causative organism (a) Typhoid Paratyphoid, Cholera, Gastroenteritis and dysentry caused by bacteria (b) Amebiasis caused by Amebic cysts (Protozoa) (c) Hepatitis or polio caused by virus (d) Histoplasmosis caused by fungi (e) infections caused by worm etc. Eggs of some intestinal worms and larvae of others find their way into water. Crustacean cyclops contain larvae of guinea worm, round worm, etc.

The genus Salmonella, which contains the typhoid bacillus, has more than 800 species of bacteria. These cause Salmonellosis, comprising of diseases like diahrrea, typhoid and paratyphoid fevers are common in humans and other animals. The usual habitat of this group of organisms is the intestinal tract of the infected individual and it is spread to susceptible individuals through fecal-oral route.

Salmonella are excreted through feces by the patients even after illness. Temporary carriers excreting the organisms for 2 to 3 weeks after illness are common. Chronic carriers excrete Salmonella upto a year. Three per cent of the typhoid fever patients excrete organisms indefinitely. If such a carrier is present in the community a continual influx of S. Typhosa into raw sewage can be expected and its elimination during sewage treatment will be of paramount importance.

An epidemic of gastroenteritis involving 2500 persons out of the total population of 15,000 occurred in Madera, california in August 1965 and it was correlated with the high coliform counts of the city's water distribution system. The probable source of the epidemic was the undisinfected sewage from an adjacent sewage irrigation field that could enter the well.

Though Salmonella are transmitted by other modes, water route for its spread plays a major role in the occurance of Salmonella out breaks. It is well established that Salmonellosis could be eliminated by proper water treatment. This has been achieved in western countries even though none of the conventional sewage treatment processes could produce salmonella free effluent.

The results so far in literature show that the total bacterial counts of raw sewage when it was treated in an activated sludge treatment plant, were reduced by 92-98% and the coliforms, S.Typhosa, paratyphoid bacilli and V.Cholera and shigella were reduced by 91-99%.

In a study on the oxidation ponds, consisting of three cells in series and treating 5 MGD of raw sewage, Joshi (.) observed that Salmonella were completely eliminated while they were always present in the raw sewage in the range of 4 to 540 per 100 ml.

The survival of Salmonella on soil in grass farms irrigated with sewage was 3 to 6 weeks. However, their survival on vegetables like tomatoes, lettuce and carrots is less than seven days.

Thung showed that the effluent of a pond with detention period ranging from 30 to 60 days will be free from Salmonella provided no short circuiting take place.

Sidio inocculated Salmonella cultures into the pond influent and reported their complete destruction in 12 days.

Intestinal pathogens belonging to Salmonella and shigella are found by CPHERI to be completely eliminated from sewage during treatment in oxidation ponds.

Enteric bacterial diseases are quite common in India. As a result, raw sewage contains large numbers of these infectious organisms and none of the conventional sewage treatment methods can eliminate them completely. In order to break the link in the chain of transmission of these diseases by the water route, it is essential that sewage effluents should be properly chlorinated. Unfortunately, this is never practised, though recommended. Alternately, we will be able to achieve this end by utilising properly designed stabilisation ponds for treatment of sewage. This is practicable in several regions in India, not only because of the low cost involved but also because of abundant sunshine and favourable temperates to effectively operate the ponds for the elimination of enteric bacterial pathogens.

REMOVAL OF BACTERIA

Average coliform and enterococci reductions of the order of 80 to 99.9 per cent are achieved in ponds with 2 days detention in summer and 4 days detention in winter.

The die away of coliforms and bacterial pathogens in stabilisation ponds are believed to be mainly due to the prevalence of pH values in excess of 8.0 and even as high as 9.5 to 10.5 at certain hours generally in afternoons. This may be due to other causes also such as the release of antibacterial substances by some algae.

Experiments carried out at Nagpur showed that in the presence of algae, E.coli was completely eliminated within 4 to 8 days depending on temperature. However, when sewage was buffered and kept at 7.5 E.coli was not completely eliminated even after 13 days inspite of the presence of alga

REMOVAL OF PARASITES

Considerable knowledge exists in regard to the fate of Helminths in various conventional sewage treatment systems. In general all these systems remove 40-90% depending on the treatment process. Studies have shown that ascaris, trichuris and hook worm ova reductions in activated sludge process were 93 to 98% and 98 to 100 in Trickling Filter process. The Trickling Filter process effected 88 to 99% removal of Entamoeba histolytica.

The environment in oxidation ponds was found to be not conducive for the propogation of the snail vectors of Bilharziasis. In over a year of observations on a pond series at Lusaka no helminths, cysto or ova were found in the effluents from the pond through they were isolated from raw sewage. Studies in Israel have shown that cysts of Entamoebahistolylica were present in the influent, but never in the effluent.

Field studies were carried out on protozoan cysts and helminthic eggs by CPHERI on stabilisation pond at Bhandewadi which consists of a set of 3 cells operated in series at 4' depth with total detention period of 7 days and treating 0.5 MGD. The data revealed that though the raw sewage had a concentration of 635 to 1705 protozoan cysts per litre and helminthic eggs in the range of 135 to 447 per litre the final effluent was completely free from any of these parasites. Only 50% was removed in settling and 90% in chemical treatment in India. For treated effluents which are proposed to be used for irrigation it is desirable that as high a removal of helminths as possible is achieved to safeguard the health of farm workers. From this point of view the utilisation of stabilisation pond effluents for irrigation would be more desirable than the direct use of raw sewage or primary treatment plant effluents.

Of all the sewage treatment processes stabilisation pond is the only one that removes helminthic eggs and protozoan cysts completely. Since the usual chlorination doesnot kill helminthic eggs, it is desirable to see that the effluents from the other treatment systems should be heavily chlorinated.

REMOVAL OF VIRUSES.

Long storage appears to be the simplest method for reducing viral levels in sewage. Table gives the time required at different temperatures to reduce by 99.9% viruses and bacteriae added to sewage. Berg found that increasing the temperature of sewage by 10°C almost doubles the average rate at which the viruses are destroyed.

Organism	Number of days		
	4°C	20°C	28°C
Poliovirus 1	110	23	17
Ecovirus 7	130	41	28
Ecovirus 12	60	32	20
Coxsacvie Virus A9	12	--	6

The activated sludge process appears to be the most effective method for removal of virus. 99% of the virus, 90% of Polivirus 1 and 98% of coxsacvie virus (was removed in 45 mits., by activated sludge).

Data concerning the survival of virus in sewage stabilisation ponds in limited. In the studies at Nagpur, 8 samples out of 121 were positive to enteric virus in the influent of one stabilisation pond and non positive to virus in the effluent. The studies in South Africa on large stabilisation ponds indicate that the virus content is reduced but not eliminated entirely in the ponds.

The number and types of virus found in sewage are subject to rather wide variation. The average density of enteric virus in sewage in USA is of the order of 500 virus units per 100 ml of sewage and virus coliform ratio is 1:1 1:100,000. The sewage in Nagpur has a similar density of enteric viruses and values upto 300 virus units per 100 ml of raw sewage have been recorded.

(1) primary sewage treatment has no effect on enteric viruses (2) T.F. gives about 40% (3) A.S. gives 90-98% (4) chlorination reduces the number and virus may still be detected.

Oxidation ponds in Nagpur removed 90% of enteric virus. In these studies enteric viruses are estimated quantitatively using a plaque technic after concentration of the sewage sample by membrane filtration.

The investigations on a stabilisation pond at Bhandewadi (Nagpur) treating 0.5 MGD of Nagpur city sewage indicated substantial reduction in entorovirus. Even when Sabmonella could be completely eliminated in the pond .

enterovius were still present most often. Though in very low concentrations in the pond effluent samples, the removal being in the range of 87 to 100%.

Owing to exposure to sun rays and longer detention times oxidation ponds are likely to remove virus more than conventional method.

The outbreak of polio in Edmontón, Canada clearly indicated the importance of chlorination of settled sewage before discharging into a river. The work of Neege (   ) was significant in that it showed that 1 ppm of free residual chlorine with 30 min. contact time was sufficient to inactivate the virus. Other evidence indicate that residuals of less than 1 ppm require asmuch as 4 hr. contact to be effective. Kelly and Sanderson observed that depending on pH and tem., at least 9 ppm of combined residual is required with a 15 min contact period to inactive enterovirus.

TUBERCULOSIS BACILLI

In their preliminary studies on the survival of M. Tuberculosis in the Oxidation ponds fed by the effluent of a septic tank receiving part of the sewage from T.B. Sanatorium at Tambaram, near Madras, Viraraghavan and Raman concluded that this organism gets completely eliminated.

Bhaskaran (   ) have concluded after an experimental study that sedimentation, septic tank treatment and biological filtration are not effective in removal of M.Tuberculosis present in sewage. Tuberclusis bacilli were reduced by 88% in A.S. process.

Bhaskaran(   ) has observed that a dose sufficient to leave 1 mg/l residual chlorine at the end of 30 mts may be adequate for proper disinfection of effluents obtained from treatment of sanatoria sewage containing tubercule bacilli. Greenberg found that M.Tuberculosis survives the activated sludge treatment. He reported survival of these bacteria after anaerobic digestion.

SUMMARY

Pathogenic bacteria, viruses and parasites in treated effluents constitute potential health hazards when the receiving waters are used for drinking water supply, irrigation or recreation. It may be seen that though T.F., A.S., anaerobic digestion and oxidation pond reduce the numbers of pathogenic bacteria, viruses and parasites from sewage, the effluent still contains a portion of them making it potentially hazardous from P.H. point of view. Stabilisation pond treatment would appear better suited as regards removals of parasitic ova and viruses in view of the long storage available.

The sludge from primary S.T., T.F., A.S., and digesters contain large number of pathogenic ova, pathegenic bacteria and virus. The sludge should be heat treated (135°F for 1 hour) or dried for a long time to destroy them.

EFFLUENT UTILISATION

In India stabilisation pond effluents have been used at different places with success for growing different crops. In Bhilai, for example, vegetables like Bhindi, Brinjal and Gowarpalli are being grown from the past years regularly in a 10 acre farm using stabilisation pond effluent for irrigation. In Bhopal also the effluent from T.T. Nagar ponds is being used for growing vegetables, flowers, etc. In the Institute's farm at Nagpur, crops like tomato, cauliflower, cabbage, chillies, wheat, cotton and fooder plants were grown with success. The Institute's experiments with essential oil bearing plants such as Mentha and citronella using stabilisation pond effluents have also been successful.

Size of the farm for 1 MGD flow.

Interval between two successive irrigation	At the rate of 10,000 gal/acre/day
5 days	200
10 days	100
20 days	50

The nutrients contained in the raw sewage, namely, nitrogen, phosphorus and potash are taken up by the algal cells which fluorish in the sewage stabilisation ponds in the presence of nutrients.

PISCICULTURE

Indian major crops like Catla catla, L.Rohita, L.Calbaru and C.Mrigala can flourish in primary as well as in secondary ponds. For example in Bhilai an initial, stocking of 2000 fingerlings of L,rohita, C.catla of the average weight of 18.7 gm and 5.5 gms respectively was put in the stabilisation ponds in December, 1963. At the end of one year the average weights C.Catla and L.rohita were found to be 900 gms and 140 gms respectively. Similar successful experiments were carried out at Nagpur and Bhopal also. It is not recommended to stock the main pond with the usual type of fish. However, Ophiocephalus which is known for its ability to utilise both dissolved oxygen as well as atmospheric oxygen (surface-breather) may be stocked in the main stabilisation pond. Ophiocephalus has been reported to be having a good market value at Calcutta particularly owing to its rich iron content. Other fish can be better grown in a subsidiary pond.

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HARVESTING ALGAE

The yield of algae in a stabilisation pond may vary from one ton/acre/month in winter to five tons/acre/month in summer depending on climatological conditions. Algae contain 50-60% protein, 5-20% carbohydrates.

Gloyna's Formula -

$$V = (3.5 \times 10^{5}) N q La Q^{(35 - T_m)}$$

Oswald

Rewalla $K = \frac{1}{t}$

225 to 300 lbs/13

MONITORING EFFLUENT DISPOSAL FROM WASTE STABILIZATION PONDS
A CONCEPTUAL OUTLINE

Dr. R. PITCHAI

INTRODUCTION

The effluents from waste stabilization ponds may be either disposed of by discharging into water courses or reused, wherever applicable, for productive purposes. In all such disposal situations, water quality data needs arise, for a variety of purposes. Water quality monitoring should be carried out through a carefully planned and designed system if the data returned by the system is to be useful and cost-effective. The mission of the system should be clearly specified, the parameters and their characteristics carefully identified, background data should be systematically employed and a monitoring system designed which will use perhaps both instrumentation and prediction techniques. The conceptual outline of such a water quality monitoring system is described in this paper.

OBJECTIVE

The objective of this presentation is to introduce the concept of water quality monitoring systems and indicate their possible application in system design for monitoring effluent disposal from waste stabilization ponds.

PLANNING AND DESIGN ASPECTS

The planning and design of a water quality monitoring system implies logically

° specification of the mission of the system desired,

+ [illegible], Public Health [illegible]ineering Department, College of Engineering, Guindy, Madras. 600025.

- derivation of the criteria, characteristics, or in this case, the description of the requirements of water quality parameters from the specified mission of the system.
- enumeration of alternative methods or devices which will meet the requirements specified,
- evaluation of the alternatives with reference to their capabilities and costs,
- ranking the alternative methods or devices in terms of the degree to which they fulfil the requirements, and
- selecting the best alternative (s) and implementing the same.

THE NEED FOR MONITORING

In defining the mission of a water quality monitoring system, considerable care must be exercised since the ultimate utilization of the system will depend upon the validity of this initial mission statement. We recognize that data on the quality of the stabilisation pond effluent or the receiving water body into which it is discharged, may be needed for one or more of several purposes such as

- mere description of existing quality,
- determining normal hourly, daily, seasonal or long-term variations and trends in quality,
- evaluating the impact of existing or planned wastewater discharges on the water quality,
- determining the suitability of the effluent or receiving water for some specific uses such as irrigation or fishing,

- correlating observed effects in the receiving water with possible causes,
- assessing whether prescribed effluent or receiving water quality standards, have been met, or
- a record of surveillance for enforcement purposes.

THE MISSION REQUIREMENTS

Once the mission of the water quality monitoring system is clear, a list of the water quality parameters whose space and time description will be required to support the mission can be drawn up by the designer and data user, working together. The state of the aquatic environment is established by describing a set of state vectors throughout the four dimensional space, with a prescribed accuracy. The state vector is a finite number of measures of parameters (e.g., temperature, D.O., productivity, etc.). In the monitoring system for effluent disposal from waste stabilization ponds, an illustrative list of the parameters of interest could be as shown in TABLE I.

In any given body of water, it is not expected that the same state variables or parameters will be required in all regions (for example, different variables are important near the water surface than at the bottom). The prescribed accuracy should be recognized as not necessarily equal in all four dimensions. The data user can also establish the priorities and relative weights of the variables.

THE ELEMENTS OF SYSTEM DESIGN

The next step in the system design is the evaluation of alternative methods by which the requirements could be met. The evaluation of alternative methods now implies consideration

TABLE I

ILLUSTRATIVE LIST OF PARAMETERS OF INTEREST IN MONITORING WASTE STABILIZATION POND EFFLUENT DISPOSAL.

Description of variable.	Possible Priority category*	Units	Possible Range of interest*	Accuracy*
Water Temperature	1	°C	20.0 to 40.0	0.5
D.O.	1	mg/l	0.0 to 40.0	0.1
B.O.D	2	mg/l	0 to 100	1
p^H	3	Units	6.0 to 9.0	0.1
Suspended solids	2	mg/l	0 to 500	5
Total solids	3	mg/l	0 to 1000	10
Phosphates, as PO_4	3	mg/l	0.0 to 50.0	0.1
Nitrogen- Total	3	mg/l	0 to 100	1
NH_3	3	mg/l	0.0 to 25.0	0.1
NO_2	3	mg/l	0.00 to 1.00	0.05
NO_3	3	mg/l	0.0 to 25.0	0.1

* To be specified by user. The values in the Table are illustrative.

of the trade offs possible between a system which accomplishes its mission by making a very large number of observations and another system which accomplishes the same by making a small number of observations but with a great deal of sophisticated data analysis to predict the actual environmental conditions between stations. An ideal combination of hardware (i.e., instruments for monitoring) and software (computer programs which predict the variables at intermediate points between stations) usually yields the minimum cost system to accomplish the mission. The design of such a system required prior knowledge of the environment to be monitored: the greater the level of prior knowledge of the state vectors, the fewer the engineering estimates required in the system design. Therefore, an initial data base has to be established collecting already available relevant data from all authentic sources and historical records.

SYSTEM DESIGN TECHNIQUES

A hierarchy of techniques exists for the design of monitoring systems. The higher the order of the analysis scheme, the greater the reliance on our understanding of the environmental mechanisms active in the water body to be monitored. The zero-order approach relies completely on the data provided by the instrumentation to describe the body. In the first-order method, it is noted that values may be interpolated between spatially separated observation points to provide the required picture of the water body, thereby reducing the number of sampling points. With second-and higher order techniques, more and more recognition is given to the known interactions of the variables in order to project values throughout the volume based on fewer and fewer observation points. The first-and higher order methods require the development of Inter-sensor Prediction (ISP) techniques - a digital computer software effort. We briefly describe the zero-order and higher order techniques here.

i. <u>Zero-Order Design Method</u> Consider the design criteria for a monitoring network with the stipulation that the state vectors be determined entirely by the instrument system observations. Such design criteria for the spacing of the sampling stations are based on the required mission accuracies, the instrument errors, and an extensive study of the historical data to establish the anticipated maximum change in a variable of interest over a specified spatial increment. Since values are usually known only for a limited number of locations in the region of interest, the spatial gradients determine the degree to which a point value is an estimate of the value of the variable at some distance away from the point. The objective of the design method is to determine a spatial sampling interval which will assure that these estimates fall within required mission accuracy to ahigh degree of probability. Thus, establishment of the spatial sampling interval must be founded on the maximum gradients which may be anticipated in the region of interest. The following paragraphs discuss a practical design procedure based on this premise.

In developing the design criteria, a gradient G is used to compute the maximum possible error between the measured variable at the sampling station (point) and its value at some distance r from the station in the θ-direction; G (θ) is the maximum magnitude of the gradient known to have occurred in the θ-direction at or near the station, as determined from the existing data base. The maximum uncertainty $\Delta V_g (r, \theta)$ in estimating a variable V at some distance r in the θ-direction from a point where the value is known, is

$$\Delta V_g (r,\theta) = \{G(\theta)\} . r$$

In addition to the uncertainty due to gradients, imperfect sensors will result in an independent contribution to the overall uncertainty or error. Since measurement errors due to sensors (ΔV_s)are independent of errors due to spatial gradients (ΔV_g), the maximum total error E is the square root of the sum of the two squared errors. An expression for total error is

$$E(r,\theta) = \left[\Delta V_s^2 + \Delta V_g^2(r,\theta)\right]^{1/2}$$

Maximum error contours can be developed for each variable of interest based on the above expression. These contours can then be used to establish the necessary station spacing which satisfies the mission requirements.

The concent of 'area of influence' must be introduced at this point in the discussion. The area of influence is that region surrounding a sampling station which includes all the points for which we are confident that the difference between the true value at the point and the observed value at the station is within the required mission accuracy. The degree of confidence is identically the degree to which we are confident that the assumed gradient rosette based on historical data has not been exceeded. The boundary of the area of influence is the error contour having a value equal to the required mission accuracy. Settling $E(r, \theta) = V_m$, the mission accuracy, yields,

$$\Delta V_m = \left[\Delta V_s^2 + \Delta V_g^2(r,\theta)\right]^{1/2}$$

substituting for $\Delta V_g(r, \theta)$ and solving for r, we obtain

$$r_m(\theta) = \frac{\left\{\Delta V_m^2 - \Delta V_s^2\right\}^{1/2}}{G(\theta)}$$

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$$i.e., \quad r_m(\theta) = \frac{\Delta V_m}{G(\theta)}\left[1 - \left(\frac{\Delta V_s}{\Delta V_m}\right)^2\right]^{1/2} \simeq \frac{\Delta V_m}{G(\theta)}$$

r_m can be estimated with a good confidence from the ratio $\Delta V_m / G(\theta)$, which is the radius if there is no instrument error at all. This is because the other factor $\left\{1 - \left(\frac{\Delta V_s}{\Delta V_m}\right)^2\right\}^{1/2}$ is close to unity for instrument errors less than or equal to as much as a half of the mission accuracy desired.

ii. First-and Higher Order Design Methods The previous discussion dealt with obtaining a complete description of the environmental variables solely with observations at instrument stations. It did not include or consider the possibility of estimating the state of a variable at a point between instrument stations from the observations at two or more of these stations. In real-world situations the state of the variables at any time is not a completely random statistic. There is a cause-effect relationship between one set of variables influenced by forcing functions such as winds, tides, fresh water and waste water discharges, man's activities, etc., and another set of variables which are man's indicators of the physical, chemical, and biological environment of the water body and descriptive of the energy transformations taking place in the water. For instance, the tidal exchanges and wind-induced circulation patterns, along with radiation energy and man's waste discharge largely affect the temperature patterns within a water body at any time. Photosynthesis, respiration, reaeration, mixing, and changes caused by man-made waste loads and fresh water influence the dissolved oxygen (DO) profiles. Similarly, principal influencing processes can be identified for describing the state of most sets of variables.

A mathematical description of the above processes based on their mechanisms is a tool that can be effectively employed to predict the state of the variables and thereby add to the information that an instrument network can furnish by itself.

With such a mathematical ISP technique, the number of instrument stations required to monitor the water body and determine the state of the variables to the mission accuracy desired can be reduced considerably. Thus a tradeoff between the number of stations and the fineness of the mathematical description of the processes leading to interstation prediction techniques is envisaged to determine the optimum combination of the two. Designs of monitoring systems based on these principles have been carried out elsewhere and it should be possible for us to employ the technique for monitoring stabilization pond effluent disposal systems.

NATURAL FACTORS CONTROLLING WASTE STABILISATION POND PERFORMANCE

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S. PERUMAL

INTRODUCTION

This paper discuses such natural factors that control the performance of facultative type oxidation ponds. The factors are sunlight, photosynthetic oxygen production, temperature, characteristics of sewage, wind action and toxicity. These are detailed below.

SUNLIGHT

Aerobic stabilisation of organics in an oxidation pond depends on photosynthetic oxygenation of the waste water.

Photosynthesis is controlled by Sunlight. The quantum of light that falls on a horizontal surface such as the surface of a pond, i.e. visible light insolation or visible solar radiation depends on the latitude of the location. It depends also on the period of the year, the elevation of the location and the extent to which the sky is clouded.

The visible solar radiation is expressed in terms of Langleys i.e. gram calories per cm^2 per day. The probable average values for different latitudes at sea level are shown in Table 1 (15) for Northern Latitudes which cover India.

The visible radiation may be corrected for elevations higher than sea level by multiplying with a factor (1 + 0.0033 El) where El is the elevation above MSL in hundreds of metres (2).

TABLE 1

VISIBLE SOLAR RADIATION AT SEA LEVEL IN LANGLEYS PER DAY

North Latitude	January		May		August		November	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
34°	114	53	290	176	267	159	128	70
30°	136	76	290	184	271	166	148	90
26°	156	99	288	189	273	172	166	109
20°	183	134	284	194	272	177	190	138
16°	200	154	279	194	270	177	206	154
10°	223	179	270	192	266	176	228	176
8°	230	187	266	191	263	174	234	182

The visible radiation has also to be corrected for cloudy weather (2). The correction for cloudiness has been given as (approximately).

= Min. visible radiation + (Max-min) Cl.

where Cl = fraction of time weather is clear.

The sky clearance factor for a few places in India is given below (2)

TABLE 2

SKY CLEARANCE AT DIFFERENT PLACES IN INDIA

Name of Place	Latitude	Sky clearance factor			
		January	May	August	November
Trivandrum	8.29	0.71	0.28	0.27	0.31
Madras	13.04	0.52	0.44	0.23	0.24
Hyderabad	17.26	0.71	0.57	0.20	0.53
Bombay	18.54	0.83	0.65	0.16	0.68
Nagpur	21.09	0.67	0.59	0.14	0.64
Bhopal	23.16	0.72	0.77	0.18	0.76
Ahmedabad	23.02	0.75	0.79	0.17	0.76
Delhi	28.35	0.66	0.86	0.40	0.80
Calcutta	22.32	0.80	0.36	0.15	0.68
Srinagar	34.05	0.22	0.61	0.54	0.71

PHOTOSYNTHETIC OXYGEN PRODUCTION

The quantum of sunlight available for photosynthesis has been considered above. The weight of oxygen which can thus be produced from a given quantum of sunlight may now be discussed.

Mathematical formulations have been proposed by Oswald, et.al. (15), Rich (22) and Arceivala, (2) for Oxygen production during photosynthesis. The formulations have the following steps.

It is assumed that the limiting criteria for algal growth is the availability of Sunlight, S, expressed as calories per cm^2/day and not nutrients. The assumption is valid for sewage lagoons where algal nutrients are in abundance.

The light energy is trapped during photosynthesis and storedas heat of combustion in theal gal cell material. The heat of combustion thus stored per unit area of pond may be equated to

$$S.E.$$

Where E is the efficiency of conversion of light energy to heat energy.

The efficiency of conversion is quite small. Based on pilot plant studies Oswald (15) have estimated the efficiency to be 4%. Rich assumes the same value Arceivala, (2) estimate from existing ponds an apparent efficiency of 6% or even higher.

A knowledge of the heat of combustion, He expressed as kilocolories per gm. wt . of algae should give the weight of algae produced per unit area of pond as

$$\frac{SE}{HC}$$

The heat of combustion per unit weight of algae can be determined from a knowledge of the composition of the algae or experimentally, from a sample of the algae. Oswald (15) as also Rich (22) and Arceivala (2) suggest 6 kilo calories/ gm weight of algae.

The weight of oxygen (O) produced per unit area of pond per day may be computed from a knowledge of the weight of oxygen (P) produced per unit weight of algal cell material. Rich (22) has assumed oxygen production by typical algae to be 1.25-1.75 gms of O_2 per gm of algae. Arceivala (2) and Oswald (15) assume a value of 1.63 gms. per gm.

The final equation for photosynthetic oxygen production may be written as

$$O = \frac{P.S.E.}{HC} \qquad \text{Where}$$

O is in Kg/hect/day.

P is usually 1.25 to 1.75

E is usually 4 - 6,

HC is usually 6,

NOTE: The numerical values for the symbols as furnished should be used directly as corrections for units have already been incorporated.

The application of the formula requires a judicious selection of the values for P and E. If the higher values (1.75 and 6) are adopted the oxygen production indicated will be double the value given by the lower and more conservative values (1.25 and 4).

A question that arises is whether the entire oxygen produced according to the formula is available for biological oxidation of the wastes. The doubt arises in the context of the supersaturation of dissolved oxygen noticed in the upper layers of waste stabilisation ponds during noons. At such periods, it is quite likely that some of the oxygen produced escapes into the atomosphere. Oswald (15) considers that occasional mixing may be necessary to ensure use of the entire oxygen produced by algae.

TEMPERATURE EFFECTS

The temperature which influences pond performances is the actual pond temperature, temperature of the influent sewage, flow into the pond and the area of the pond. No rational methods have been developed for determining pond temperatures though empirical methods have been suggested.

Pond temperatures are however known to generally follow the ambient temperatures but fluctuate less. In view of the uncertainty about how various factors affect pond temperature, we may assume as an approximation that the average pond temperature equals the average ambient temperature.

The influence of temperature on algal metabolism in the pond has been considered by Gloyna (9) and Arceivala (2). Gloyna (9) has reported 20°C as the optimum temperature for oxygen production by algae and 4°C and 35°C as the lower and upper limiting values. If the pond temperature approaches 35°C particularly when the ponds are shallow, the beneficial green algal population will decrease and the blue green algae will dominate giving rise to odour nuisances. Arceivala (2) considers 20°C to 40°C as the favourable range for photosynthesis. He has also reported that at temperatures higher than 35°C, green algae will disappear.

The maximum summer temperatures in the pond may well exceed 35°C in tropical areas. At Madras midday pond temperatures of even as high as 43°C have been recorded during summer periods. However it was observed that the temparatures tapered off depthwise very rapidly.

Regarding bacterial metabolism in the pond, the effect of temparature is twofold. One in regard to the ultimate BOD, and the other in regard to the rate of bacterial activity.

The ultimate BOD expresses the complete oxygen demand of a waste as against the demand measured in the laboratory at 20°C over 5 days. The ultimate BOD at the conventional 20°C has been generally found to be about one and a half times the 5 day value for domestic sewage.

As the temperature increases, the ultimate BOD will increase. For domestic sewage the ultimate BOD at any temparature can be computed as

$$\text{Ultimate BOD}_{(t)} = \text{Ultimate BOD}_{(20)} \left| 1 + \frac{t-20}{5} \right|$$

The significance of temperature effect on ultimate BOD is that higher the pond temparature (as in summer) the greater will be the oxygen to be supplied.

In respect of the rate of bacterial activity, the rate will increase with an increase in temparature. In the case of BOD progression in BOD bottle, the effect of temparature on the biodegradation rate constant is given by the formula

$$K_t = K_{20} (1.047)^{t-20} .$$

The formula has been applied by Arceivala (2) to estimate the pond performance at different temperatures. Gloyna (9) has estimated the effect of temparature on biodegradation in the pond based on laboratory and pilot plant studies. He has adopted 35°C as the optimum temparature for biological activity in the pond and estimated the reaction rate at other temparatures as

$$K_t = K'_{35} (1.072)^{t-35}$$

Thus the significance of temparature effect on bacterial activity is that higher temperatures will necessiate lesser detention periods.

It can be seen from the above that the effect of temparature on bacterial activity can be readily incorporated in pond design in regard to detention period and oxygen requirements. However no such easy application is possible in regard to the effect of temparature on algal activity.

CHARACTERISTICS OF SEWAGE

The special characteristics of sewage which will influence pond performance are the ratio of settleable organics to non-settleable organics in the waste, the septicity and the toxic contents.

The ratio of settleable to non-settleable organics is important in facultative oxidation ponds because the settleable matter is stabilised by anaerobic degestion and only the non-settleable portion is stabilised in the aerobic zone requiring dissolved oxygen. Therefore the higher the non-settleable matter in a waste the greater will be the oxygen demand and consequently surface area requirement.

Some of the factors which tend to increase the ratio of non-settleable organics to settleable organics are, long passage through sewers and turbulance as during pumping. Septicity may also increase the ratio.

Septicity may influence pond performance in another way also. Due to septicity the sulphates in the sewage will be reduced to Hydrogen Sulphide and when the concentration of Hydrogen Sulphide in the pond goes up beyond a critical value photosynthetic organisms which can utilise

Hydrogen Sulphide may take over the pond without producing enough oxygen and thereby causing anaerobic odourous conditions.

WIND ACTION

The effect of wind action on pond performance is both positive and negative.

Wind action normally contributes to mixing up of the pond contentsand tends to make the pond a completely mixed system for which the biodegradation rate is more than a true plug system. The mixing also helps in a fuller utilisation of the oxygen produced in the pondby bringing into contact the bottom oxygen deficient layers with the top oxygen rich ones. Excessive wind action may however be objectionable as it may upset the facultative functioning of the pond

TOXICITY

Toxicity may not be a matter of concern for domestic sewage. However where industrial wastes are also involved, toxicity may have to be considered. The toxic substances may affect algal or bacterial activity in the pond or both. Remedial measures may be increase in surface area, or detention period or pretreatment to remove the toxic elements.

CONCLUSION

The effect of natural phenomena and environmental factors on pond performance have been considered above. It may be seen that a rational application to pond design is possible only in the case of temperature, bacterial activity and photosynthetic oxygen production. Such an application is not possible in respect of temperature influence on algal activity, characteristics of sewage, wind movement and toxicity. In these cases, all that can be done is to make judicious allowances in design.

DESIGN OF WASTE STABILISATION PONDS

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INTRODUCTION

This paper considers those design features of facultative ponds which control the biodegradation of organic matter. The features which are important in this context are the surface area of the pond, the detention time provided in the pond and the depth of the pond. Other features like inlet and outlet arrangements, embankment details, treatment of pond floor and sides, the type of pretreatment to be provided etc. are considered separately.

SURFACE AREA

Surface area is important because it controls the quantity of oxygen which can be put into a pond by photosynthetic oxygenation (and to a small extent by surface reaeration which is usually neglected)

Surface area should be sufficient to maintain aerobic conditions in the upper layers of the pond. When surface area is inadequate, anaerobic conditions may prevail at the surface of the pond all the time or occassionally during cloudy days depending on whether the surface is grossly or only slightly inadequate.

Surface area criterion is generally expressed as its inverse function i.e. as kilogrammes of 5 day BOD at 20°C which can be applied or removed per day per hectare of pond surface (Kg BOD/hect/day). The criterion is generally termed the "areal BOD (or organic) loading rate".

There has been considerable variance in the areal organic loading rates recommended by different authorities. Many of the recommended rates are based on studies of field ponds and have been influenced by local conditions such as sunlight intensity, cloudiness, liability to winter freezing and local considerations such as the extent to which odours have to be avoided.

Some of the reçommended areal loading rates are listed below (29).

Authority	Recommended Areal BOD loading (kg/hect/day)	Remarks
Smallhorst	33 to 55	Evolved at Texas with ice free conditions and temperate climate. Apparently designed for aerobic conditions for most of the depth.
Oswald	44 to 55	Evolved at California with ice-free, equitable climate. Apparently designed for same conditions as above
Towne	Atleast 110	Ice-free climate. For operation without serious odours.
Hunt	220 to 264	Evolved in Kenya for favourable climate. Aerobic conditions were maintained at surface upto 330 kg/hect/day.
Ten State Standards	25	Subject to ice cover during part of the year.

Some authors have developed rational approaches to permissible areal loadings. Rich (22) and Leychok (6) consider the BOD load which can be removed per unit area of a pond. They have assumed that BOD removal in the pond is entirely by aerobic mechanism and make no allowance for BOD removal by anaerobic digestion in the bottom layers. The latter mechanism does not require oxygen and its neglect in the formula serves as a factor of safety. The authors have postulated:

Oxygen required (kg/day) = Ultimate BOD load to be removed in pond (kg/day)

= Ultimate BOD load in influent

minus Ultimate BOD load in effluent.

The ultimate BOD loads are to be calculated for the particular pond temperature on the basis discussed in the earlier paper. The oxygen requirement has to be met by photosynthetic oxygen production for which also the formula has been already discussed.

The authors assume that the entire quantity of oxygen produced byalgae is available for biological oxidation. However, this may not be the case as some of the oxygen may escape during midday hours when the pond is supersaturated with dissolved oxygen.

The assumption of Rich (22) in regard to the full utilisation of oxygen implies a certain degree of underdesign. But this may well be compensated by the overdesign implied by neglect of the removal of the percentage of BOD by anaerobic digestion. Rich's form formula is applicable for BOD removals near about 90%.

Arceivala (2) have furnished a theoretical approach similar to Rich for determining the surface area for ponds. They have also published a map of India showing the recommended 5 day BOD loadings for ponds at different latitudes (see Appendix). The basis for the Map is not given, but the loadings are stated to be approximate and applicable to towns at sea level and where the skies are clear for atleast 75% of the days in a year. For meterological and elevation conditions other than described, judicious corrections to the recommended loadings are necessary.

The recommended values are based on the assumption that the pond is 0.9 to 1.5 m deep and that the volume of pond gives sufficient retention time (See under DETENTION PERIOD). The loadings are reported to be suitable for 80-85% BOD reductions during all seasons. Where such high BOD removals are not necessary, eg., when effluent farming is proposed or when occasional odors can be tolerated, e.g., when the site is far from habitations, higher loading rates are suggested to reduce area requirements.

Siddiqui (26) has contended that the settleable faction of BOD in the incoming waste proposed as 50% for domestic sewage, need not be taken into account for determining loading rates, because this faction will be digested anaerobically at the bottom without demanding dissolved oxygen. He has suggested the use of the Map of Arceivala, (2) taking into account only the non-settleable BOD.

The total neglect of the settleable area as influent BOD in the determination of surface area as proposed by Siddiqui (26) may lead to underdesign because some faction of the settled organics will diffuse upwards into the aerobic zone exerting extra oxygen demand and also because the proposal does not leave any compensating factor to take care of the partial escape of oxygen from the pond.

Rational approaches apart, some field data are available regarding satisfactory areal loadings observed in certain parts of India.

In some cases satisfactory performance has been reported in stabilisation ponds even at such high loadings as 380 to 490 kg/BOD/hect/day whereas in other cases aerobic conditions have been reported to fail even at loadings of 220 kg/hect/day (2). At Madras, where the sewage is normaly septic experimental studieshave indicated satisfactory performance only at or below 230 kg/hect/day (18). Even with this loading, aerobic conditions disappeared in the pond during prolonged periods of cloudy weather.

One reason for the wide variation in performance of Ponds in India may be the difference in the composition of sewage (relating to septicity and the percentage of suspended and soluble organic matter) from location to location.

In view of the wide variations in pond performance the areal loading for oxidation ponds may have to be selected based on local experience and local conditions such as climatic variations, nature of sewage and the extent to which occasional odours can be tolerated near the pond location.

Experience at Madras shows that a BOD loading of 110 kg/hect/day may be suitable for oxidation ponds for institutions like hospitals, college campuses, etc. This loading may increase the area but it will ensure absence of odours at all times. As ponds for institutions are likely to be located close to residences, even chance odours may not be desirable.

For municipal sewage treatment where the ponds are likely to be located atleast some distance from residences, a BOD loading of about 230 kg/hect/day may be satisfactory. This loading will give an effluent fit for discharge into water courses and will also ensure odour free conditions except during prolonged cloudy weather.

BOD loadings higher than 230 kg/hect/day may give satisfactory performance in some locations and fail at other locations depending on sewage septicity, cloudiness, temperature, etc. Loadings above 230 kg/hect/day and upto 330 kg/hect/day may be suitable for ponds designed for pretreating sewage before sewage farming. Sewage farms are not likely to be located near residences and occasional upsets and odours in the ponds in the farms may not cause public complaints. Occasional deterioration in effluent quality may also not matter.

It should be noted that the loadings recommended above are in terms of the total 20°C, 5 day BOD of the influent sewage and not the soluble or non-settleable faction of the BOD. Also, it should be remembered that the recommendations have only a broad application and their adoption for each specific case should follow a detailed consideration of local factors.

DETENTION PERIOD

Whereas sufficient surface area is necessary in a pond for providing the required oxygen, sufficient detention capacity is necessary to enable the pond organisms to utilise the oxygen and stabilise the influent sewage. Various authors have proposed differing mathematical approaches for estimating the detention period for ponds. Their approaches are discussed below.

Arceivala (2) estimate detention period on the assumption that BOD removal in a pond follows the same first order pattern as BOD progression in a BOD test.

The BOD progression in BOD test is written as

$$y = L(1-1/10^{Kt})$$

Where y = BOD satisfied upto time t;

L = ultimate BOD

k = Reaction rate constant (per day) at the operating temperature;

t = time (days) of reaction; days (On taking logarithms and rearranging

$$t = \frac{1}{K} \operatorname{Log} \left(\frac{L}{L-y} \right)$$

Applying this equation to the stabilisation pond, the detention period t, required for the pond will be

$$t = \frac{1}{K} \operatorname{Log} \frac{\text{Ultimate BOD in influent}}{\text{Ultimate BOD permissible in effluent}}$$

The equation can be rewritten as

$$t = \frac{1}{K} \operatorname{Log} \frac{Si}{Se}$$

Where Si = BOD_5 of influent at 20°C

Se = BOD_5 of effluent at 20°C

The reaction rate K should be for the temperature which will obtain in the pond during the coldest month of the year so as to provide for the worst condition.

As discussed in an earlier paper the reaction rate constant at different temperatures may be calculated by the formula

$$K_T = K_{20} (1.047)^{T-20}$$

where K_T = Value of K at T°C

K_{20} = Value of K at 20°C

Laboratory studies give a K_{20} value of approximately 0.10 for domestic sewage.

The above formulation assumes that (i) the detention period provided is fully available for aerobic activities of bacteria which will be the case only if dissolved oxygen is available in the pond all the time i.e. night and day, and for all the depth and (ii) the sewage flows through the pond as in a plug system without any mixing.

In practice, both assumptions may not be reaslised in full. Thus, unless the pond is very much underloaded, D.O. may disappear in the pond during nights and even during daytime it may be absent in the lower zones of the pond not satisfying assumption (i). Similarly, there may be considerable mixing in a pond due to wind movements and temperature gradients, which is contrary to assumption (ii).

Assumption (i) leads to an underdesign; but, assumption (ii) introduces a factor of safety since the reaction rate K will be higher for a mixed system than for a plug system.

An additional factor of safety is that the formula ignores the removal of part of the BOD at the bottom of the pond by anaerobic digestion which is a common feature of facultative type oxidation ponds.

Rich (22) has proposed an equation for detention period based on the same assumptions as Arceivala (2) (6).

Marais and Shaw (13) formulated an equation for detention period on the assumption, that instead of plug flow there is complete and instantaneous mixing in the pond, i.e., the BOD concentration is the same at all points in the pond whether near the inlet or near the outlet and equals the BOD concentration in the effluent. Another assumption is that the BOD removal follows a first order equation. The formulation is

$$Se = \frac{Si}{K' t + 1} \quad \text{or}$$

$$t = \frac{1}{K'} \left(\frac{Si - Se}{Se} \right)$$

where K' = reaction rate. The reaction rate is dependent on temperature. Suwannakaran and Gloyna (28) postulated, based on laboratory studies, that

$$K'_T = K'_{35}(\theta)^{T-35}$$

where θ = Temperature coefficient ranging from 1.085 to 1.072

K'_T = reaction rate at pond temperature T°C

K'_{35} = reaction rate at standard temperature of 35°C

For municipal wastes K'_{35} has a value of 1.2 according to thelaboratory and pilot plant studies of Gloyna and his co-workers (9)(10) (28)

Marais (14) has suggested acorrection to his earlier equation to allow for the BOD removed in the sludge layers by anaerobic digestion by substituting

$Si(f_p + C_p f_s)$ for Si in the Marais-Shaw formula

where f_p = fraction of influent BOD which will remain in pond water.

f_s = fraction of influent BOD which will settle out.

c_p = fraction of fermentation products from settled sludge which will reenter pond liquid.

It is to be remembered that the complete mixing assumed by Marais and Shaw may not exist in natural conditions just as true plug flow conditions also may not exist. Also, there may be difficulty in evaluating the various constants involved in the equation.

Hermann and Gloyna (10) and Suwannakaran and Gloyna (28) studied detention requirements by observing field installations and laboratory-scale models. Their research resulted in the following design formula (9)

$$t = C.Si \times \theta^{(35-T)}$$

where C = conversion factor with a value of 3.5×10^{-2} and other symbols are as before.

The formula is generally applicable for BOD_5 removals of 80 percent to 90 percent. Solar energy for photosynthesis is assumed to be available.

The formula is derived empirically and Gloyna (9) states it has considerable merit particularly in the temperate and warmer areas.

Siddiqui (26) considers that detention period should be equal to or more than 6.5 day for 90% BOD removal. This recommendation is made for conditions where pond temperatures are not likely to fall below 15°C.

Amongst the various formulations, the equations of Arceivala, Marais and Shaw modified by Gloyna, and Hermann and Gloyna are temperature dependent. The original equations of Marais and Shaw and the recommendation of Siddiqui do not provide for temperature effects though Siddiqui has specified a limiting minimum temperature.

The Arceivala equation implies that the detention period is dependent on the percent BOD remaining in the effluent while the Marais-Shaw formula implies that it is proportional to the percent BOD removal in the pond. The Hermann Gloyna equation implies that the detention time is dependent only on the influent BOD.

The nuances of the different equations is brought out in the following example. Let it be required to treat one million litres of sewage per day from 300 mg/l influent BOD to 30 mg/l effluent BOD in one case and one million litres of sewage per day from 200 mg/l influent BOD to 20 mg/l effluent BOD in another case. According to the Arceivala (2) formula and the Marais and Shaw (13) formula the detention periods will bethe same for both the cases. But as per the Gloyna (9) equation the detention periods will vary in the ratio of 3:2. The Gloyna equation appears to be analogous to those used in the design of conventional design of secondary treatment where volumetric requirements are dependent on influent BOD load expressed as kg influent BOD/day/unit volume of trickling filter or aeration tank.

DEPTH

Having fixed the surface area and volume (flow per day x detention time) required for a pond it may seem unnecessary to consider depth independently since it will equal volume by surface area. However, independent consideration of depth is necessary because depths below certain lower or upper limits may affect pond performance.

Shallow depths less than 0.9 m are objectionable because they will allow bottom vegetation to develop, obstructing light penetration and promoting mosquito breeding.

Shallow depths are objectionable also because they affect the facultative functioning of oxidation ponds. In facultative ponds, the bottom layers have to be truly anaerobic since methane bacteria are sensitive to oxygen and when depth is small, the dissolved oxygen may diffuse into the sludge layers inhibiting the anaerobic digestion of the settled organics.

Shallow depths will also result in greater diffusion of the products of partial fermentation of sludge into the upper layers, increasing the faction of influent BOD which has to be stabilised aerobically.

Shallow depths also offer less buffer against high summer temperatures in hot climates, the effects of which have been considered in an earlier paper.

Much study has not been done on the depth for oxidation ponds. The earliest work was by Parker (16) who reported that performance did not suffer when depth was reduced from 0.90 m to 0.45 m. Parker's study, however, was on a pond with a very low BOD loading (about 50 kg/hect/day) and with an influent sewage pretreated in an anaerobic lagoon.

Arceivala, (2) reported that 1.5 m depth gave a more consistant performance over varying pond temperatures that 1.2 m depth though the over-all efficiency of the latter was slightly better. The studies were on ponds dosed with raw sewage at fairly high loadings.

The Public Health Engineering Department, Tamil Nadu (18) reported comparative studies at Kodungaiyur, Madras, on 1.2 m deep pond and another 2.4 m deep pond, both dosed at 230 kg/hect/day. The deep pond did not function better than the shallow pond. The BOD removals were slightly lesser in the deep pond. The pond had a slight unpleasent odour and it did not behave like a typical facultative pond. Floating sludge was present at the surface very often. The sides of the pond were anaerobic and black. The colour of the pond was pink rather than green. Sulfides were present in the effluent during early morning hours almost always and dissolved oxygen was absent in the pond many times, even during midday hours. In contrast, the shallow pond behaved like a typical facultative pond with green colour and supersaturation of dissolved oxygen during midday.

In another comparative study at Kodungaiyur a 4.0 m deep pond and a 1.2 m deep pond were both dosed at about 400 kg/hect/day. In this study, while the shallow pond functioned atleast partially like a facultative pond, the deep pond never exhabited dissolved oxygen, and produced sulfides and unpleasant odours to a much greater degree than the shallow pond. The reason for the upset of deep ponds as observed in the studies is not well understood. However, one explanation may be that in the deep ponds, where the oxygen deficient zone is larger, the sulfates are reduced to sulfides and the sulfides in their turn affect algae growth and make the entire pond go anaerobic.

In the Kodungaiyur studies the sewage was highly septic due to long travel from the city to the pond site and the initial septicity must have aided further sulfate reduction in the deep ponds. When sewage is fresh, ponds may probably survive increased depths unlike in the case at Kodungaiyur Gloyna (9) has recommedded a minimum depth of 2.0 m for ponds in temperate regions. Arceivala (2) (4) recommend a depth exceeding 0.9 m to avoid emergent vegetation. However, they caution against depths greater than 1.5 m to avoid anaerobic conditions in the pond. Siddiqui (26) considers the optimum depth to be 1.5 m - 1.8 m and states that deeper pondsmay not increase the efficiency.

The Madrasstudies (18) indicate the disadvantages of increasing the depth excessively. A suitable depth may be between 1.2 m - 1.8 m. The shallow depth may be adopted when the sewage is expected to be septic and the greater depth when the sewage is fresh.

When the depth of a pond, calculated by dividing pond volume by surface area is found to be inadequate, the depth should be increased to the optimum value, and the detention period will then increase above actual requirement. When the calculated depth is excessive, the depth should be reduced to the optimum value and the consequent reduction in detention period should be compensated by increasing the surface area above requirement.

CONCLUSION

It may be seen that the approaches of the various authors towards the design of ponds are varying. The extent of variation is well illustrated by the problem worked out in the appendix. The final results are abstracted below.

TABLE

Comparison of results according to different formulations for population 40,000 sewage flow 100 lpcd, BOD 300 mg/l and 90% removal.

Sl.No.	Author	Surface area in hectares	Depth in meters	Detention period in days
1.	RICH	7.20	--	--
2.	ARCEIVALA (Rational)	7.20	1.2	21.6
3.	ARCEIVALA (Map)	4.10	1.2	12.3
4.	MARAIS-SHAW	8.15	1.2	24.4
5.	GLOYNA	6.86	2.0	34.3
6.	SIDDIQI	2.05	1.8	9.3
7.	PRESENT RECOMMENDA-TIONS	5.25	1.5	19.7

Design 4 is apparently conservative and will ensure trouble free performance during all seasons. Design 2 also seems to fall into the same category. Design 5 may create problems if the sewage is septic as the depth is rather high but the surface area is apparently more than adequate. Design 3 may create problems during prolonged cloudy weather in view of the comparatively small surface area. Design 6 may function satisfactorily under special conditions, like very fresh sewage, and uninterrupted sunshine. Design 7 may be expected to give a generally satisfactory performance, but when the sewage is highly septic it may be desirable to limit the depth to 1.2 m.

APPENDIX

WORKED OUT EXAMPLE

Design an Waste Stabilisation Pond based on the various formulations given the following:-

Location	14° Latitude
Elevation	600 m above sea level.
Temperature	30° max - 18° min
Population served	40,000
Sewage flow	100 litres per capita daily
BOD_5 for raw sewage	300 mg/1
Desired effluent BOD	30 mg/1
Sky Clearance factor	0.75
Efficiency of conversion of solar energy by algae 4%	4%
Heat of combustion of algae	6 kilocalories/gm

I. SURFACE AREA

A. Solution after Rich.

Summer Conditions

BOD_5 to be removed = 270mg/1

Ultimate BOD to be removed at 20°C = 270 x 1.5

= 405 mg/1

Ultimate BOD to be removed at 30°C $= 405 \times \left\{ 1 + \frac{30-20}{50} \right.$

= 486 mg/1.

Oxygen requirement $= \frac{486 \times 40,000 \times 100}{10^6}$

= 1900 kg/day

See Table

ARCIVALA

Visible Solar Radiation in May at 600 m above sea level

= (194 + (276 − 194) x 0.75)(1 +0.0033 x 6)

= 266 calories/cm^2/day

Photosynthetic oxigenprtduction = $\frac{1.63 \times 266 \times 4}{6}$

= 286 kg/ha/t/day

Area requirement = $\frac{1900}{289}$

= 6.6 hectares

Winter conditions

Ultimate BOD to be removed = 405 x (1 + $\frac{18-20}{50}$)

= 405 x 0.96

= 390 mg/1

Oxygen requirement = $\frac{390 \times 40,000 \times 100}{106}$

= 1560 kg/day

Solar radiation in December at 600 m above sea level

= (146 + (209−146) x θ.75)(1 +0.0033 x 6)

= 199 Cals/cm^2/day

Photosynthetic oxygen production = $\frac{1.68 \times 199 \times 4}{6}$

= 216 kg/hect/day

Area required = $\frac{1520}{216}$

= 7.20 hectares.

B. Solution after Arceivala (Rational Approach)

The solution will be the same as above provided the value of P & E are the same. In as much as the values of P & E have been fixed in the problem the same result will workout here also.

C. Solution after the map of Arceivala

The permissible loading at 14°
latitude (by interpolation) = 287.5 kg/hect/day

This value is applicable at sea level and for a sky clearance factor of 0.75.

The problem however is for an elevation of 600 m

Thus corrected loading $= 287.5\ (1 + 0.0033 \times 6)$

$= 293.25$ kg/hectare/day.

The BOD_5 load in the influent $= \dfrac{300 \times 40,000 \times 100}{10^6}$

$= 1200$ kg/day

Area required $= \dfrac{1200}{293.25}$

$= 4.10$ hectares.

D. Solution as per Siddiqi.

Non-settleable BOD load (assumed at 50%) in the influent = 600 kg/day

Loading rate from the map of Arceivala et. al. = 293.25 kg/hectare/day

$= \dfrac{600}{293.25}$

$= 2.05$ hectares.

E. As per present recommendations

Influent BOD_5 load = 1200 kg/day

Recommended loading = 230 kg/hect/day

Area required $= \dfrac{1200}{230}$

$= 5.25$ hectares.

II. DETENTION PERIOD

A. Solution after Arceivala

Summer conditions

$$K_{30} = K_{20}\ (1.047)^{30-20}$$

$$= (0.1)(1.047)^{10}$$

$$= 0.1581$$

$$t = \frac{1}{K} \text{ Log } \frac{Si}{Se}$$

$$t = \frac{1}{0.1581} \times \text{Log } \frac{300}{30}$$

$$= \frac{1}{0.1581}$$

= 6.3 days.

Winter conditions

$$K_{18} = K_{20}(1.047)^{18-20}$$

$$= 0.0911$$

$$t = \frac{1}{0.0911} \times \text{Log } \frac{300}{30}$$

= 11 days.

B. Solution after Marais-Shaw & Gloyna

Summer Conditions

$$K'_{30} = 1.2\ (1.072)^{30-35}$$

$$= 0.8476$$

$$t = \frac{1}{0.8476} \left(\frac{300-30}{30}\right)$$

$$= \frac{9}{0.8476}$$

= 10.6 days.

Winter conditions

$$K'_{18} = 1.2\ (1.072)^{18-35}$$

$$= 0.368$$

$$t \quad \frac{1}{0.368} \left(\frac{300-30}{30}\right)$$

= 24.4 days.

C. Solution as per Gloyna

Winter conditions

$$t = 3.5 \times 10^{-2} \times 300 \times 1.072^{35-18}$$

= 34.3 days.

Summer conditions

$$t = 3.5 \times 10^{-2} \times 300 \times 1.072^{35-30}$$

= 15 days.

D. Solution as per Siddiqi.

t = 6.5 days (empirical)

FINAL SOLUTIONS

A. After Rich

Surface area required = 7.20 hectares.

B. After Arceivala (rational approach)

Surface area required = 7.20 hectares.

Detention period = 11 days

Resulting Depth $= \frac{40,000 \times 100 \times 11}{10^3 \times 7.20 \times 104}$

$= 0.61$ m.

Recommended depth = 1.2 m.

Detention period $= \frac{4.10 \times 10^4 \times 1.2 \times 10^3}{40,000 \times 100}$

= 12.3 days

Detention period (theoratical) = 11 days.

D. After Marais Shaw

Detention period = 24.4 days

Recommended depth = 1.2 m

Surface area $= \frac{40,000 \times 100 \times 24.4}{10^3 \times 1.2 \times 10^4}$

= 8.15 hectares.

E. After Gloyna

Detention period = 34.3 days

Depth to be provided = 2 m

Resulting surface area $= \frac{34.3 \times 40,000 \times 100}{10^3 \times 2 \times 10^4}$

= 6.86 hectares.

F. After Siddiqi.

Surface area = 2.05 hectares.

Depth to be provided = 1.8 m

Resulting detention $= \frac{2.05 \times 10^8 \times 180}{40,000 \times 100 \times 1000}$

= 9.3 days.

More than the suggested minimum of 6.5 days.

G. Present Recommendations

Surface area = 5.25 hectares.

Recommended depth = 1.5 m

Resulting detention time = $\frac{5.25 \times 10^8 \times 150}{40,000 \times 100 \times 1000}$

= 19.7 days.

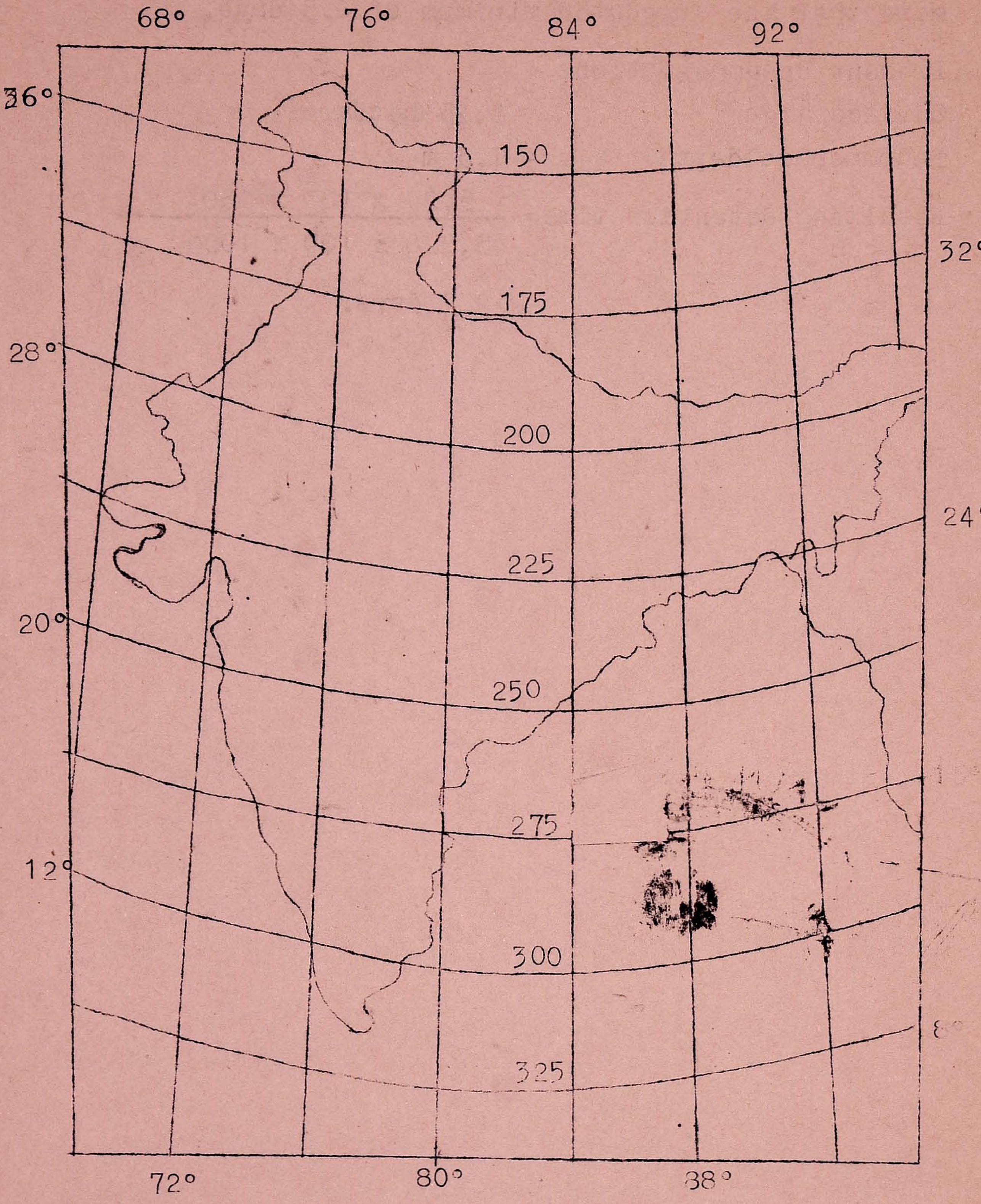

FIGURE 1 BOD LOADING IN KG./HECTARE/DAY
AT DIFFERENT LATITUDES
(TO CONVERT TO LBS/ACRE/DAY
DIVIDE BY 1.12)

SOME SPECIAL ASPECTS OF WASTE STABILISATION PONDS

A. RAMAN.

INTRODUCTION

Some aspects of waste stabilisation ponds design and performance which have not been considered so far are discussed in this paper.

SLUDGE ACCUMULATION

It has been pointed out earlier that the suspended solids in sewage will settle to the pond bottom and undergo disgestion. The algae in the pond which die out will also settle to the bottom and undergo digestion. The inert solids left after digestion will remain at the pond bottom and this digested sludge will accumulate with time.

In most literature from abroad it has been reported that sludge accumulation in waste stabilisation ponds will be negligible and needs no special consideration. The observation may apply only to ponds which are dosed at a very low BOD loading, say 20-50 kg/hect/day. Ponds in our country are dosed at much higher loadings (220-330 kg/hect/day) and in these cases, the sludge accumulation will be substantial.

Approximate calculations can be made for sludge accumulation in stabilisation ponds on the following basis, neglecting the contribution of sludge by dead algae and bacterial cells which may be comparatively small.

Assume BOD of 300 mg/1, suspended solids of 400 mg/1 and BOD loading of 230 kg/hect/day. Let flow be 0.5 million litres.

Then total BOD Load $= 300 \times 0.5 = 150$ kg/day

Area of pond $= \frac{150}{230} = 0.65$ hect

Total suspended solids inflow per year

$= 400 \times 0.5 \times 365 = 73{,}000$ kg.

Fixed solids in raw sludge = 40%

Fixed solids in digested sludge = 60%

Total suspended solids left after digestion (dry basis)

$$= 73,000 \times \frac{40}{100} \times \frac{100}{60}$$

$$= 48,700 \text{ kg.}$$

Weight of digested sludge (wet basis) assuming 90% moisture

$$= 48,700 \times \frac{100}{10}$$

$$= 4,87,000 \text{ kg.}$$

Volume assuming sp.gr. of 1.05

$$= \frac{4,87,000}{1.05}$$

= 4,80,000 litres or 480 cu.m.

Depth of sludge accumulation $= \frac{480}{0.65 \times 100 \times 100}$ m

= 0.0075 m or 7.5 cm per year.

Some actual observations made on sludge accumulation in stabilisation ponds at Madras are abstracted below:

Location.	Age	Total depth	sludge depth
Kodungaiyur	4 years (Treating Raw Sewage)	1.2 m	0.26 m
I.I.T.	5 years (Treating raw sewage)	1.5 m	0.15 m
Central Polytechnic.	4 years (Treating raw sewage)	1.2 m	0.14 m
T.B.Sanatorium Tambaram	8 years (Treats septic tank effluent)	0.9 m	0.08 m

The effluent of sludge accumulation in stabilisation ponds does not seem to have been reported in literature. A study has been made in Madras on two oxidation ponds dosed at the same surface loading, one of which was 6 years old and had 0.4 m depth of sludge out of 1.2 m total pond depth and the other which was new and had no sludge accumulation but was otherwise similar to Pond I. Generally, there was no difference between the ponds in regard to BOD removal, but during prolonged cloudy weather, anaerobic conditions earlier in the first pond. Presence of algal scum and black sludge (lifted up from the bottom) was also greater in this pond. There is a chance of bottom vegetation developing when sludge accumulation has reduced the pond depth considerably. The critical depth of sludge when a pond will have to be cut out of operation, the supernatant liquid drained out and the sludge removed after it dries in situ. The sludge in the lagoon will be well-stabilised and will be suitable as fertiliser. In order to facilitate desludging it is important that ponds are constructed in multiple cells.

EVAPORATION

The rate of evaporation from ponds will depend on an ambient temperature, wind movement, relative humidity and other factors. The rate may not differ much from the rate of evaporation in fresh water bodies. In South India the rate is about 8 mm/day maximum in summer and the water loss per hectare will be 80,000 litres/day which will represent 10% of the sewage inflow for a BOD loading rate of 250 kg/hect/day and a BOD concentration of 300 mg/l. When the BOD loading is kept conservative, say about 80 kg/hect/day, the water loss may be 30%. The water loss may be impprtant when the effluent is intended to be used for agriculture especially because the water loss will be maximum when the water requirement is also maximum i.e., in summer. The water loss may also result in increase in dissolved salts in the effluent.

The increase will be about 10% in the first case and 40% in the second stage. The effect of increase in dissolved salts on the irrigation utility of the effluent will be obvious. The water loss will also result in increase of the concentration of organic matter in the pond liquid. The effluent of such increase on pond performance is a matter for study.

PISICULTURE

The stabilisation pond environment because of its green colour may appear to the casual observer as well suited for pisciculture. But several environmental factors in the pond are against its success. A prime requirement for successful pisciculture in a pond is the presence of dissolved oxygen all the time. In ponds loaded even at moderate loadings of 115 kg/hect/day the D.O. has been found to run out at night. Another sensitive factor is the concentration of free ammonia in the pond. Free ammonia in harmful to most fish even at such low concentration as 1 mg/l. Except when raw sewage is very dilute, the ammonia concentration in the pond will exceed this figure. At Madras in some studies with Tilapia, the fish died out within a few hours an introduction into a pond with high ammonia (8 mg/l) though D.O. was present to saturation level.

Generally, only coarse varieties of fish such as Ophiocephalus may be able to survive in facultative ponds, thanks to their ability to use atmospheric oxygen when dissolved oxygen is absent. The fish generally lie submerged in the sludge and harvesting them by netting may be difficult. The netting may also stir up the sludge and affect pond performance. The keeping quality of the fish when grown in sewage ponds has been found to be poor. Hence, pisciculture with the Ophiocephalus species even may not have economic significance in facultative ponds.

Pisciculture may be successful in maturation ponds, provided the ammonia content is sufficiently low. But, before a commercial utilisation of this idea, due consideration should be given to the health risks involved. It has not been established conclusively that fish grown in sewage does not carry pathogens despite cooking and that its consumption is not a health risk. Another possible health risk is the physical transfer of pathogens from fish to other foodstuffs during handling in the kitchen.

The health aspects should be studied very carefully before pisciculture is adopted commercially. For the keeping quality of the fish grown in sewage effluents. At Kodungaiyur, in Madras, fish grown in a polishing lagoon have been found to spoil quickly.

PINK PHENOMENON

Development of a pink colour has been reported from certain oxidation ponds designed as facultative ponds. In Madras City, an oxidation pond (now defunct) serving a housing colony was found to be permanently pink. In certain experimental ponds at Madras (Kodungaiyur), pink colour has been observed occassionally in some ponds and for prolonged periods in other ponds. Pink colouration has been reported also in waste stabilisation ponds at Vijayawada, and Ahmedabad and in some ponds in the U.S.A.

Pink ponds are attended by odours. In some cases, the odours have been found to be worse then from anaerobic ponds. The pink ponds may also suffer in regard to organic purification. The control of the phenomenon is therefore of interest to the Engineer.

The pink colour has been ascribed to certain photosynthetic purple sulfur bacteria such as Chromatium vinosum, Thiopedia rosea, Thioplycoccus, Rhodothece, etc. At Madras, the responsible organism has been found to be similar to Merismopedia tenuissima. The pink colouration of the organisms has been found to be due to predominance of carotene, a participant pigment in photosynthesis. This pigment supresses the green colour of chlorophyll which is also present in the organisms.

The metabolism of the pink organisms seems to be tied with hydrogen sulfide. The organisms use hydrogen sulfide as the hydrogen donour in photosynthesis instead of water molecule as in the true plant photosynthesis and release free sulphur instead of free oxygen. Due to the absence of oxygen production during photosynthesis the pink ponds will be anaerobic even at the surface unlike facultative ponds and hence they may give off odours.

Pink conditions seem to be governed by initial septicity of the sewage which will convert the sulfates in the sewage to sulfides, moderately high BOD loadings and increased depths. In studies at Madras a 1.2 m deep pond loaded at 230 kg BOD/hect/day was found to be green while an identical pond loaded at 460 kg/hect/day became pink. A pond 2.4 m deep dosed at 230 kg/hect/day was also pink while a pond 4 m deep dosed at 460 kg/hect/day presented the deepest pink colour. Control of pink conditions require that surface loadings should not be too high and the depth also should not exceed 1.2 m very much. These stipulations may be particularly important in cases where the sewage is not fresh and arrives at the pond site in a septic condition.

FIELD AND LABORATORY TESTS FOR WASTE STABILISATION PONDS

Certain simple tests can be carried out in the field to test whether an stabilisation pond is functining satisfactorily. One test will be to check for hydrogen sulfide in the pond. The test can be carried out by putting a drop or two of lead acetate solution at various points in the pond. A black, brown, or whitish colour will respectively indicate high amount of sulfides, moderate amount of sulfides or absence of sulfides. The critical time for presence of maximum sulfides in a pond is at daybreak and the presence of sulfides in traces at such times cannot be taken as an evidence of pond failure. Presence of high amount of sulfides at noon or in the evening will be an indication that the pond is not functioning properly and that it may give rise to odour nuisances.

Another simple test which can be carried out in the field is for dissolved oxygen. The elaborate procedures for laboratory determination of D.O. will not be necessary and all required accuracy can be obtained by means of a field kit with the reagents in dropper bottles and a test effluent early in the morning indicates a high pond performance. At midday, the D.O. should be quite high and for above saturation values. Absence of D.O. in the pond at such times indicates that anerobic conditions have set in which may be due to overloading or cloudy weather.

Sludge accumulation in a pond can be determined in the field by pushing in a glass tube of 25 mm O.D. slowly into the water until it has gone down a few inches into the bottom soil, giving the tube a few turns and then slowly withdrawing the tube. The bottom end of the tube will have to be roughened up inside by means of a carborundum stone to help the bottom soil to adhere to the glass and form an effective plug for the sludge and the water above. The withdrawn tube will give the actual water depth and the sludge accumulation can be calculated as design depth minus actual water depth.

It will be desirable to carry out regular laboratory tests on the performance of waste stabilisation ponds, if for nothing else at least to obtain data which will be available for use elsewhere in the country. The frequency of observation will have to be decided dependent on the laboratory facilities. The tests should be for both raw sewage quality and effluent quality. The raw sewage sample should be composited over 24 hour period preserving it properly with ice. In regard to effluent, grab sampling may be sufficient except that it may not give a correct estimate of suspended solids. The tests on raw sewage should include total BOD.soluble BOD on centrifuged or filtered sample, suspended solids, sulfates, sulfides, free ammonia and total nitrogen. The tests on the effluent should atleast for total BOD, BOD of filtered (No.4 Filter Paper) sample, suspended solids and free and total ammonia. A final filtered effluent BOD of about 20 ppm or less may be considered as satisfactory. The purification in the pond may be calculated as filtered effluent BOD/total BOD of raw sewage.

COST CONSIDERATIONS

The cost of providing stabilisation ponds includes both land cost and construction cost. Land cost may vary significantly from place to place and from location to location in the same place. The construction cost will include items like earth work, inlet, outlet chambers, distribution lines, effluent collecting channels, fencing installation of necess approach way and general lighting including warning sign pos.

Estimates for stabilisation ponds may generally follow the same pattern anywhere, but may significantly differ in overall value in respect of certain major item. These are land value, provision of lining for the water face of the bund and the type of such lining.

Land costs may vary substantially from place to place even in the same place from location to location. Depending upon whether the land is cultivable or not the costs may even be as high as50,000 acre even in locations away from cities. Lining of ponds may be practiced in many ways. Complete lining using concrete slabs though is the most desirable form may prove prohibitively costly at some locations. Alternative lining may be tried with stone pitching or sand asphalt mixtures in which case the costs may reduce.

A model estimate has been prepared and is included under Appendix. The estimate isbased on a design of pond for treating about 6 million litres of sewage per day with a BOD of 300/mg/1 at an organic loading rate of 230/kg/hect/day with a total depth of 2.8 m out of which 1 m is the free board Lining with the cement concrete slabs has been provided (on the water face) from the toe of the embankment to 0.6 m on the top of the bund.

The rates adopted are expected to be the best average rates for the respective items of work, for most Indian locations. However, where necessary suitable assumptions can be incorporated.

Maintenance charges for ponds may include cost of lighting, general repairs and renewals, and pay of staff. The estimate as prepared now provides only for a minimum of staff as the provision of lining may well do away with the necessary for any elaborate maintenance arrangements.

The capital cost of the installation works out to Rs.6,00,000/- per 6 million litres of sewage flow per day. The capitalised cost over 30 years at 7% interest (factor 0.08058) works out to Rs.7,25,000/-. For a contributory population of 60,000 the per capita capitalised cost works out to Rs.12.10. Its comparision with conventional treatment plant, designed with conventional loadings is indicated in TABLE 1. It may be seen that the stabilisation pond method is a reasonable one with a per capita cost that is substantially low as compared with other mechanised methods of sewage treatment. As a general comparison TABLE 2 indicates the range of costs for sewage treatment works for different sewage flow rates at average Indian locations.

TABLE 1

Break up details of cost for comparing cost of waste stabilisation ponds with other conventional treatment methods.

Population = 60,000. Flow 6 million litres/[illegible]ay.

	Oxidation Pond		Conventional Plan[illegible]	
Capital costs				
1. Plant	1,50,000		18,00,000 (at Rs. 0.[illegible]0 per litre)	
2. Land at Rs. 50,000/hectare	4,50,000		50,000	
Total		6,00,000		18,50,000
Per capita		10		3[illegible]
Running costs				
1. Power	1,000		70,000	
2. Staff	6,000		42,000	
3. Maintenance & Repair	3,000		28,000	
Total		10,000		1,40,000

Capitalised cost for comparison

	Oxidation Pond	Conventional Plant
Capital cost	6,00,000	18,50,000
Capitalisation of Annuity over 30 years at 7%	1,25,000	17,50,000
Total	7,25,000	36,00,000

TABLE 2

General comparison of costs for sewage treatment by stabilisation pond aerated lagoon, oxidation ditch and conventional treatment using Trickling Filter ( )

Process	Cost per capita for construction of plant.	Capital cost plus capitalised running costs per capita	Total annual expenditure per capita to defray all running costs including repayment of loan.
1. Waste stabilisation pond.	Rs. 8.80 to Rs.15.70	Rs.10.60 to Rs.27.20	Rs. 0.93 to Rs. 2.30
2. Aerated lagoon	Rs.12.00 to Rs.19.00	Rs.32.20 to Rs.55.80	Rs. 2.80 to Rs. 4.86
3. Oxidation ditch	Rs.14.00 to Rs.21.00	Rs.43.75 to Rs.79.60	Rs. 3.80 to Rs. 6.06
4. Conventional treatment.	Rs.25.00 to Rs.75.00	Rs. 40.88 to Rs.152.00	Rs. 3.55 to Rs.13.22

NOTE: 1. In each item the first data in cost pertains to the cost of plant for 2,00,000 contributory population and the second data in cost pertains to that for 50,000 population.

2. Repayment of loan has been assumed over 20 annual equated instalments at 6 per cent per annum, interest rate.

OPERATION AND MAINTENANCE OF WASTE STABILISATION PONDS

T. Damodara Rao

INTRODUCTION:

Waste stabilisation can be brought about in a number of ways amongst which waste stabilisation pond method is important. The stabilisation can be done with help of algal photosynthesis as in aerobic oxidation pond, by anaerobic action as in anaerobic ponds, in aerated lagoons and in aerobic anaerobic ponds referred to as facultatitive ponds. All of these can be classified as waste stabilisation ponds. A certain amount of attention is necessary to keep these treatment units in operation to acheive necessary treatment.

BRINGING AN ANAEROBIC STABILISATION POND INTO OPERATION:

When the organic load applied on a waste stabilisation pond exceeds the oxygenation due to algal photosynthesis and surface diffusion of oxygen from atmosphere, the entire dissolved oxygen in the contents of the pond disappears and anaerobic conditions set in. In practice, it is observed that all ananerobic actions consist of two phases. In the first phase, organic matter gets reduced to organic acids, Malodourous organic compounds as also NH_3 and H_2S are found to come and in this phase. The pH tends to be about 5 or so. The next phase is called gasification phase in which the organic acids get converted to methane. This conversion actually results in a high degree of organic removal. The destniction of organic acids results in the pH rising up even above 7.0. In an anaerobic pond operating satisfactorily, the pH will be more than 7.0 and bubbles of gas would be seen breaking the surface of the pond. When this is happening, malodourous emanations will be consistently absent from the waste stabilisation ponds. It is not unusual to find a setback in the operation due to sudden change in either the weather or the loading pattern or some other unexplained reason. Then it will be seen that the surface of the pond takes on a glassy look with a disappearance of the bubbles. The pH will be less than 7.0 with increase in acidity. If the abnormatity is detected and rectified and the condition brought to normal, the healthy anaerobic trend can once again be restored. To bring a new anaerobic pond into operation, it is usual to use an anaerobic sludge with an admixture of cow dung. The methano bacterium in the cow-dung will establish itself in the pond and gradually give rise to methane gas. The methonobacteria are, however, very sensitive to temperature changes. It is found when the temperature is either low or high, the methanobacteria do not thrive. And, in this condition, methane gas may not be generated with consequent deteriosation in the effluent condition.

In anaerobic waste stabilisation ponds, the depth is usually 6 feet or more. The detention time for the waste will be high. Sludge accumulation will not be substantial as gasification results in very small quantity of sludge. If methane formation is absent, sludge accumulation may both be substantial and problematic.

AERATED LAGOONS:

Both anaerobic lagoons and aerobic lagoons for waste stabilation require large area and volume if left to natural conditions. There are large variations in the effluent quality due to changes in natural conditions. To ensure that such variations do not affect the effluent, oxygenation can be induced by providing diffused aeration or mechanical stirring. In such a set-up, the area requirement can be reduced to about 1/8th the area of a waste stabilisation pond. The cost, however, is higher for treatment of the waste. By aerated lagoon, the waste can be treated to a consistent standard and the season, temperature, depth etc. do not exert the same effect. Aerobic and anaerobic conditions could exist at the same time in aerated ponds. In cold climates, the constant motion of the contents of the lagoon may result in loss of heat and low temperature. This may have an impact on the degree of treatment as bacterial activity is influenced by temperature.

AEROBIC POND:

In aerobic pond, the depth is limited to about 1'. Large amount of algal are produced. On days when it is sunny, patches of water may have a high temperature of 35°C. The D.O. may also be high with a pH of 11.00. In such a condition, magnesium salts may be precipitated and these in turn may enmesh the algae and settle down. The water may clear up and allow sunlight to reach the bottom of the pond. Such conditions give rise to the algal mats rising up and giving rise to foul odours due to putrefaction. For this reason, it is advisable to have depth of 5' or so for the waste stabilisation pond. In such a case, the top 1' or so will act as an aerobic gone and the bottom will tend to be anaerobic. The odourous substances that may be coming out will be rendered in occur by the aerobic zone.

FACULTATIVE PONDS:

Facultative ponds are the aerobic anaerobic ponds that are adopted for waste stabilisation. As discussed before, aerobic condition due to algal photosynthesis occurs in the top layers of these ponds. The bottom layers have a substantial sludge layer supporting anaerobic conditions. Methane generation is noted to occur in the lower region.

BRINGING A NEW FACULTATIVE POND INTO OPERATION:

The sewage or the waste water is let into the waste stabilisation pond through a pipe of suitable size flowing either under gravity or by pumping. Initially, where domestic sewage is concerned, the stagnation of the waste in the pond gives rise to build up of algae and further addition of domestic waste gives rise to algal bloom thus stabilising the waste treatment. If there is an occasional increase in the load, the waste stabilisation pond can take care of it. If overloading is continuous, some of the following troubles commence.

(i) The green algae replaced by blue green algae occassionally, if the overloading is continuous, odours such as pigpen odour will be observed.

(ii) If the over loading is heavy, anaerobic conditions may set in. Then, grey colour occurs on the surface. Evolution of NH_3 and H_2S may become noticeable.

(iii) Occassionally, the surface may show pink colour which is probably due to sulphur bacteria.

In case of over loading, a part of the waste water may be bye-passed until the pond recovers from the effects of over loading, Permanent arrangement must however, be made for extra loads that have not been provided for in the design.

The floating scum mat that is found when blue green algae predominate must be removed. A net with a long handle can be used for this. The weed growth on the sides must be prevented. Otherwise mosquito breeding can result. To control mosquito breeding use of larviciding oil will be effective. Care should be taken to see that such steps do not affect the action of algae by photosynthesis.

Depending on the load, the dissolved oxygen varies throughout the day. If the load is high, the dissolved oxygen may disappear completely in the night and during cloudy days. At such times, disagreeable odours may become noticeable.

Since the effluent from stabilisation ponds are having algae, fish can be reared in the effluent.

The following table details the operational defects and the remedies.

TABLE I.

	Observation.	Pond condition.	Preventive step.
i.	Bright green colour to some depth from below the surface.	Very good.	Remove marginal vegtation and floating scum accumulation.
ii.	Blue green in colour.	Good.	Algal mats and scum accumulation to lbe removed regularly.
iii.	Green or blue colour on surface to small depth cakes of sludge floating up distinct sulphide odour.	Tending to be overloaded.	Removal of floating matter. If overloading is temporary, bye pass the flow so as to reduce load on the pond.

	Observation.	Pond condition.	Preventive step.
iv.	Grey, black or dark brown. Oily appearance of the surface with dark grey floating soilds.	Overloaded and anaerobic.	If temporary, bye-pass the flow so as to reduce load on the pond. If extra land is likely to be permanent suitable permanent remeady such as expansion necessary for cleaning existing pond, necessary before recommissioning.
v.	Surface pink red or dark grey colour.	Tending to be anaerobic.	May be due to presence of sulphur bacteria. Bye-pass part of influent until normally is established.

MAINTENANCE OF POND SURROUNDINGS:

A well maintained pond with proper clearance will add greatly to the attrativeness of the local. Fencing of the area will prevent tresspass by stray cattle and passers-by. Mosquito breeding can be eliminated by removing shrubs and other growth in the region of pond.

ANAEROBIC PONDS FOR TREATMENT OF DOMESTIC SEWAGE

M.SUBRAMANIAM.

INTRODUCTION

Anaerobic lagoons can be considered as long detention septic tanks using earthen basins without covers. They can also be considered akin to sludge digestion tanks with the exception that no mixing, gas collection or temperature control is provided.

Anaerobic lagoons differ from facultative ponds in having lesser area or lesser detention period. They produce effluents which are of much lower standards than waste stabilisation pond effluents.

The use of anaerobic ponds for the treatment of domestic sewage was first reported by Parker ( ) from Melbourne, Australia. Anaerobic lagoons have been widely used in Canada in the Alberta Province. Sentis ( ) has reported their use in theSasketchawan province. Gloyna ( ) has reported the systematic use of anaerobic lagoons in Israel for the pre-treatment of domestic waste water.

Much work does not seem to have been done in India on anaerobic lagoons for municipal wastes, though climatically the method is very much suited for the country. Raman ( ) has reported a pilot plant study on anaerobic lagoons at the Engineering College, Madras. Varadarajan ( ) also have reported on Pilot Plant studies on anaerobic lagoons at Kodungaiyur, Madras. It has also been reported that Ahamedabad had used deep ponds for sewage treatment with the ponds functioning anaerobically.

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Recently field applications of anaerobic lagoons have been started in Tamil Nadu. For the Kumbakonam Municipality, anaerobic lagoons have been constructed as pretreatment devices before secondary treatment in an aerated lagoon. Also anaerobic lagoons have been proposed for pretreatment of sewage before sewage farming for the Coimbatore and Tirunelveli Municipalities.

THEORY OF PURIFICATION

The stabilising action in an anaerobic lagoons depends on methane digestion. It has already been explained in an earlier paper that escape of 16 gms of methane from an anaerobic system means the removal of 64 gms of BOD from the system.

In anaerobic lagoons, methane digestion takes place mainly in the sludge layers at the bottom. The setteable organics in the influent sewage are directly transferred to the sludge layers by settling, but, the non-settleable organics are only indirectly transferred to the sludge layers. Their indirect transfer is brought about by absorption by digesting sludge when it boils up in the lagoons during the escape of methane gas and comes into contact with the sewage.

TEMPERATURE EFFECTS

Methane digestion ishighly sensitive to temperature. The optimum temperature for the mesophilic methane bacteria involved in lagoons in 37°C and temperatures below 20°C slow down the bacterial activity considerably.

It is because of this temperature dependence that there is continuous sludge boiling in anaerobic lagoons in summer and very little sludge boiling in winter.

Because of reduced sludge boiling in winter, the removal of non-settleable BOD in Anaerobic lagoons may not be high and the overall BOD removal in the pond may be considerably lesser in winter than in summer.

DETENTION PERIOD

The detention period usually provided for anaerobic lagoons treating domestic sewage ranges from 2-5 days. In the range mentioned, the actual detention period may not affect the removal of settleable organics but it may influence the removal of non-settleable organics because longer the detention period the greater will be the opportunity for digesting sludge coming up during sludge boiling to absorb the non-settleable matter in the flow through liquid.

SURFACE AREA

Surface area does not appear to be of consequence in anaerobic ponds treating domestic sewage. By providing the required detention period in deeper ponds, surface area requirement can be made lesser and lesser. The surface area usually provided is less than 1 hect. for 500 kg BOD/day compared to 1 hect. for 230 kg BOD/day provided for waste stabilisation ponds.

DEPTH

Just like surface area, depths also may not affect anaerobic lagoon performance.

Anaerobic lagoons have functioned satisfactorily at 1 m depth but the usual practice has been to adopt depths in excess of 2 m. Depths upto 4.5 m have been tried successfully in field installations.

PURIFICATION OBTAINED

Because of the dependence of the method of temperature. the purification in anaerobic lagoons may vary greatly from winter to summer.

The BOD removal in anaerobic lagoons may be between 50 - 65% in winter and 70 - 75% in summer.

The suspended solids in an anaerobic lagoon effluent will not be the original suspended solids in the sewage (which would all settle out in the pond) but the digesting sludge as lifted up by the escaping methane gas. The S.S. removal in the pond has been found to be 60 - 80%.

POND CHARACTERISTICS

Anaerobic lagoons will have a dark glassy appearance unlike the green colour of stabilisation ponds.

The Wave action in anaerobic ponds has been noted to be less than in Stabilisation ponds.

Scum formation in anaerobic lagoons will be greater than in oxidation ponds. However, it has been found that the scum does not become permanent as in septic tank but is broken up by wave action.

The percent volume of sludge accumulation per annum in anaerobic lagoons will be greater than in Stabilisation ponds because of the lesser volume provided. The loss in pond volume due to sludge accumulation can be calculated rationally in the same manner as discussed for oxidation ponds.

Sludge accumulation in anaerobic lagoons may not adversely affect BOD removal but may cause increase in suspended solids in the effluent.

EFFLUENT CHARACTERISTICS

The effluent from an anaerobic lagoon will be devoid of oxygen and will carry considerable sulfides. It will have a comparatively high immediate BOD and may also some odours.

HEALTH AND AESTHETIC ASPECTS

Anaerobic lagoonsmay not effect as much reduction in bacterial organisms as waste stabilisation ponds. Hence, there may be risk to public health in the use of anaerobic lagoon effluents for growing vegetables.

Anaerobic lagoons also present opportunities for the breeding of culex mosquitoes which are the vectors for Filariasis. Special consideration has to be given in the construction and operation of anaerobic lagoons to avoid culex breeding.

The anaerobic pondmay not present a very pleasant appearance due to its dark colour and the presence of floating scum. The pond may also give off some odours, though the odour may not be as strong as expected.

APPLICATIONS

Anaerobic lagoons are primarily suited when the sewage is strong with a BOD of about 300 mg/1. When the sewage is weak, anaerobic lagoons may not be advantageous.

Anaerobic lagoons have application as a cheap substitute for primary settling. They will be cheaper because of the comparitively lesser cost for the earthen basin as compared to cost of masonry settling tanks and elimination of sludge digestion tanks and sludge drying beds.

Anaerobic lagoons may be used for pretreating sewage for growing restricted crops like fodder grass when available area is insufficient for stabilisation ponds.

Anaerobic lagoons may also be useful for pretreating sewage for further treatment in mechanically aerated lagoons or in stabilisation ponds.

Anaerobic lagoons have been used in Canada to pretreat sewage for discharge into rivers, but such application may be possible only when the receiving stream has considerable flow, i.e. when the stream can as well receive settled sewage.

CONSTRUCTION AND OPERATION

In order to avoid nuisances and health dangers special consideration is necessary in the selecting of the sites for anaerobic lagoons, in their construction and operation.

As anaerobic lagoons are prone to odours they should be located away from habitations in the direction of wind. The ponds should also be well away from the habitations (atleast 0.75 km) and not too close to roads from where the pond surface can be seen.

Anaerobic ponds will have to be desludged frequently, once in 4 or 5 years. The lagoons should be constructed in 3 or 4 units so that one unit can easily be desludged at a time.

Where local conditions permit, it will be advantageous to provide pipe outlets to dewater the lagoons for desludging.

There may be great danger of culex breeding in anaerobic lagoons marginal vegetation is allowed to develop. To avoid growth of vegetation it is necessary to line the inside banks of the pond atleast to 0.5 m above and below the water line with contrete slabs or rough stone pointed with cement mortar.

In the operation and maintenance of anaerobic lagoons special attention should be paid to mosquito control. Larvicidal spraying and control of marginal vegetation are of very great importance in avoiding mosquito dangers and should not be neglected.

CONCLUSIONS

Anaerobic lagooning can be a cheap substitute for the primary settling of strong sewages and may be useful when primary treatment alone is proposed or when separate secondary treatment is proposed by waste stabilisation ponds or aerated lagoons.

With careful selection of site, and proper construction and maintenance anaerobic lagoons may not present aesthetic or public health hazards.

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WASTE STABILISATION PONDS FOR INDUSTRIAL WASTE TREATMENT

T.DAMODARA RAO

INTRODUCTION

Waste stabilisation ponds offer an economical method of treatment for industrial wastes. Usually the waste water from an industry is having higher organic content when compared to domestic sewage. It is usual for each industry to have its own characteristic waste which can not be treated in municipal sewage treatment plant. The stabilisation ponds come in handy in such situation and can handle the industrial wastes satisfactorily. When the organic load is some what low, facultative ponds are found to be effective. When the organic load is fairly high anaerobic ponds are able to function satisfactorily.

The following characteristics of industrial wastes may affect the functioning of the stabilisation ponds.

i. High alkalinity as in the case of tanning effluents and textile processing effluents where liming and alkali both are involved.

ii. High acidity asin pickling wastes, distillery wastes etc.

iii. Organic compounds such as cyanidi, Phenol etc.

iv. Inorganic substances like copper, chromium, lead, arsenic, borun etc.

It is necessary that the wastes should have a proper balance of carbon, nitrogen and phosphorus for development of bacterial population which will help to reduce the organic load. The domestic sewage has a satisfactory composition but many industrial effluents do not have such proportion.

Hence, it is sometimes difficult to have a satisfactory bacterial population develop in the industrial waste. The situation is corrected to an extent if domestic sewage can be mixed with the industrial waste. Another method used is adoption of anaerobic ponding wherein the bacterial population required is less than what will be necessary for aerobic reactions.

To reduced the concentration of toxic substance, addition of domestic sewage or even fresh water may be adopted Some kind of pretreatment to convert the toxic matter to inocuous substance may to achieve satisfactory bacterial build-up may also be necessary.

Many of the industrial effluents can be treated in facultative stabilisation ponds and anaerobic stabilisation ponds. Some of the examples are given below for facultative ponds.

TANNERY WASTES

The tanneries use 400-800 gallons of water for treating 100 lbs of hides. The main constituents which given access to the waste water are the sodium chloride which is used as a preservative for the skins and the organic matter released from the skin during processing. The sodium chloride portion can be segregated while the portion containing the organic matter can be treated in stabilisation ponds. The 5 days B.O.D. of the tannary waste will be about 1000-2000 mg/l with a pH of about 8.2 to 8.5. Oxidation ponds at about 150-200 lbs of B.O.D/acre are successful in reducing the B.O.D. to acceptable levels. A detention time of 30 days has been found to be satisfactory.

OIL REFINERY WASTES

The effluent from oil refinery has a high oil content

(2000-3000 mg/l) free and (80-120 mg/l) emulsified. The phenolic compounds range from 12-30 mg/l. The B.O.D. ranges from 100-300 mg/l. It also contains high concentration of Hydrogen sulphide. A detention time of 60 days for the facultative ponds has given a B.O.D. reduction of 40 to 90% and phenol reduction of 61 to 99% percent.

SUGAR MILL WASTE

The waste having a B.O.D. of 1200 mg/litre has been successfully treated in two anaerobic ponds of 7 days detention followed by 4 aerobic ponds of 10 days duration. The B.O.D. of the effluent was 125 mg/l.

FERTILISER FACTORY WASTES

The wastes from fertiliser factory will have little organic content. The high nitrogen content is however a matter for objection. The nitrogen which is present as ammonia can be lost to the atmosphere if the waste is made alkaline and held in a pond. On a laboratory scale a detention time of 5 days has resulted in a nitrogen removing of 55% to 90%. The nitrogen results in a high yield of algae.

Anaerobic lagoons have been found to be useful for treating the following wastes.

A. DAIRY WASTES

The dairies use about 4 to 5 litres of water for each litre of milk handled. The BOD of the waste is about 1250 mg/l. A detention time of 10 days has been found to result in 90% removal of BOD in the anaerobic stabilisation pond. The remaining 125 mg/l of BOD can be treated in an anaerobic stabilisation pond. /

DISTILLERY WASTES

Large quantities of molasses are available from sugar industries. The distilleries use mollasses for production of alcohol. The spent wash which remain after recovery of alcohol has a high organic content. The following are the characteristic of the spent wash.

i. Colour - Dark brown
ii. Odour - Molasses
iii. pH - 3.5 - 3.65
iv. C.O.D. (Dichromate value) mg/l
Total - 1,18,000
Dissolved - 1,06,000
v. B.O.D. 5 days 20°C Total - 41,380
Total - 99,000
Suspended solids mg/l - 350.

It is possible to treat this strong effluent by anaerobic ponding. This method has been adopted at Tiruchi. The treatment is carried out anaerobically in two ponds, the primary pond having a detention time of 70 days followed by a secondary pond of 40 days detention. The effluent from the secondary/an aerobic pond was found to have a fairly low BOD of about 2000 mg/l when the two anaerobic ponds function in series satisfactory.

An interesting point to be noted with regard to treatment of distillery wastes in the laboratory by anaerobic poinding is that addition of Ferrous sulphate in a low dose of 50 mg/l resulted in a noticeable spurt in the activity of the anaerobic ponds. The spent wash odours were also reduced.

PAPER MILL WASTES

The waste water coming out from paper mills is mostly organic in nature. It has a BOD of about 260 mg/l and a pH of about 10. The wastes also contain lignin and its derivates which impact colour to the water. But nitrogen and phosphorus are absent. This waste can be treated by anaerobic ponding. A detention time of 10 days has been found to result in 75% removal of the BOD.

CONSLUSION

Where strongwastes from industries are to be treated stabilisation ponds can be used for the purpose. Pilot plant studies with the particular wastes must however be carried out for a satisfactory design of the stabilisation pond required for the purpose can be evolved.

Pulp & Paper - 14,000 - 60,000 gls/Ton
Steel - 4000 gls/Ton Pig iron
Do - 18000 - 40,000 gls/Ton Steel
Petroleum - 70,000 - 80,000 gls per 100 barrels of crude
Gasolen 20 gls/gal
Cement 750 gls/Ton
Coal carbonisation 3500 gls/Ton
Tannery - 750 gls/ton of hide
Cotton
Bleaching - 20-40 gls/yard
Dyeing - 1000 - 2000 gls/100 lbs of yarn dyed.
Rayon - 1,60,000 gals/Ton

UTILIZATION OF EFFLUENT FROM WASTE STABILISATION PONDS

Dr. B.B. SUNDARESAN
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INTRODUCTION

Effluents from fully or partly treated sewage plants are rich in nutrients which can be utilised beneficially for the growth of fish followed by cultivation of suitable food and vegetable crops. Most of it is being wasted now and it is paradoxical to witness deficiency in fertilizers all over the country whereas easily available nutrients for crops are being wasted without purposeful use. In addition the shortage of water for cultivation can be overcome in most of the places. In short a comprehensive scheme involving treatment of objectionable sewage, using the treated sewage for growth of fish and utilising the same for quick growing coconut plants such as 'dwarf' variety will be more meaningful in the present stage of development. Shortage of water and fertiliser and ground water depletions have become the order of the day, in several parts of India.

Several water supply schemes functioning in rural areas are at present not followed by any beneficial schemes for the waste water disposal and the used water is being wasted without purposeful use. This is a potential health hazard leading to breeding of <u>Culex fatigon</u> species of mosquitos which are responsible for the spread of filariasis. Water supply without proper drainage and disposal will lead to endemic filarial conditions in such places.

Hence the present method of giving water supply without any waste treatment units will be harmful from publichealth considerations. In order to avoid such health hazards it is advisable to collect the waste through suitable sewers.

As sewerage (under ground drainage) schemes are expensive, it is being given low priority in planning. It is desirable, to have atleast a surface collection system with suitably lined surface drains, which will prevent stagnation around houses or groups of houses. This can be led to a common point where stabilisation pond can be provided for treatment.

Effluent from stabilisation pond is suitable for quick growing edible variety of fish and the final effluent from this fish pond can be utilised for the quick growing coconut plants which will also yield additional revenue.

EXPERIMENTAL STUDIES AT ENGINEERING COLLEGE, GUINDY

A well developed sewage treatment demonstration plant with stabilization pond and fish pond forms part of the Public Health Engineering Department of the College of Engineering, Guindy, Madras. The effluent from the stabilization pond is led into the fish pond and the edible variety of fish such as Mrigal and Cyprinus carpio have been introduced to study the growth pattern and productivity (TABLE 1). It is seen that the Cyprinus carpio (Bankok Variety) attained a maximum weight of 620 gms and a length of 38 cm (15") in 6 months time. This is a remarkable growth when compared to the growth of the same fish in other ponds maintained by the Fisheries Department. The remarkable growth of the fish in this fish pond ismainly due to the high level of dissolved oxygen concentration, algae and nutrients in the sewage effluent.

The dissolved oxygen from the suspended light and dark bottles were determined for 6 hours exposure between 10.00AM and 4.00 PM. The difference in D.O. between light and dark bottle represents the gross photosynthetic oxygen production in mg/litre or grams/m^3. By averaging the oxygen production

TABLE I

GROWTH PATTERN OF CYPRINUS CARPIO AND CIRRHINA MRIGALA

	CYPRINUS CARPIO						MRIGALA						
Days from start	No. of samples.	Length in C.M.	Length in inches $\bar{x}$	Length in inches σ	Weight in grams. $\bar{x}$	Weight in grams. σ	No. of samples.	Length in C.M.	Length in inches $\bar{x}$	Length in inches σ	Weight in grams. $\bar{x}$	Weight in grams. σ	Weight of Tilapia cropped out.
(500 Nos. introduced each weighing 0.3 grams fingerlings)							(65 Nos. introduced each weighing 65 grams and average length 6.5")						
38	14	13.0	5.14	±58.7	58.7	±10.01	5	18.8	7.4	±0.38	96.8	±14.53	Nil
53	5	15.8	6.20	± 0.25	75.0	± 2.90	4	18.8	7.4	±0.50	89.5	±21.65	5.00 kg
60	9	16.4	6.44	± 0.37	80.0	± 7.80	4	18.38	7.25	±0.42	82.25	±23.00	4.00 kg
71	14	18.0	7.10	± 0.70	83.1	± 8.40	8	18.42	7.63	±0.48	97.50	±20.50	7.50 kg
91	13	19.0	7.54	± 0.67	86.0	± 8.40	8	20.32	8.00	±0.66	107.00	±19.20	9.00 kg
101	7	22.0	8.70	± 0.45	141.0	±42.0	3	22.35	8.80	±0.25	135.00	± 7.25	7.50 kg
109	40	28.8	11.33	± 1.40	334.5	±87.5	14	24.20	9.53	±0.60	195.60	±38.60	Nil
124	22	29.5	11.60	± 1.20	356.60	±76.80	16	24.38	9.60	±0.60	203.30	±32.10	3.80 kg
144	16	31.8	12.50	± 0.97	412.80	±14.50	11	26.33	10.40	±1.25	215.20	±61.80	9.00 kg
160	24	34.7	13.65	± 0.86	471.0	±28.20	10	26.67	10.50	±0.70	256.20	±20.00	25.00 kg
165	25	35.6	14.00	± 1.09	491.00	±53.30	11	28.00	11.00	±0.75	306.00	±45.10	12.00 kg
187	30	36.8	14.50	± 0.7	544.0	±66.20	15	30.50	12.00	±0.80	375.00	±39.70	15.00 kg

Note : $\bar{x}$ = Arithmetical mean. σ = Standard deviation.

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between two succeeding metre depths and totalling them up the production per square metre was obtained (TABLE 2). Oxygen production from photosynthesis was in the range of 10.7 to 43.30 grams/m^2 for the six hour period. Sreenivasan (27) reported that gross oxygen production from photosynthesis was 33.2 gms/m^2 for a seven hour period in a fresh water pond. Hull (11) reported the values as 29 gm O_2/m^2/day, whereas Bartch (5) recorded 26 gm O_2/m^2/day in sewage stabilization ponds. Sreenivasan reported that even in an algal laden waters highest production recorded was 42.3 gms O_2/m^2 Copeland and Dorris (8) reported that 29 grams O_2/m^2/day as the highest value. The present observations indicated a fairly high level of oxygen production when compared with values reported by them.

The effluent from the Fish pond ispumped for irrigating about 200 coconut palms. It is seen that these plants have grown well and have started yielding in 6 - 7 years. This would be a viable scheme for small towns and panchayats in rural areas.

SEWAGE UTILIZATION SCHEME FOR RURAL COMMUNITIES

There are several sewerage systems under operation in India in which the sewage is discharged after partial or no treatment. Several other schemes are under execution whereas a large number have been given a low priority due to high cost of such system. In order to indicate the remunerative nature of sewage treatment plants, a small town of 5000 population is taken as a model, and a possible scheme has been indicated here.

Per capita supply	:	25 litres/day
Population	:	5000
Total flow	:	5000 x 25 = 1,25,000 lpd = 125 m^3/d

TABLE II

GROSS PRODUCTION OF OXYGEN BY LIGHT AND DARK BOTTLE EXPERIMENT

Days from start	Depth in mts.	Initial O_2 in mg/lit (i)	At the end of 6 hrs Dark bottle in mg/l (D)	At the end of 6 hrs Light bottle in mg/l (W)	(W-D) in mg/l	(W-i) in mg/l	Total gross prod in gms $O_2/m^2/6$ hrs.	Total gross prod in gms O_2/m^2/day.	Net prod gms O_2 $m^2/6$ hours.	Net prod gms O_2 pr m^2 per day
73	0.0	5.6	1.2	19.8	18.6	14.2	16.5	33.0	12.35	24.70
73	1.0	4.7	0.8	15.2	14.4	10.5				
110	0.0	5.8	1.6	24.3	22.7	18.5	18.55	37.1	14.05	28.10
110	1.0	5.2	0.4	14.8	14.4	9.6				
130	0.0	6.3	1.2	26.1	24.9	19.8	20.8	41.6	15.85	31.70
130	1.0	5.4	0.6	17.3	16.7	11.9				
165	0.0	5.8	0.2	24.3	24.1	18.5	21.65	43.30	16.50	33.00
165	1.0	4.7	0.0	19.2	19.2	14.5				

Note: W - light Bottle. D - Dark Bottle. i - initial O_2

$\frac{18.6 + 14.4}{2} = \frac{33.0}{2} = 16.5$ = Total gross production = $\frac{14.2 + 10.5}{2} = \frac{24.7}{2} = 12.35$ = Total gross production.

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BOD load 200 mg/l	:	$\frac{1,25,000}{10^6} \times 200$
		= 25 kg/day

Stabilization Pond

BOD loading rate	:	200 kg/hect/day
Area required	:	.125 Hectares
	:	= 1250 m^2
Assuming side slopes	:	1.3
Size at top	:	5[illegible] m x 24 m
Size at bottom	:	47 m x 17 m
Free board	:	1.0 m
Depth	:	1 Metre
Volume	:	50 x 25 x 1 = 1250 m^3
Detention time	:	1250/125 = 10 days.

Fish Pond

Detention period	:	5 days.
Area required	:	625 m^2
Fish pond area	:	40 x 16 x 1 metre.

Land required (Stabilization and Fish Pond and Coconut Palms)

Stabilization pond	:	1272 m^2
Fish pond	:	640 m^2
200 coconut palms	:	4000 m^2
Marginal space	:	2088 m^2

Total area	:	8000 m^2 (2 Acres)

Cost of the scheme

		Rs.
(i)	Land area 2.0 Acres (Rs.1000/acre)	2,000-00
(ii)	Cost of stoneware pipe and specials including laying and jointing	5,000-00
(iii)	Cost of pond construction including the R.C.C.slabs for oxidation pond and fish pond and inlet and outlet chambers	10,000-00

(iv)	Cost of coconut plants 200 Rs.10/- each	2,000-00
(v)	Cost of pumps (if required) (one for pumping to the inlet chamber and another to pump from outlet chamber)	6,000-00
	Total	25,000-00

Revenue

(i)	Fish Production	3,000-00
(ii)	Coconut production Rs.20/- per palm per year	4,000-00
	Total	7,000-00

REVENUE THROUGH THIS SCHEME

Quick growing dwarf variety of coconut seedling may be planted which will start yielding in about 3 years. This will fetch a good revenue to the Panchayat. Similarly quick growing species of edible variety of fish such as Catla-catla, Mrigal, Rohu, or Cyprinus corpio may be introduced in the fish pond. These species of fish will grow more than 1 Kg/per year and the yield will also be more in this type of water due to the dense algal concentration and high nutrient value of the effluent. By implementing the above sewage reclamation programme in rural areas, it is possible to provide good environmental conditions to the community and in addition, add to the revenue of the Panchayat through the sale of fish and coconuts.

The total initial cost of the proposed scheme will be about Rs.25,000/- if pumping is to be provided, or Rs.19,000/- without pumping. Pisciculture at the end of the first year will fetch a revenue of Rs.1000/- and at the end of the third year the amount will be Rs.3,000/-. At this time the coconut will also start yielding and it will give a revenue of Rs.4000/-.

Total revenue after 3 years is estimated to be about Rs.5,000/- per year.

If some voluntary labour force is also available to carry out the works such as earth work excavation etc. then the cost will be less by Rs.3,000/- in the initial cost of the scheme. Therefore the total invested amount can be got back in 5 to 10 years time. Thereafter it will be a regular source of income to the rural community.

ANALYTICAL CONTROL OF WASTE STABILIZATION PONDS

R.M. SUBRAMANIAN

P. BALAKRISHNAN

INTRODUCTION

The satisfactory functioning of any waste stabilization pond depends as much on a proper analytical control of its performance as on a good design construction. Whereas the later processes help in placing a tool in our hands, it very much warrents a scientific handling of it to ensure an effective shape of the end product. This is possible only through a r egular control of the pond performance by meaningful laboratory and field examinations for certain specific parameters. Written in this background this paper presents a concise account of analytical techniques involved in the analytical control of waste stabilization ponds.

SULPHIDES

In a pond system, sulphides are derived from the reduction of sulphates both anaerobic as well as facultative ponds. Whereas in the anaerobic pond the liberated sulphides continue to accumulate, they are oxidised back to sulphates in a facultative pond. The significance of sulphides are two fold. Its presence in a facultative pond is to be considered critical only at times of noon and not at other lesser oxygenation times such as the dawn or dusk. In an anaerobic pond however the time factor may not influence any decision on pond performance based on sulphide levels.

The field estimation of sulphides is dependent on the property of the chemical Lead Acetate to displace the sulphides from its combination form of Hydrogen Sulphide and the subsequent formation of lead sulphide, a brown to black precipitate depending upon the intensity of the sulphide present. The chemical can be used either in the form of a solution added in drops to a test tube containing the pond liquid or as readily available Lead Acetate strips which can be conveniently dipped into the pond liquid. The end colour formation is the same in either case and serves as a qualitative test only.

Quantitative estimations can be made only under laboratory controlled conditions and use the principle of gas displacement and iodimetric titration. Carbondioxide from Kipp's apparatus using marble chips and Hydrochloric acid is passed through an acidified portion of the pond liquid and this displaces the gaseous sulphide which is absorbed later in a solution of Zinc Acetate. The completion of displacement must always be ensured before proceeding further which involves addition of Potassium Iodide crystals where upon the sulphides liberate the iodine which is estimated by titrating against sodium thiosulphate using starch as indicator.

DISSOLVED OXYGEN

Photosynthesis to a very large extent and atomospheric oxygen exchange to a limited extent are the only sources of oxygen introduction into a pond system. Consequently the level of Dissolved Oxygen(D.O) is largely dictated by the intensity and rate of photosynthetic activity. Naturally, hig concentration of D.O. can be anticipated in a pond system only during day time, being maximum at noon.

Obviously presence of D.O. in a pond is an indication of aerobic activity. Thus a successful facultative pond must exhibit good D.O.levels in the upper layers which will however tapper down depthwise. Midday D.O.levels of 30 to 40 mg/l. very much exceeding the saturation level are not uncommon for ponds operating in temperate climates. In fact, such high concentrations are obligatory for a successful function of the pond system. In effect, this only indicates a brief phase of algal bacterial symbiosis, during which the bacterial uptake of D.O. very much falls short of the algal oxygen output. Such conditions progressively get evened out during the later part of the day. It may be mentioned here that even truely anaerobic ponds may exhibit minimul surface D.O. concentrations at times.

The detection of D.O. is best carried out with a D.O. meter, which uses the principle of a galvanic cell with lead and silver electrodes. When the electrodes are dipped into the pond liquid the conducting property of the D.O. completes the circuit and generates a small current in the order of micro amperes which in turn is measured and related to D.O. levels using a precalibrated chart. A simpler alternative will be to use the principle of the famous Winkler's method The basic procedure entails the oxidation of Managanous Hydroxide in highly alkaline solution. Upon acidification in the presence of an Iodide, the Manganic Hydroxide dissolves and free Iodine is liberated in an amount equivalent to the oxygen originally dissolved in the sample. The free Iodine is titrated with a standard Sodium Thio Sulphate solution, using starch as an internal indicator, in much the same manner as described for the final titration for Sulphides. This method involves a precise control over the addition of chemicals and their reactions to yield a reliable quantitative estimation of D.O. Such specific precautions are possible only under laboratory conditions.

In the field however the same method can be tried in a simpler way. The required reagents will be (i) Manganous Sulphate (480 gm of $MNSo_4 . 4H_2O$ in 1 litre of distilled water) (ii) Alkaline Iodide solution (500 gm of Sodium Hydroxide and 150 gm of Potassium Iodide in one litre of distilled water) (iii) 36N. Sulphuric acid (iv) Starch Indicator (5 to 6 gm of starch in 1 litre of distilled water boiled and cooled). The reagents are best carried in glass dropper bottles. A 15 ml test tube is gradually filled to two thirds full with the pond liquid without aerating it. About 2 drops of reagent i. is added followed by a 2 drops of reagent. ii The development of a brown precipitate is indicative of D.O. which must be further confirmed by mixing the contents gently by holding the tube between the thumb and second finger and followed by adding 2 drops of reagent iii which will dissolve the precipitate and form yellow solution. When a drop of reagent iv is added the immediate development of blue colour entails the presence of D.O. It is to be cautioned that handling of reagent iii requires special care in view of its acidic nature.

BIOCHEMICAL OXYGEN DEMAND

The test commonly abriviated as B.O.D. is an extension of the D.O.estimation, and measures the quantity of D.O. required for aerobic biochemical stabilization of organic matter, over an interval of 5 days at a controlled temperature of 20°C. In a facultative pond system theinfluent B.O.D. is composed of organic matter whereas the effluent B.O.D. is composed of algae. Hence, a true indication of influent B.O.D. reduction in the pond has to be based only on B.O.D. estimations carried out on filtered effluents. Such a concept however does not warrent itself in the case of anaerobic ponds.

The significance of B.O.D. in a pond system is that it indicates the presence and extent of putriscible organic matter contained in it. Consequently it may be argued that the algal load of B.O.D. in facultative pond effluents may offset influent B.O.D. removals. This however can be obviated to advantageously by algal harvesting.

B.O.D. estimations are obviously possible only under laboratory conditions. In essence, the test comprises of introducing a small portion of the pond liquid into the standard B.O.D. bottle with pre-aerated distilled water at 20°C and of known D.O. The contents are incubated at 20°C in standard B.O.D. incubators for over 5 days at the end of which time, the remaining D.O. is again estimated. A knowledge of the consumption of the D.O. during the test period and the dilution factor helps in computing the B.O.D. as a simple multiple.

The conducting of the test requires precautions of the highest order at the hands of an experinced analyst which are beyond the scope of the restricted coverage of this paper.

CHEMICAL OXYGEN DEMAND

Most of the biochemically degradeble organic matters can also be subjected to such stabilizations by purely chemical systems which supply the req uired oxygen under controlled conditions. The Chemical Oxygen Demand (C.O.D.) test employs this principle and covers in its scope such organic matter as covered by the B.O.D. test also.

Essentially the C.O.D. is a plant control test devised to cut short the tediousness and time consuming nature of the B.O.D. test which requires as much as 5 days even for the operator to evaluate the pond performance leaving alone its rectification when indicated. In as much as the entire C.O.D. test can be completed in a matter of 2 to 3 hours and as atleast for a given sewage sample the C.O.D. bears a fixed relationship to the B.O.D. a knowledge of percentage C.O.D. removal in the pond system can be approximated to the percentage B.O.D. removal, thereby revealing the pond performance in a matter of hours.

The C.O.D. value is estimated at laboratory conditions wherein a measured volume of the pond liquid is digested for 2 hours with a fined quantity of Potassium Dichromate, concentrated Sulphuric acid, Mercuric Chloride and Silver Sulphate. After digestion the amount of dichromate left unreacted is determined by using standard Ferrous Ammonium Sulphate and Ferroin indicator.

The B.O.D and C.O.D values can be correlated to express the biodegradability of organic matter and is usually denoted as the Treatibility Index. Computed as the ratio of B.O.D. to the difference of C.O.D. and B.O.D. The lower the index, the lesser will be the biodegradability and higher the index, higher will be biodegradability and treatment efficiency as condensed below.

Treatability index	Extent of Biodegradability
Less than 0.1	Difficult
0.1 to 0.3	Practically stabilised condition.
0.3 to 1.0	Insufficiently stabilized
Values beyond 1.0	Improper functioning of treatment

TOTAL KJELDHAL NITROGEN

Nitrogen is an important nutrient of the pond system and is contributed by the influent wastewater as organic nitrogen, and free ammonia. In the pond these nitrogen forms are used up by the cells and this results in a reduction of ammonia content. Further nitrification when occuring converts the ammonia to nitrite and nitrate. However ammonia can also be increasing in a pond as the end products of anaerobic activity in the bottom layers also contribute ammonia. Nitrate nitrogen is the final stage of conversion in the nitrogen cycle, and its presence in the effluent is an indication of complete nitrification.

The total nitrogen is determined under laboratory conditions by the Kjeldhal method whereby a measur ed quantity of the pond liquid is digested after adding Copper Sulphate and concentrated Sulphuric acid until it becomes colourless. The digested sample is made upto a known volume by using a strong alkaline solution and the Ammonia is distilled from the solution in to boric acid and estimated by titrating against Sulphuric acid using Methylorange or Mixed Indicator.

pH

The pH can be defined more precisely as the Hydrogen ion activity in moles per litre. The estimation of p^H will aid to calculate Carbonate, bicarbonate and Carbondioxide proportions in the control of pond systems. The practical pH scale extents from 0, very acid, to 14, very alkaline with a centre value of 7 corresponding to exact neutrality.

The pH value shows a diurnal variation like dissolved oxygen and shows a maximum value around 8.5 and may even rise upto 9.0 during midday in temperate conditions. The purification occurs with a steady increase in pH value in a pond system due to the algal population and photosynthetic action which releases carbondioxide from carbonates in the stabilization ponds.

The field estimation of pH is best done by using universal pH indicator papers which are commercially available. The strips are directly immersed in the pond liquid and the change of colour as compared to the colour chart supplied with the paper will indicate the pH.

In the laboratory the pH can be measured either electrometrically or colorimetrically. The electrometric estimation of pH is done by using a pH meter with glass electrodes and is more reliable. After intial setting up of the pH meter by using buffers of known pH values the electrodes are immersed in to the sample of the pond effluent whereby the circuit is completed and the pH read on the meter. The glass electrode is relatively immune to interference from colour, turbidity, colloidal matter and chlorine. The colorimetrical estimation of pH is done at the laboratory by using certain indicator solutions which yield known colours on addition to the sample. For pond liquids normally Cresol Red solution can be used which will cover the pH range of 7.2 to 8.8 and the colour change will be yellow to red which can be conveniently compared by using BDH make colour discs, which are specifically manufactured for this purpose.

SUSPENDED SOLIDS

The suspended matters in influent sewwge are of organic origin and inorganic sludge. In the pond system the settleable organic matter and other inert matters settle

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158 down and are stabilised anaerobically. Algae in suspension are responsible for the suspended solids in the effluent. Under laboratory conditions the pond liquid is filtered through a millipore filter paper which is dried at 105°C and estimated later for computing the suspended solids with reasonable accuracy. But a considerable portion of the algal mass may be lost during filtration and consequently these estimations are likely to be misleading. Hence alternately centrifuging the pond liquid at 3500 r.p.m for 5 minutes and noting the centrifuged solids content can be considered as a method of visual estimation of algal population in the pond system.

CONCLUSION

A proper analysis of the pond system will be the only guide for monitoring the performance of the waste stabilization ponds consequently a improper maintenance of ponds is very much dependant on the adoption of uniform techniques and more than that a good understanding of the involved principles. The analysis of composite samples collected at regular intervals will present the actual performance of the pond system. When no facility is available to examine the samples as soon as it is collected, special precautions like keeping the samples at low temperatures of 0° to 3°C during the time of transit to the laboratory must be employed as chemical changes do occur in the samples even at minimal time intervals of transit.

P.H.E. Training Programme
Sponsored by the
Ministry of Works and Housing,
New Delhi.

ASSESSMENT REPORT BY THE TRAINEES

Name of the Course Fourth All India Training Course on Waste Stabilisation Pond Practices

Venue Madras

Duration 11-9-75 to 18.9.75

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1. Impressions about the lectures. More Informative and clear

2. Impressions about the field visit. Useful

3. Suggestions regarding the syllabus. Oxidation ditch may also be included

4. Suggestions regarding the duration of the Course. May be increased to 12 days

5. Was the course useful to the Candidate? Definitly yes.

[signature] 18/9/75

(K. S. Shanmugan)

LIST OF DELEGATES WHO ATTENDED THE FOURTH REFRESHER COURSE ON WASTE STABILISATION PONDS AT MADRAS FROM 11-9-1975 TO 18-9-75

...

1) THIRU K. AARON,
Assistant Engineer,
Tamil Nadu Housing Board,
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M A D R A S-600039

2) THIRU G. BALAKRISHNAN,
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Public Works Department,
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Chepauk,
M A D R A S-600005.

3) THIRU T.H. CHANDRAJIT SINGH,
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Public Works Department,
Water Supply Division No.1.
Manipur Post,
IMPHAL

4) THIRU M. CHANDRA SEKARAN,
Assistant Engineer,
Public Works Department,
Building Sub division No.1,
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M A D R A S-600018.

5) THIRU Y.V. DAMLE,
Executive Engineer,(Planning I),
3rd Floor Annexe Building,
Municipal Corporation of Greater Bombay,
BOMBAY - 1.

6) THIRU D. JAYACHANDRAN,
Assistant Engineer(Designs),
Highways and Rural Works,
12, Ist Main Road,
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7) THIRU KODUMUDI SHANMUGAM,
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Public Works Department,
South West Sub Division,
South Presidency Division,
Chepauk,
M A D R A S-600005.

8) THIRU M. KOLANDAIVELU,
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Public Works Department,
Buildings Sub Division-II,
Buildings Division-IV,
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9) THIRU B. MANICKA VASAGAM,
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Office of the Chief Engineer,(Irrigation),
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10) THIRU S. MUTHURAMAN,
Assistant Engineer(Rural),
Tamil Nadu Water Supply & Drainage Board,
Chepauk,
M A D R A S-600005.

11) THIRU NAMBI AYYADURAI,
Assistant Engineer,
Designs Circle,
Tamil Nadu Water Supply & Drainage Board,
Chepauk,
M A D R A S-600005.

12) THIRU M. PASUPATHY,
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Tamilnadu Slum Clearance Board,
Division VI,
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13) THIRU R. SALEH,
Sub Divisional Officer (P.H.E.),
Sub Division No.2,
Kohima,
N A G A L A N D.

14) THIRU K.G. SHANTHALINGAM,
Assistant Engineer,
Tamil Nadu Slum Clearance Board,
Division III, Thandavaraya Pillai Chatram,
M A D R A S-600010.

15) THIRU K.V. SRINIVASAN,
Sub Divisional Officer B/R,
C/o. Garrisan Engineer,
Fort St. George,
M A D R A S-600009.

16) THIRU K. SIROMANI RAO,
Assistant Engineer(Technical)
Office of the Chief Engineer,
P.W.D. Chepauk,
M A D R A S-600005.

17) THIRU C.P. TANEJA,
Executive Engineer,(Planning).
Show room No.16-A,
Sector 7-C.
CHANDIGARH

18) THIRU S. VISWANATHAN,
Executive Engineer,
P.W.D. Buildings Division III,
Chepauk,
M A D R A S-600005.

11-9-75 Raman 5 day Test

BOD 5-20°C

100 ppm - weak

200 ppm - medium

300 ppm - strong

320 at Madras

rises even to 500-600 during draught.

Sewage 1,000,000 gallon

Population 25,000

To convert gallon to lbs.

BOD = 1,000,000 × 10 × $\frac{300}{10^6}$

= 3000 lbs

~~= $\frac{3000}{25000}$ =~~

0.08 lbs/day per head (India)

0.20 " (Foreign countries)

Pop GPD BOD

3000 × 15 × 0.08 lbs = 240 lbs in 45000 gallons

$\therefore \frac{240 \times 10^6}{45000 \times 10}$ = 240 ppm

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$SO_4 \rightarrow H_2S\uparrow$ septic sewage

GRIT

COD = Chemical oxygen demand.

Pulp Mill waste		Normal	Dairy	Soft Drinks Bottling Plant	Slaughter House	Molasses Spent Wash	~~Urea Fertiliser~~
ph	10.5	7	7 to 8	10	7	4.5	
Total solids	2000	400	2700	3600	8000	80,000	
BOD	200	200	1250	2800	100	40,000	
COD	985	380	2000	4200	200	1,00,000	
N	Nil	30	1076	-	100	1000	
Phosphorus	Nil	5	112	-	-	400	

Fertiliser

Urea - 1065
NH_3 - 1410
CO_2 - 1860
other Dissolved solids - 1280

Upgrading 18/9/75 A.Raman

Small Ponds
1. Presetting
2. Serial tanks to parallel tanks
3. Change inlets & outlets
4. Round off corners.

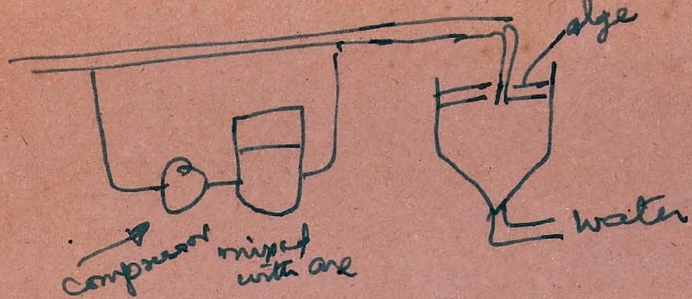
Large Ponds

1. Mechanical devices
2. Multiple inlets & outlets.
3. Recirculation of part of effluent to influent.
   For serial ponds, ideal.

Removal algae

1 Primary settling tank
add alum & coagulate & Also filter effluent.
(to reduce ph value from 8 to 7 pass CO_2.

2,



· when air pumped in algae floats
water drawn from bottom.

3 Secondary Pond in series – deeper:
algae settles down

1 Do not provide for maximum expected.
then Devide into many small Pons
Construct small one, watch, then Construct others later.